行政院國家科學委員會專題研究計畫成果報告

半導體產業的技術學習與外溢
Technology Learning and Spillovers in the Semiconductor Industry

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一、中文摘要

本計劃研究台灣及韓國半導體產業的技術學習及外溢效果，發現台灣產業的外溢效果較韓國強，但學習效果較韓國弱，這項結果與政府政策、產業結構、產品選擇、企業規模等有關。

關鍵詞：技術學習、技術外溢、半導體產業

Abstract

In this project, we study the pattern of technology learning and technology spillovers in the semiconductor industry of Taiwan and Korea. We find that there is more technology learning and less technology spillover in Korea compared to Taiwan. We offer to explain this difference in terms of government policy, industry structure, product specialization, and firm size.

Keywords: Technology learning, Technology Spillovers, Semiconductor industry

二、緣由與目的

高科技產業生產的學習效果及外溢效果是晚近頗受注目的課題。學習效果指的是累積生產的經驗愈多，產業的生產效率愈高；外溢效果指的是一家公司的生產會影響到別家公司的生產效率。學習效果在過去是論者用來支持幼稚產業發展的理論基礎，晚近則被轉用來支持策略性貿易政策。學習效果如果加上技術外溢則產生外部性，此時政府干預就變成理所當然的事。因此學習效果是否存在，技術是否具有外溢性遂成為策略性貿易或政府干預高科技產業發展是否合理的關鍵問題。本研究的目的是探討台灣及韓國半導體產業發展中的學習及外溢效果，並比較其不同。

三、結果與討論

In comparison, technology learning was mainly facilitated by private firms and internalized within those firms. The Korean government played little role in facilitating technology learning. It attempted to facilitate technology spillover within the domestic industry but only succeeded to a limited extent. Technology sourcing in advanced countries was the main conduit of technology learning for Korean semiconductor firms.

The first Korean semiconductor firm, Korea Semiconductor, was established in 1974 by a Korean engineer, named Ki-dong Kong, who had worked for an American semiconductor firm, Integrated Circuit International Inc. (ICIC). Kong and ICIC provided the initial technology input to Korea semiconductor which was absorbed into Samsung group in 1975. The other major Korea semiconductor firms, Goldstar and Hyundai, were established in 1979 and 1982 respectively.

Technology Transfer from the United States and Japan was the major source of technology learning. Samsung established a subsidiary, Tristar Semiconductor, in Silicon Valley of the US. The subsidiary established a pilot production line to recruit local technicians to engage in product development, which was then transferred to the parent firm for mass production. Goldstar, on the other hand, dispatched a large number of engineers to US companies like Western Electric and Honeywell for training and technology transfer. It also took over the pilot semiconductor plant established by the government-owned research institute, Korea Institute of Electronics Technology (KIET). Hyundai also established a subsidiary, Modern Electrosystem, in Silicon Valley in 1984 to source local technology.

In addition to technological sourcing through direct investment and training programs, Korean semiconductor firms also licensed technologies from the US and Japan. Between 1982 and 1986, 53 technology licensing contracts were signed by Korean firms. For example, Samsung signed 19 Technology-licensing contracts during the period, including 16K SRAM technology from Micron (US), and 64K SRAM, 64 EEPROM technology from SSI (US).

Like Taiwan, at the beginning the production of Korean semiconductor industry was concentrated on miscellaneous logic ICs. Such as those used in electronic watches, microwave oven, calculators, etc. Internal demand within the consumer electronics divisions of the Korean conglomerates provided the initial impetus to production. The Korean firms, however, soon discovered that they were unable to catch up with fast-changing technologies in this field. Starting from 1980, Samsung decided to concentrate its business effort on DRAM, of which the product is homogeneous and technology can be learned and accumulated over time. Samsung first acquired relevant technologies from Sharp, Micron, and SSI, and improve upon them by internal R&D. In the meantime, it invested aggressively on newest equipments and expanded the technology. In 1984, Samsung introduced 64K DRAM when it was totally dependent on foreign technology. In 1990, Samsung embarked upon mass production of 4M DRAM and was at the frontier of the technology. That is to say, within six years Samsung has mastered the technology it acquired from Sharp and Micron. From 64K to 4M DRAM, technology passed through three generations of products. Despite the 64-fold increase in storage capacity, the production technology of DRAM remained largely the same, only the level of precision required for production has been greatly enhanced. Samsung excelled in processing technology but was relatively weak in product design. Fortunately, the design capability required for DRAM is much less than that for microprocessors or application-specific ICs.

In Taiwan, technology learning is achieved through a network of semiconductor firms with government-owned research institute, ERSO, driving the learning cycles. New technologies were acquired was then dispersed through the industry. Turnover of technicians and engineers is the main conduit for technology diffusion. In Korea, technology learning is conducted within the firm. There is more accumulation than diffusion of technology in Korea. Higher degree of accumulation and lower risk of technology spillover provides Korean firms with more incentives to invest in R&D. As a result, Korean firms spent much more on R&D than their Taiwanese counterparts. The choice of product specialization is important to this difference. The key to competitiveness in DRAM production is processing rather than product (design) technology. Processing technology is subject to learning but more difficult to spill over.

In contrast with Korean firms, Taiwanese firms focus on application-specific ICs where product (design) technology is crucial. Product technology is more likely to be subject to spill-over. IC design house is an important industry in Taiwan, but not in Korea. Product design in Korea is conducted within the firm, and therefore, there is less possibility for spill-over. Separation of design and fabrication in IC production in Taiwan provides more chances for technology spillover. Technology learning is mainly performed at the foundries.

IC design houses in Taiwan not only

work together with local foundries, but they also work with international foundries. Interactions between design houses and foundries also provide opportunities for technology spillover. For example, Taiwan's two major design houses VITEL and MOSEL have long contracted OKI of Japan for foundry service. They entered DRAM production with ease, benefiting from technology spillover.

Compared to Samsung, Hyundai and LG entered DRAM production at later dates. To catch up with Samsung, both imported technologies from foreign countries and served as OEM (original equipment manufacturers) subcontractors. In particular, Hyundai worked with Texas Instruments of the US and LG worked with Hitachi of Japan. There was intensive competition among Korean semiconductor firms but very little technology diffusion took place. The Korean firms paid handsomely for technology imports: The Korean government initiated three consecutive R&D consortia, in 1986-88, 1989-93, and 1993-97, to facilitate technology diffusion. But except for the 1986-88 project (VLSI), very little has been achieved. This is due to the reluctance of the leading firm, Samsung, to share its technology with the followers. This is because the technologies intended to be developed in these consortia are application rather than generic technologies.

Firm size also matters in the way technology is acquired. Korean firms are much larger than Taiwanese firms with easy access to low-cost funds. Korean firms prefer to acquire technology through contracting (market transaction), internalize it and improve upon it. They may also establish laboraties in the U.S. for technology sourcing. Technologies they acquired are often applied to large-scale production. On the other hand, Taiwanese semiconductor firms hire technicians in whom technologies are embodied. They sometimes provide stock options in addition to regular salaries as part of the financial package to attract technicians. Technologies acquired by Korean firms are likely to be codified while technologies acquired by Taiwanese firms are likely to be tacit. Both technologies can be improved upon but codified technologies are more easily shared within the organization. When codified technologies adapted to the organization and improved upon by in-house R&D, they became organization specific and hard to imitate. Tacit technologies, meanwhile, are often person-specific and not rooted in the organization. Tacit technologies move with the persons possessing them. Given the nature of technologies, spill-over is more likely to take place in Taiwan but more organizational learning is possible in Korea.

In Korea, the center of knowledge is located within the firm whereas in Taiwan it is located in research institutes and universities. In Korea, semiconductor firms are located apart from each other to avoid knowledge spillover whereas in Taiwan, semiconductor firms are located around the knowledge center to benefit from spillovers. Taiwanese firms built links to the largest knowledge center of the world, Silicon Valley of the U.S. through personal connections and supplier-buyer relationship. Meanwhile, Korean firms have to invest in Silicon Valley to create proximity to the knowledge center.

Losing to Taiwanese firms in terms of technological spillovers, Korean firms gained on the ground of technology learning. This is because Korean firms engage in large-scale production and apply homogeneous technologies. Consistent investments on new equipments and applying them to the same production enable Korea firms to learn from production failures and to improve upon production efficiency. In comparison, technology learning is less significant in Taiwan where semiconductor firms keep changing their product line-up.

As learning is a cumulative process of incremental improvement, consistency of production is important. The incentive system of Taiwanese firms is not as conducive to learning as that of Korean firms. Implicit life-time employment contract in Korea encourage skilled workers to accumulate production experience and to improve upon work efficiency. Implicit profit-sharing labor contract in Taiwan encourage skilled workers to innovate products for a one-shot gain as it creates in premium for the value of its stock options.

四、計劃成果自評

本研究計劃大體完成原定目的，也就是比較台灣及韓國在半導體產業中的技術學習與外溢的不同，但大部份的分析僅止於定性的分析，無法完成定量的分析是其缺憾。

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