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Globalization for Nation Building: Industrial Policy for High-Technology Products in Taiwan

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Technoglobal Means for Technonational Ends

Taiwan's technology policy embodies seemingly contradictory principles. The Taiwanese state has actively cultivated a rich set of international interactions with firms from advanced industrial countries. The state has not tried to terminate these links despite the fact that these interactions arguably create more dependence on the outside world than independence from it. This globalist orientation appears to clash with another fundamental principle of Taiwan's technology policy—innovation as a nationalist project to build up local technology infrastructure and the domestic economy. How has Taiwan resolved this apparent contradiction in its technology policy?

In the spectrum of East Asian technology policies from the explicitly technonational strategies of Korea and Japan to the MNC-embracing policies of Singapore, Taiwanese policy occupies an intermediate position. The goal of establishing domestic technological capabilities that do not depend completely on serving as a base for foreign MNCs is one shared with Korea and Japan and rejected by Singapore, the regional headquarters of Japanese and American multinationals. Taiwan parts company with its technonational Northeast Asian cousins in its willingness to accept a level of international participation in its strategic technology sectors; and the mutual dependence entailed by its technology strategy of fostering international linkages. Instead of pushing out or isolating foreign firms once the transfer of technology to local champions is complete, Taiwan has maintained these linkages between local firms and foreign ones in the home market and abroad. In short, Taiwan has used technoglobal means to leverage ongoing international linkages and to realize the technonational ends of enhancing the ability of domestic firms to play in global markets.

In the terms established in the forthcoming book, *Crisis and Innovation*, these "technohybrid" tactics have engendered a dependence on (or at least an interdependence with) the outside world that would be anathema to the early technonationalism of South Korea and Japan. Thus, the contradiction between the nation-building project and the technoglobal one is only resolved through sacrificing of the technonational ambition of more complete control over the forefront of technology.

Taiwan's hybrid mix of technoglobal means and technonational ends has four key features: 1) low cost competency building to create strategic suppliers, 2) the use of multiple technology channels, 3) tolerance of foreign multinational firms in the domestic economy, and 4) the problem of full-setism. The first three features explain how Taiwan has leveraged, and continues to use international industrial linkages to build up its national economy. The fourth feature demonstrates that the tension between technoglobal tactics and technonational ends has not been completely resolved, even in a country where international economic interdependence has not been rejected on nationalist grounds.

The first feature is low-cost competence building to create strategic suppliers. The Taiwanese have built up strategic suppliers of international firms rather than promoting expensive vertically integrated national champions like the Korean *chaebol*s.

These suppliers have gained new competencies through their interactions with international customers. The Taiwanese state worked to build up the capabilities of firms and the general industrial infrastructure through its R&D apparatus—licensing foreign technologies, negotiating the licensing on behalf of Taiwanese firms, and granting subsidies to encourage local firms to enter high technology markets. Despite the active state role, tight budget constraints circumscribed this interference by the state. The political interference did not extend to rigging the financial market in favor of very large firms in order to have the scale economies for independent innovation, an intervention that typically involves massive state subsidization of the favored firms. Smaller state efforts had to be focused on building up a limited scope of competencies to have any punch.

In general, the state focused on the narrower set of capabilities demanded by the large branded MNC demanded from their suppliers, rather than attempting to build national champions with a broad range of competencies. This low-cost approach accounts for the great divergence in size of the high-technology firms between Taiwan and its Northeast Asian neighbors. Korean and Japanese high technology firms tend to be large conglomerates whereas their Taiwanese rivals, even today, are typically more middling in scale and are more narrowly focused in scope. This strategy also accounts for the continued dependence, which is often reciprocal, between Taiwanese strategic suppliers and their foreign partners, and customers. By focusing on building a narrow range of process technologies suitable for suppliers, these firms did not acquire the broader scope of competencies needed to innovate independent of a set of cooperative arrangements with firms possessing complementary innovation assets.

The second feature in building Taiwan's innovation system and high technology sector is the cultivation of multiple technology channels. The state's R&D efforts and licensing of technologies from abroad has been one critical channel. The state often used its research equipment and employees to form new, privately managed companies. The Taiwanese firms also capitalized on an increasingly intensive set of interactions with key customers to gain new technologies. While the state's efforts helped this MNC-supplier channel of technology, the Taiwanese firms were also able to capitalize on the trend in the electronics industry of branded firms using greater outsourcing of production. This strategy of greater outsourcing created an incentive among foreign-branded firms to increase the competence of their main suppliers. The state did not stand idly by, but took the initiative to make this trend work to Taiwan's advantage.

Another major means of acquiring technology has been the wave of returning engineers and technicians from abroad, principally the United States. The senior management of most Taiwanese high technology firms was educated abroad and had subsequent work experience, particularly in the U.S. companies in the information technology sectors. The technology embodied in returning human capital was critical because the returnees were trained at the great U.S. research universities. They brought back, also, practical skills learned on the job in U.S. centers of innovation that could not have been taught in the university system of Taiwan or even the US.

The third feature in Taiwan's efforts to build a high-technology future is the acceptance of multinationals presence in strategic sectors, even after Taiwanese domestic firms have achieved capabilities equivalent to those of the foreign-based companies. There have been few adverse policy consequences for ventures with prominent foreign backing, such as TSMC and TI-Acer. In the case of TSMC, the state actively sought out foreign involvement. Philips has major manufacturing operations in electronics in Taiwan and has received no pressure to move out once Taiwanese firms have similar prowess in electronics manufacturing. Indeed, Taiwanese policy tries to lure foreign firms that can round out the industrial infrastructure for high-technology industries, but forgoes the efforts to force the foreign firms into joint ventures with local firms to achieve that elusive goal of control. As of 1999, three foreign high-technology firms were among the top twenty manufacturing firms in Taiwan, and they were in sectors in which there is significant local competition. Simply put, the Taiwanese have been concerned to draw value-added activities to Taiwan, but have been relatively unconcerned about national ownership compared to their Northeast Asian neighbors, Korea and Japan. On the other hand, Taiwan has been reluctant to give foreign MNCs sweetheart deals in order to lure them to Taiwan as Singapore.

The final feature is the problem of the Taiwanese state and industry falling prey to full-setism. Full-setism is the idea that a nation should produce every key component in a given sector, a full set of the key activities in that sector. The problem in attempting to round out a critical industry sector by doing all of the important activities associated with that sector, is that it does not give due consideration to the fit between the capabilities of the local economy and the overall requirements for a given sectoral activity. Taiwanese authorities have fallen prey to full-setism in both sectors examined in this chapter. They tried to push into dynamic random access memory (DRAMS) in the IC sector and into hard disk drives (HDD) in the PC sector because they thought that Taiwan needed these critical activities to complete successfully in each sector. Technology policymakers ignored the inherent conflict between Taiwan's industrial structure skewed to small and medium-sized enterprises (SMEs) and the large economies of scale needed to compete in DRAM and HDD. Full-setism is a recurring problem of Taiwanese technology policy. Its recurrence suggests that the Taiwanese authorities were fundamentally motivated by technonational ideas to build up their domestic economy, as were their East Asian neighbors. Forging strong global linkages provided a different means to the same end of nation building. Given the nationalist ideology, the occasional bids for a more complete national economy in defiance of economic constraints should not come as a surprise.

There is a temporal aspect to Taiwan's technology policy that should not be ignored. The ability of the state to determine Taiwan's technology policy orientation has diminished over time as new technology firms and traditional conglomerates have begun to take charge of Taiwan's technology upgrading. The decline of the state's power relative to private enterprise has not changed the overall direction of policy. In a case that arguably parallels Japan's, the decline of state power has not heralded a distinctly different approach to technology policy. Taiwanese policy embodies elements both of technonationalism and technoglobalism, and may yet produce an even a denser set of international linkages with private enterprise leading the way. In Japan,

technonationalism arguably still informs the interactions among Japanese and foreign firms, even if the overt role of the state has declined.

This shift from public sector to private sector dominance of Taiwan's technology policy was not a result of the Asian financial crisis. The relative health and isolation of Taiwan's financial system from the international financial system minimized the impact of the East Asian financial crisis on Taiwan's economy.[1] The twin trends of the growth in size of the new high technology firms and the willingness of the older conglomerates to enter high-technology sectors once the industrial infrastructure for these new sectors matured caused the shift from public to private dominance over Taiwanese technology policy. These trends started before and continued through the East Asian financial crisis.

This paper examines two sectors, integrated circuits (ICs) and personal computers (PCs). These sectors have figured prominently in Taiwan's technology policy. Both have had their share of success and failure, and they have also had somewhat divergent outcomes. Taiwan's IC sector exemplifies the best that this technoglobal strategy for nation building has to offer a developing country. Taiwan's IC industry has created true interdependence between its leading strategic suppliers and their international customers. The Taiwanese foundries and their foreign chip-designing clients are equal partners. Each depends on critical technologies that the other possesses. In the case of the PC sector, Taiwan's strategy has led to development of the industry and enhancement of Taiwan's PC technology, but the Taiwanese PC makers, important suppliers of the branded firms, have few critical technologies that the branded firms cannot easily acquire elsewhere. In PCs, dependency is the price of development.

Having It All: Development and Inter-dependency in the IC Industry

The Development of the Technology Policy and R&D Infrastructure

The fundamental conflict in the early years of IC technology policy in Taiwan was between tight technology budgets and lack of private alternatives. Private firms were unwilling to invest in risky high-technology industries, and the government was not prepared to commit sufficient resources to create public firms or to lure private investors. Furthermore, the international leaders of the IC industry at the time were all large, integrated device manufacturers (IDMs). Technology policymakers tried to find a niche for Taiwan's small firms in an industry dominated by large firms from the leading industrial states. With a lack of large-scale funding from public and private sources, technology policymakers focused on building government research assets that would compensate for the lack of endeavors by private or even public firms. This research apparatus would later be deployed to develop other industries in the future.

[1] A number of Taiwan's commercial banks are quite weak right now, but this weakness is not a result of the Taiwanese government directing massive credit to favored high tech firms. Rather, the weakness derives from the fact that the high-tech firms have other channels, principally the stock market and venture capital, from which to raise capital so the commercial banks are stuck lending to the traditional sectors, such as building and textiles/apparel, which are themselves facing a crisis. Interviews by author. The interview subjects were an investment banker involved in tracking the health of Taiwan's financial system and a scholar from National Taiwan University's business school.

The institutional infrastructure building began with the founding of the Industrial Technology Research Institute (ITRI) in 1973. Subsequently, research institutes under the ITRI umbrella were formed. The most important of these was the Electronics Research Service Organization (ERSO), founded in 1974. Premier Sun, also established the Science and Technology Advisory Group (STAG) in 1978 under the premier's office to advise and oversee technology policy. Another proponent of technology upgrading was K.T. Li, who had held a number of ministerial positions before taking charge of STAG at the time of its formation. The Science and Technology Advisory Group held de facto veto power over technology policy and which was composed almost entirely of foreigners of non-Chinese descent. Taiwanese technology policymakers decided that they wanted the best advice available regardless of nationality. The Hsinchu Science-based Industrial Park (HSIP) was founded in 1980. This park provided tax breaks and other incentives for the high technology companies within its confines. It also ensured that adequate supplies of water and electricity were available to business located in the park. These supplies are critical to the operation of the IC industry. Recently, a second science-based industrial park has been set up in southern Taiwan. Around the HSIP, the state built up the training capabilities of local universities, particularly Qinghua and Jiaotung. Jiaotung boasts the National Nano-Device Laboratory, a very large and advanced fabrication facility for training students.[2]

Leveraging MNCs to Create a Domestic Industry

The Taiwanese state's technology policy apparatus launched two key initiatives to develop the IC industry in Taiwan. Combining government R&D facilities and technology from multinational corporations, the Taiwanese state was able to spin off firms from ERSO. Spinning off in the Taiwanese context meant ERSO trained personnel in the acquired foreign technology and then allowed these ERSO-trained engineers and ERSO equipment to leave ERSO's control to become privately managed companies.[3] However, given the political opposition to excessive expenses for high-technology promotion, these firms were not national champions flush with cheap capital provided by the state, but small firms built on the cheap.

While building R&D institutions was not controversial, the proposed usage of ERSO and government funds to promote the IC industry was. Thus, the total funding to acquire foreign IC technology for the first spin-off project was limited to US$15 million. In 1975, the Ministry of Economic Affairs (MOEA) and ITRI agreed to buy the technology and RCA was selected as the provider. In 1976 RCA signed an agreement with the Taiwanese government, and in 1977 a fabrication facility within ERSO was up and running with better yields than RCA's own facilities.

[2] There is a rumor that the NNDL will shut down, but the fact remains that this facility is much larger and more advanced than its equivalent at MIT.

[3] The term control is consciously used here as equipment and even space within ERSO buildings were often lent to the new companies. Thus, there were often transfers of control, but not transfers of ownership. However, the personnel were no longer ERSO employees in any sense.

After another round of much heated debate about whether to proceed, the government in 1980 decided to privatize the RCA project, creating United Microelectronics Corporation (UMC).[4] Privatization of in-house personnel and facilities does not appear to have been the first choice of the technology policy establishment, but the state tried and failed to find private firms to take over the fab.[5] With arm-twisting, the state forced private firms Sampo, Teco, Yao Hua, Walsin Lihwa to contribute small amounts, but the state-owned Chiaotung (Jiaotong) Bank armed with its new fund to promote high technology served as the main investor.[6] Through the bank, the Taiwanese government still contributed 49 percent of UMC's initial capital investment of US$14 million. The firm was, nevertheless, privately run even though the management and engineers were generally former ERSO employees.[7] By the end of 1982, UMC was at a break-even point.[8] The firm concentrated on low-end application-specific ICs for watches, musical instruments and telephones, and the firm did not represent a departure from the standard IDM model of keeping design and fabrication in-house.

Following the founding of UMC, the foreign advisory body, STAG, pushed for a large and ambitious program to catch up to the technological frontier.[9] This proposal was opposed not only by the agencies responsible for macroeconomic stability, the Ministry of Finance and the Council of Economic Planning and Development, but also by the some officials within ERSO who worried that a premature push would result in commercial failure. Finally, intervention by the top leadership, including Premier Sun and President Ching-kuo Chiang, won the day for a new push toward the technological frontier.[10] This new project, dubbed the VLSI project, was charged with bringing the Taiwanese up to the very large scale integration (VLSI) technology of one-micron geometry in both design and process technology. Once again, ERSO was the chosen vehicle through which to pursue the project. This controversial new plan had a budget of only US$72.5 million to be spent over six years (1983-88).[11]

The VLSI Project was able to lure Chinese-American design houses, such as Mosel and Vitelic, to Taiwan to participate in ERSO's design portion of the project. These firms successfully designed VLSI-scale chips, but they sold or licensed these to Korean and Japanese firms in 1985-86 because there was no fabrication facility in Taiwan equipped to produce the VLSI chips. This sale to foreign competitors shocked

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[4] Hong (1997), p. 51 claims that UMC was launched in 1979, but the other authors, such as Mathews and Cho, p. 160, list 1980 as the date. The discrepancy may be due to the timing of approval of the plan and the actual creation of the firm.
[5] Meaney (1994), p. 174 and Hsu (1997), pp. 50-51 argue that Dr. Sun and other technocrats, such as Dr. Shih and Dr. Hu who submitted the actual UMC proposal to MoEA, were against having a state firm because general policy in Taiwan had been away from such an agenda. Hsu (1997), pp.56-57 fn. 36 suggests that the technocrats simply wanted to reduce their exposure to risk, especially given the expenses incurred in the Ten Great Projects.
[6] Mathews and Cho, p. 196 fn. 13.
[7] Hong (1997), p. 51.
[8] Mathews and Cho, p. 167.
[9] Hong (1997), p. 53.
[10] Mathews and Cho, p. 169.
[11] Ibid.

the government into reviving a dormant 1984 proposal to spin-off ERSO's new VLSI pilot fab as another commercial venture.[12]

The technology policymakers felt that a foreign partner was needed, both to provide technology, and, more importantly, to serve as an investor to protect the new project from further criticism about wasteful government spending. In 1986, Philips agreed to sponsor a stake (originally set at 27.5 percent) and the China Development Corporation**,** a para-statal bank owned by the governing Nationalist Party, contributed 48.3 percent and other private investors made up 24.2 percent.[13] It has also been suggested that TSMC might have needed Philips for some of the crucial IC fabrication patents that Philips owned.[14]

The Rise of the Pureplay Foundry Model

The formation of TSMC with cooperation from Philips marks the beginning of the foundry model, an industrial relationship in which a firm fabricates but does not design its own chips. The foundry model that has flourished in Taiwan is based on interdependence between the strategic supplier of foundry services and the customers, many of whom are foreign firms. The foundry model has allowed for the upgrading of technology, but it has also dictated a much larger measure of tolerance for interdependence with foreign clients as the foundry firm has to be able to fill its fabs with client orders and the foreign firms have to be able to find fabrication capacity for their chips. The foundry model has been embraced in Taiwan as a globalist means to build the national industry, rather than rejected as insufficient in terms of the technonational goal of technological independence. Interdependence has met the nationalist goals of enhancing domestic technological capabilities so the state has not attempted to roust foreign firms from the local production.

TSMC's foundry model represented an innovation in the industry where the integrated device manufacturer (IDM) model combining design, fabrication and often packaging functions in one company was still the dominant format for the IC industry. The 1980s witnessed the rise of some "fabless" design houses, but the fabless firms still encountered difficulties producing their chips at high quality and on demand. Morris Chang, President of ITRI and soon to be head of TSMC, proposed to create a new type of firm that would concentrate solely on fabrication of ICs, the foundry model, and thus serve the demand for fabrication presented by the growing design house market. It was, however, unclear if this type of foundry model would work because the knowledge about the designs necessary to fabricate the chips was still not completely codifiable. In the IC industry, codifiability means the ability of the chip designer to encapsulate in the design plans of the chip everything that the fabricator of the actual chip has to know to produce the chip. This ability to transmit all the required information within the design itself was

[12] Ibid., p.170 and Hong (1997), p. 54.
[13] Mathews and Cho, pp. 197-98 fn. 20.
[14] These patents concerned some basic CMOS fabrication process technology. IPC Interview. Interviews were conducted under the auspices of MIT's Industrial Performance Center unless otherwise noted. The author would like to thank Professors Berger, Lester, Sodini and Akinwande and Dr. Timothy Sturgeon for letting him participate in the IPC's globalization research of which these interviews comprise a part.

very difficult and helped to explain why most firms were still IDMs that brought the chip designers and fabricators together in one firm to figure out how to produce the chips. Indeed, upon hearing Morris Chang's plan for a pureplay foundry, Gordon Moore of Intel commented, "Morris, you've had a lot of good ideas in your time. This isn't one of them."[15]

The foundry model suited small firms, such as TSMC, trying to advance technologically because these firms could learn through serving their customers. Initially, customers, such as VLSI Technologies, passed on technologies to TSMC without which TSMC would have been unable to fabricate their chips.[16] Later on, as TSMC's expertise grew with a wide-range of products and processes, the main learning process from customers came in the form of feedback that could be leveraged to refine and expand TSMC's fabrication methods. It was also important that TSMC did not design and produce its own chips because this allayed the fears of potential customers that the foundry contractor would steal its designs.[17]

Although the codifiability issue made the foundry model a gamble, the pureplay foundry business eventually replaced the IDMs as the greater part of Taiwan's IC production. In essence, the technoglobal strategic suppliers to the world beat out the more technonational IDM firms that tried to combine and control all the major IC activities within their own domestic companies—at least in Taiwan. The state did not try to limit the success of the technoglobal foundry model that it had created in order to favor of the IDMs. Instead, it permitted the gradual conversion of IDMs, such as UMC into foundries. By 1992, TSMC had pulled even in sales with UMC, the biggest domestic firm up to that point, and by 1993 had clearly surpassed UMC in sales. Furthermore, it was clear by 1994 that the technology necessary to transfer designs to foundries had been completely developed. Many of the current managers of TSMC's fabs returned to Taiwan from the United States to work for TSMC at this time because it became clear that this model would work well.[18]

The feasibility of codifiability, and the return of experienced engineers and managers from the United States, helped to account for the gradual increase of the foundry share from a plateau of roughly one third of Taiwan's total fabrication in 1992-1995 to a consistent majority share from 1997 onwards (see Figure 1).

Why did the foundry model succeed better than the other models in Taiwan? The mainstream IDM approach was very difficult because it required simultaneous development of the next generation of process and product design technologies. Given Taiwan's tight credit system, firms did not have the access to the large amounts of patient capital necessary to pursue this simultaneous development of process and product technology. Between 1993 and 1997, total R&D as a percentage of sales hovered just

[15] IPC Interview.
[16] Mathews and Cho, p. 172.
[17] IPC Interviews confirmed the importance of learning through customer feedback and the foundry model as a safe bet for customer's IP.
[18] IPC Interviews.

above five percent compared to 10-15 percent of sales in large U.S. firms.[19] Priority was given to acquiring the economies of scale and the new equipment, which embodied an increasing share of the process technology. Capital investment averaged 69.5 percent of sales over the period 1993-97. Even this high level of capital expenditure should be viewed in the context of a rapidly growing industry that showed a net profit growth of 34.1 percent from 1995-97.[20] The pureplay foundry model solved the ongoing Taiwanese dilemma of how to advance technology on small budgets by learning from customers and concentrating on advancing technology in only one area—IC fabrication.

Private fabs began to enter the market in the latter half of the 1980s. Following TSMC, several private firms decided that the IC industry in Taiwan was viable and invested in it. Holtek and Winbond received infusions of ERSO talent. Returnees from the United States founded Macronix and Mosel-Vitelic. Along with UMC, these firms attempted to be IDMs. They all ran into difficulties in designing products and building the necessary fabrication capacity at the same time. In 1998-99, UMC reorganized its operations, by spinning off its design functions, buying Holtek, and converting its fabrication facilities to the foundry business.[21]

The foundries' focus on and mastering process technology did not make them independent drivers of the IC industry. Instead, Taiwanese foundry firms supplied process technology and state-of-the-art manufacturing capacity. Outsourcing IDMs and design houses sought fabrication capacity. The result was continual interdependence between the foundries and their customers. In industry upturns, the foundries have the upper hand as they have control of the scarce commodity, foundry capacity. In downturns, the IC designers and outsourcing IDMS have the upper hand as the scarce commodity is their chip orders and foundry capacity is abundant. Taiwanese foundries and American fabless design houses as well as some IDMs have tried to enter into long-term relationships to smooth out the cycle of dependency. Along with Philips' continued large stake in TSMC, the other major foundry in Taiwan, UMC, has sold equity to American design firms in return for dedicated fab (fabrication facility) capacity. Philips and TMSC are building a fab in Singapore, and UMC has separate agreements to build fabs with Hitachi in Japan and with Infineon in Singapore.

Taiwanese firms have also arranged similar deals with local fabless design firms either by secret stock exchanges, which is not legal under Taiwanese law if it is done to prop up stock prices, or by forging long-term contracts to deal with the vagaries of the silicon cycle. In the technonational view of the world, these intra-national deals would not be controversial and would be viewed as another example of Asian network capitalism. These native networks, however, pale in comparison to the admittedly more transparent relationships and cross-shareholding between Taiwanese firms and foreign, primarily U.S., counterparts in terms of strategic value to the Taiwanese firms due to the technology and the higher value-added orders of the foreign firms. In the

[19] For U.S. data, see Hodges *et al.* For Taiwanese data, see IT IS (1998), p. VIII-15
[20] IT IS (1998), pp. VIII-15 and VIII-19.
[21] Interviews (1997, 1999 and 2000). The 1999 and 2000 interviews were IPC Interviews.

technonationalist view this transnational interdependence would represent an unacceptable amount of dependence or at least interdependence on foreign firms.

Extending the Interdependence Model: The Chipset Firms

The other high-technology segment of the IC industry in which Taiwanese firms have been quite successful is the chipset design segment.[22] Just as the Taiwanese foundries are competitors with each other and have their most valuable strategic partners abroad, the Taiwanese chipset designers are fierce competitors and make use of both domestic and foreign allies in their chipset wars. This model of competition is quite different than the Japanese case of technological upgrading through consortia. While the Japanese consortia may have been marked by as much inter-firm competition as inter-firm cooperation, the concept of upgrading was still to organize the national "us" against the foreign competition. The Taiwanese firms have a Taiwanese identity, but this does not dictate which firms will be their strategic allies or enemies.

Since the financial requirements of the design segment are modest and the significant human capital resources of Taiwan present in the large and growing pool of local college graduates as well as the returnees, one would expect the Taiwanese to excel in this area. The chipset designers are an indication that this excellence is beginning to emerge. Again, the state played an important role as CCL (the Computer and Communications Laboratory), a former division of ERSO, licensed foreign chipset designs to local firms.[23] The local industry also received much talent from the US firm, Chips&Technology.[24] The top managers of the three largest Taiwanese chipset firms, ALI, VIA and SIS, are all returnees from the US, and two of the three firms' managers are ex-employees of Taiwan's main chipset competitor, Intel.

Three Taiwanese chipset makers have been able to enter into competition and/or alliance with Intel in this segment because Intel has relied on its cutting edge processors to push sales of its chipsets. Intel chipsets do not necessarily give the best performance and thus the opportunity for other firms has opened up.[25] The Taiwanese chipset makers have competed in the world market and with each other by leveraging both domestic and international firms as allies.

The largest Taiwanese chipset maker, VIA, has been able to compete in an Intel-dominated world. VIA has succeeded in selling a new chipset in defiance of the chipset standards that Intel has tried to set using technology from an American intellectual design firm, Rambus. VIA has not pushed the technological envelope too far as Intel appears to have done with Rambus technology.[26] VIA has had a strong relationship with the TSMC as a foundry partner and a strategic alliance with National Semiconductor through which it has access to a large IP portfolio. Acquiring the Cyrix processor division and R&D

[22] In addition to design and fabrication success stories, Taiwan has a very successful IC packaging segment, but this segment is not as technology-intensive as the other two segments.
[23] Noble (1998), p. 144.
[24] Dedrick and Kraemer (1998), p. 159.
[25] Ibid.
[26] Some have said that Intel's failure in attempting to set the Rambus standard is due to trying to push immature technology onto the marketplace. The result was a chipset with poor performance. This information is based on interviews with chipset manufacturers.

facility in Silicon Valley from National Semiconductor, VIA has expanded into the design of low-end CPUs. ALI has chosen to be a partner with Intel though Intel's recent difficulties with Rambus technology have hurt ALI as well. ALI also has partnered with TSMC to work out the fabrication problems that the chipset designs can present. Both VIA and ALI are also connected to Taiwanese computer manufacturers, major chipset consumers. The odd man out, SIS, has never succeeded in establishing a good relationship with either of the Taiwanese foundries and has no major international allies though SIS has licensed technology from abroad. SIS has taken the controversial and financially risky strategy of turning from a fables design house into an IDM through a construction of a fab. The alliances have played themselves out in the introduction of the new Pentium 4 chipsets as Intel has refused to grant a license to VIA, its most potent competitor. VIA has responded by producing Pentoum 4 chipsets without a license, which has resulted in Intel lawsuits against VIA in a number of countries. In contrast, Intel has had much better relations with ALI and SIS with licenses rather than lawsuits as the end result.[27]

Full-setism and the DRAM Dilemma

Despite the successes of the Taiwanese state in building an industry infrastructure, and spinning off a company that would reinvent the whole model for the IC business, the Taiwanese state and cooperative private entrepreneurs have not been infallible. The technology policymakers and business entrepreneurs flirted with the idea that to build a nation requires a complete set of advanced industries. In this particular case, the idea was that to have a really vibrant national IC industry, one needed to have a DRAM industry. The Taiwanese efforts to build such an industry are a pointed reminder that behind their more internationalist strategy the Taiwanese still have a nationalist project.

After the failure of the first short-lived DRAM venture, Quasel in 1986, Taiwanese firms made a second attempt to enter the DRAM product segment. The joint venture**,** TI-Acer, began production in 1991. Mosel-Vitelic built a fab in 1994 with process technology transferred from Oki.[28] With their joint venture with Infineon (Siemens), and Promos Technology, Mosel Vitelic got 64M DRAM technology from Infineon and a partner in wafer fabrication in 1996. Nanya Plastic entered into an agreement with Oki and began production in 1996. Powerchip, a subsidiary of Umax, received technology from Mitsubishi and began operations in 1996. Taiwanese government officials and private businesses encouraged these ventures because they believed that DRAMs would remain a critical driver of IC process technology and that as a large consumer of DRAMs, Taiwan should acquire access to a stable supply of this critical component. The last large ERSO-led research project, the Sub-micron Project of 1990-1994, helped Taiwanese firms develop process technologies below the 1 micron-width and also created a new DRAM spin-off, Vanguard, with technology transfer from Oki.

[27] For VIA's large difficulties with Intel compared to its Taiwanese competitors, see Faith Hung, SBN, November 1, 2001 and TENS, September 26, 2001.
[28] Mathews (1995), p. 95.

The problem with these ventures is that the Taiwanese DRAM producers have become captive suppliers of their foreign partners, and have had to assume most of the investment risk as well. Because Taiwanese firms pay fees to the suppliers of the DRAM technology, the slim margins that DRAM fabrication generates are even smaller. None of the Taiwanese firms has been able to develop the latest DRAM designs on its own. Given the need for large shares of the world DRAM market to be able to fund such research, around 15 percent, none of the Taiwanese have been able to reach R&D economies of scale.[29] In essence, the Taiwanese DRAM firms are dependent on their foreign customers for technology and orders. In contrast to the foundries, they have no hold over their clients because they own little propriety process technology, and DRAM design and manufacturing are so tightly linked that it is unrealistic that they would be vendors for a wide range of clients.

There has, accordingly, been a gradual exit from this market. When TI left the DRAM business, TI-Acer was stranded without a source for the next generation of technology and Acer sold the TI-Acer fab to TSMC to increase its foundry capacity. TSMC plans to convert Vanguard to foundry production once the current generation of DRAMs has run its course. Nanya almost closed down when they could not receive the next generation of DRAM technology from Oki, and were only saved when they received the technology from IBM in return for setting aside part of its capacity for IBM. As shown in Figure 2, after the frenzied investment came into production in the mid-1990s, DRAM has declined in market share vis-à-vis foundry (See Figure 2).

From Jewel in the Crown to Royal Pain: The Politics of Private Industry Expansion

The IC industry has been the most shining example of the state's technology wonks' success, but the IC industry has given rise to a cacophony of private industry voices increasingly critical of the state's intervention in this sector. The state's efforts came under attack relatively early in the industry's development. UMC criticized the VLSI project that created TSMC in 1986 because UMC viewed the project as taking away resources from UMC, the first state-sponsored company. Acer attacked the next project, the Sub-micron Project, from the very beginning as waste of government resources to develop more advanced process technologies and memory technologies. Acer, of course, had already agreed to build an advanced memory fab with TI in 1989. As the project drew to a close in 1993-94, UMC and TSMC quarreled over the spoils of the Sub-micron Project, a new fab that eventually became Vanguard. ITRI's budget was cut in half in 1994 by the Legislative Yuan in wake of the criticism of the Sub-micron Project as a funnel of public funds to what were deemed to be mature private enterprises.

While ITRI's funding subsequently recovered, the scope for public initiative in the area of ICs has narrowed considerably. In the late 1990s, ERSO tried to organize a consortium to research future generations of process technology, ASTRO. Unfortunately, the technology leaders, TSMC and UMC, were not interested in joining. The other major IC fabrication firms were interested in joining, but these firms were not as technologically sophisticated as TSMC and UMC. Indeed, the underlying motivation of the project was to help the lesser firms upgrade. In the end, no project was tenable in

[29] IPC Interviews with DRAM firms.

terms of obtaining the large amount of government resources necessary without the participation of the leading firms, TSMC and UMC. While the large private firms are willing to accept help to enter new industries, the combination of government fiscal constraint and the leading private firms' unwillingness to cooperate once independent innovation capability is achieved suggests that the trend away from public leadership in the IC industry will be replicated in other areas.

The shift towards private initiative in high-technology areas has been made possible by the increasing scale and scope of Taiwanese private firms, particularly those firms that arose in the new technology products areas. To present some hard data on this shift using sales revenue in 1987, four of the ten largest manufacturing firms were state-owned. By 1999, only five of the top fifty were state-owned and only one of these was in the top ten, Chinese Petroleum. In 1999, the highest ranked high-tech firm was Acer, the second-largest manufacturing firm. In 1987, Acer was ranked fifty-third and UMC, the largest IC firm at the time, was ranked 122nd. Indeed, eight of the top 50 firms in 1999 were operating in the Hsinchu Science-based Industrial Park and four of the top ten largest firms were Taiwanese high-technology firms. Two subsidiaries of Philips were also in the top ten.[30]

The Cup Half Full: Development and Dependency in the Taiwanese PC Industry

The Taiwanese computer manufacturers have developed as suppliers for the large international computer firms. While the Taiwanese foundries have a superficial similarity to the PC firms, the PC suppliers are in a more inequitable relationship with their foreign partners than the IC foundry firms. The Taiwanese foundry model was itself an innovation. Among the Taiwanese PC suppliers, there has not even been much of this type of organizational innovation. However, the dependence on the international branded firms in the Taiwanese PC industry is not an entirely disadvantageous. As Dedrick and Kraemer have argued, the Koreans and the Japanese tried to go it alone without extensive cooperation with the American firms under the Wintel standard and they failed in this endeavor. Because they never embraced the extreme form of technonationalism, the Taiwanese were able to succeed in being close followers of the lead firms and avoid the losses of costly bets on failed alternative standards. Thus, the cup half empty due to dependence on the branded PC firms may be the cup half full with technological upgrading and industrial expansion that the technonational Koreans can only look at with envy.

Foreign Firms, Domestic Suppliers and the State

In the PC industry, the state aided local firms to become suppliers to the foreign firms that had come to Taiwan to set up manufacturing facilities. Gradually, these local suppliers developed into full service original equipment manufacture (OEM) firms and then into original design manufacture (ODM) firms producing complete PCs for the own brand manufacture (OBM) firms, principally American ones. The local supplier firms,

[30] *Commonwealth (Tianxia)*, July 1987 and August 2000 for data.

sometimes with the help of the state, were able to leverage their supplier role to upgrade technologically.

Promotion of the PC industry started shortly after the promotion of the IC industry. However, initiative in this area was more equitably shared between the public and private sector. The PC industry narrowly conceived has been an assembly industry and thus did not have as high technology barriers as the IC industry. Thus, private firms were more willing to invest from the beginning to catch up to the technological frontier.

The dominant producers in this sector in the initial stage were American producers. The activities of these foreign producers in Taiwan were significant because they were pursuing the core manufacturing activities in the production of PCs whereas they only pursued the backend tasks of assembly and testing in the IC sector. In the late 1970s, foreign manufactures made up the great bulk of PC-related production in Taiwan.[31] During the 1980s, the share of foreign computers manufactured in Taiwan gradually declined from 57 percent in 1984 to 30 percent in 1990.[32] By 1995, the figure was down to 15 percent.[33] Figures for the foreign manufacturing segment are no longer kept by Taiwan's Market Intelligence Center as this segment is insignificant. However, the state did not make any efforts to drive them out. The decline in production by these American MNCs is attributable to their strategy of increasing outsourcing of production.

The large foreign presence was critical in several ways. Kawakami argues that the firms stimulated the components industry, offered technological assistance to their Taiwanese suppliers, nurtured human resources and served to demonstrate what were the new products demanded by the international market.[34] The very fact that these firms were already in Taiwan also made the transition from vertically integrated producers to OBM firms outsourcing to Taiwanese OEM firms that much easier.

The real beginning of Taiwanese PC production as opposed to component production began in the 1980s. The state had an important if unintentional role in this development. Many of the firms got their start in producing knock-offs of the Apple II. With the ban on video game machine production due to concerns that they were wrecking the moral fiber of the younger generation of Taiwanese, many of these game-producing firms in desperation began to churn out Apple II clones often with not-so-original logos, such as pineapples and bananas. In 1982, Apple persuaded the U.S. government to ban these machines. Soon, the state took a more active role in promoting the industry. In 1982, ERSO and eight private firms worked on a PC clone and finished work in early

[31] Kawakami, p. 3 argues based on the MoEA's Industrial Development Bureau's *Annual Report 1982-1983* that in 1979 the only PC manufacturers in Taiwan aside from possible procurement from the small component suppliers implied by Kawakami (pp. 16-17) were American ones. However, at least one Taiwanese firm was involved in minicomputer Chinese language input device production since 1974, IPC Interview.
[32] Kawakami, p. 6.
[33] Hwang, p. 45.
[34] Ibid., pp. 12-17.

1983.[35] In total ERSO undertook three major desktop computer projects with a variety of local firms.

While the ERSO projects were important for the PC industry, the two industry leaders, Acer and Mitac, were doing OEM for ITT since 1982 and Mitac was not part of two of the three big desktop computer projects run by ERSO. The logic behind the OEM relationship helps to explain how these firms were able to foster technological upgrading outside of ERSO while they were still very small companies. As Lee and Chen argue, these contract manufacturing firms can leverage their relationships with outsourcing partners to upgrade.[36] The experience of Mitac, Acer and other firms, such as the PCB-manufacturer, Compeq (called Compaq in English until lawyers from the U.S. Compaq caught up with it), confirms this theory of upgrading. The intensive OEM relationships with foreign, particularly U.S. firms, and the ability of relatively small firms to enter into PC production in the early years help to explain the fact that ERSO did not play as critical a role in the development and diffusion of technology as it did in the IC industry.

When not directly promoting industry, ERSO was also important in acting as an intermediary to acquire foreign IP rights. For example, ERSO bought the rights from Seattle Computer Products for DOS and sub-licensed it to local firms until Microsoft bought back the rights from Seattle Computer Products in 1986.[37] ERSO also bargained with IBM to lower the royalty fees IBM wanted to charge Acer for using what it claimed were IBM technologies after Acer abandoned ERSO BIOS. This negotiation may have had something to do with ERSO's cross-licensing arrangement with IBM.[38]

Engineer and technologists, who were trained in the United States, played a critical role similar to the IC industry. In the late 1980s, an estimated 180,000 engineers returned from work or university in the United States.[39] Acer's Stan Shih's personal background was famous precisely because he was one of the few who did not go abroad for work or education.

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[35] N.T. Wang (1992), p. 201.

[36] Ji-ren Lee and Jen-Shyang Chen (2000) argue that firms can upgrade from OEM to ODM, but, given Kawakami's evidence from the relationships between outsourcing and OEM firms in the early years of Taiwan's PC industry, this argument should also be extended backwards to the initial stage when the outsourcing firms had the incentive to upgrade the manufacturing abilities of local firms to at least a minimum acceptable level.

[37] Noble (1998), pp. 139-142 claims that the head of counterfeiting of the Taipei Computer Association bought the rights to DOS but these were suspended when Microsoft bought the rights from Seattle Computer Products in December, 1986. However, as part of the IBM and ERSO cross-licensing agreement, ERSO had acquired the rights to MS-DOS, but was unable or did not try to stop small firms from making copies beyond the bounds of its sub-licensing agreement and Microsoft suspended ERSO's sub-licensing rights. An e-mail correspondence follow-up to an IPC Interview with someone well situated to know about the policies of the 1980s does not mention the TCA incident at all. This interviewee does state that acquiring MS-DOS did allow many small firms to enter the motherboard business.

[38] Dedrick and Kraemer, p. 156 mention the cross-licensing arrangement, but do not provide the likely context of the general ERSO-IBM cross-licensing agreement.

[39] Hsu (1997), p. 73.

The state's promotion policies changed in the 1990s into more genuine joint public-private research efforts. The Computer and Communications Laboratory (CCL) was separated from ERSO and concentrated at first on notebook initiatives. While the First Generation Notebook consortium set up by TEAMA and ERSO attracted 46 firms because the cost of entering the consortium was only 50 thousand USD, the number of firms shrunk in the second and third notebook consortiums to four and fifteen notebook manufacturers, respectively. The latter two probably more resembled genuine joint public-private partnerships. Today, there are six notebook firms with a capacity of over a million notebooks a year. However, according to one of the leading Japanese firms, which just recently started outsourcing to Taiwan, only three of these firms are really capable of producing high-quality notebooks.[40]

The Glass Ceiling of OEM/ODM and Efforts to Move from Dependence to Interdependence

Serving as OEM producers to branded international firms helped to make Taiwan competitive international PC markers, but the Taiwanese wanted to be more than firms dependent on orders from branded foreign firms. They have attempted to move up the chain into design. Taiwanese firms have definitely enhanced their design capabilities, but they have not yet captured enough of the design capability to be said to be in a truly interdependent relationship with the branded PC firms. These branded firms have a number of manufacturing firms to choose from, both Taiwanese and others. The Taiwanese firms have employed a number of other strategies to change this dependency to interdependency, but it is too early to tell if they will succeed.

The Taiwanese PC producers have been heralded as shifting from original equipment manufacturing (OEM) to original design manufacturing (ODM) production.[41] The primary purpose of the out-sourcing firm in an OEM relationship is to reduce production costs so OEM production tends to have low margins. Thus, the logic behind this move to ODM is to increase margins because OEM manufacturing's low margins.[42] The addition of global logistics services seems to be a further bid to enhance or at least preserve value as global customers demand these services from OEM/ODM suppliers.[43]

Interviews with Taiwan's leading desktop and notebook PC assemblers indicate that these firms regard the ODM strategy an incomplete solution to enhancing value creation. Information from the interviews with Taiwanese firms suggests that the largest desktop PC manufacturers have begun to move their production to China because the pressure of low margins has dictated a continued search for cost-cutting measures. Thus, the increasing design capabilities of Taiwanese firms did not bolster margins enough to prevent the necessity of cutting costs by moving production to China.

[40] TENS, January 8, 2001.
[41] Schive, p. 2.
[42] Lee and Chen, p. 7.
[43] Lee and Chen, p. 7 and Schive, p. 2 and interviews conducted by IPC with Taiwanese PC manufacturers.

The cost pressure on the OEM/ODM firms has been unceasing even as the absolute size of these firms and their shares of the world market have increased through consolidation. The top four items of Taiwanese IT hardware production from 1998-2000 (of which the top ten are all PC-related) all had high production concentrations in which the Taiwan's leading firms all had significant world market shares as shown in the table 1. However, this greater concentration has not led these firms to be strategic suppliers in a closely inter-dependent relationship with their customers, such as the foundry provider-design customer relationship. One reason is that aside form**[from]** the large Taiwanese OEM/ODM firms, there are a number of large, versatile contract electronics manufacture (CEM) firms from the United States that operate plants around the world. The flipside of the existence of these competitors is the fact that the Taiwanese do not control much of the technology of design or manufacturing. Thus, they do not have any obvious advantage over any other firm capable of manufacturing a computer. In contrast, the Taiwanese foundries have developed substantial process technology as well as a performance lead over their' would be rivals (See Table 1).

One method the Taiwanese have pursued is to cut cost by moving production to low-wage parts of East Asia, principally China. During the 1990s, there has been a progressive movement of Taiwanese IT hardware production out of Taiwan. The first items to leave were low-end peripherals, such as keyboards and mice. Then, scanners, monitors and motherboards followed in the latter half of the 1990s. In the late 1990s, desktop production began to move abroad and now notebook computer manufacturing is beginning to leave Taiwan. Production abroad topped fifty percent in 2000.

The movement of production overseas has only allowed the Taiwanese firms to continue to compete in a product market with razor thin margins. It has not enhanced the margins, enabling the Taiwanese firms to move away from products in which they are dependent on their branded customers. The Taiwanese PC firms have tried to resolve these problems of low margins and dependency by diversifying away from their dependency on the PC market. These firms are gradually moving toward a wider platform of products similar to the platform of the CEM though the Taiwanese will unlikely be able to diversify into as many areas. The CEM firms' computer production is only about twenty percent of their total product portfolio.

The logical move has been to develop smart hand-held devices (SHDs) as these products, such as personal digital assistants (PDAs), within the IT sector. Cell phones are another area the PC manufacturers are trying to enter. Again, the Taiwanese manufacturers have pursued these developments in conjunction with foreign firms. Eleven firms have received cell phone technology, but only six have received the technology principally from ITRI and five have received it from foreign sources, principally U.S. ones.[44] The big three PDA firms, Handspring, Palm and TRG are looking for OEM partners in Taiwan and most of the computer manufacturers are gearing up to produce these items. Private firms have shown a greater measure of independence from ITRI, given their growing absolute size and growing capabilities over time.

[44] Data received from a Japanese firm from its Taiwanese subsidiary's July, 2000 marketing report.

Nevertheless, the old pattern of making international alliances, while receiving aid from ITRI, remains.

Building up the Infrastructure and Flirting with the Full-setism

The Taiwanese state has been active in promoting the building up the industrial infrastructure for the PC industry in the 1990s. The state has targeted critical components of the PC for development in Taiwan, such as HDD (hard disk drives) and AMLCDs (active matrix liquid crystal display). The Taiwanese state continued to follow the leading international firms rather than setting up its own standards and also refrained from promoting outright national champions for these sectors. Some of the projects have failed simply because the fit with the local industrial structure was ignored in another misguided bid to have a more complete set of critical components for the PC industry. HDD is an example of this. The promotion of AMLCD technology did not meet such a bad end because computer AMLCDs did not require large scale-economies to fund both R&D and production capacity.[45]

The pursuit of HDD is the classic example of Taiwan suffering from full-setism fever. This industry is characterized by extremely high scale barriers to entry and short product generations in a manner eerily similar to DRAM. Despite their growing size, Taiwanese firms are still small compared to the Korean *chaebol* that have the capability to leverage their resources to enter product areas with high scale barrier and short product cycles. Furthermore, the HDD industry remains dominated by American and Japanese MNCs. Singapore was able to become the regional headquarters for these foreign HDD firms because it has pursued a technoglobalist policy of encouraging MNC investment with a host of incentives. The Taiwanese were much more reluctant to pursue such a MNC-focused strategy, particularly early in the move of HDD production from the US and Japan to developing Asia in the 1980s. The Taiwanese failed to build firms with scale economies to be efficient mass producers and also generators of the current generation of products even though they pursued their strategy of utilizing ITRI and serving as suppliers to foreign firms.[46]

Conclusion

The Taiwanese have pursued their nationalist aims of achieving technological and economic development through the globalist tactics of forging international ties, particularly by serving as strategic suppliers to leading firms from the advanced industrial economies. These ties have led to interdependence and even in some cases to dependence on the advanced world, but they have arguably succeeded as well at building the nation as their more technonational neighbors. The state has developed a set of institutions including ITRI, the science parks, and the university system to facilitate the internal diffusion of technology. It has served as intermediary between local firms and international technology leaders.

[45] For the development of Taiwan's AMLCD industry, see Fuller, Akinwande and Sodini.

[46] This account of the HDD failure is based on Noble (2000).

In contrast to the other states in Northeast Asia, Taiwan has refrained from succumbing to the temptation of loosening the purse strings of the credit system to create giant firms to serve as technonational champions. The tight purse strings help explain why Taiwan suffered few effects directly attributable to the 1997-98 Asian financial crisis. The tight credit system also explains why the gradual shift away from an ITRI-centered technology strategy was not crisis-inspired, but came from the emergence of large firms with strong technological capabilities in Taiwan during the course of the 1990s. With the emergence of private sector initiative, Taiwan has only deepened its back on its strategy of serving as strategic suppliers to leading multinational firms to build the nation. Government continues its role of in training the workforce to meet the requirements of the industry. To describe Taiwan as using globalist tactics does not lessen the nation-building project behind the particular technohybrid strategy. This nationalist motivation explains why the Taiwanese state and even private firms have been and may continue to be susceptible to the fever of full-setism and its challenge of grander and greater nation building projects.

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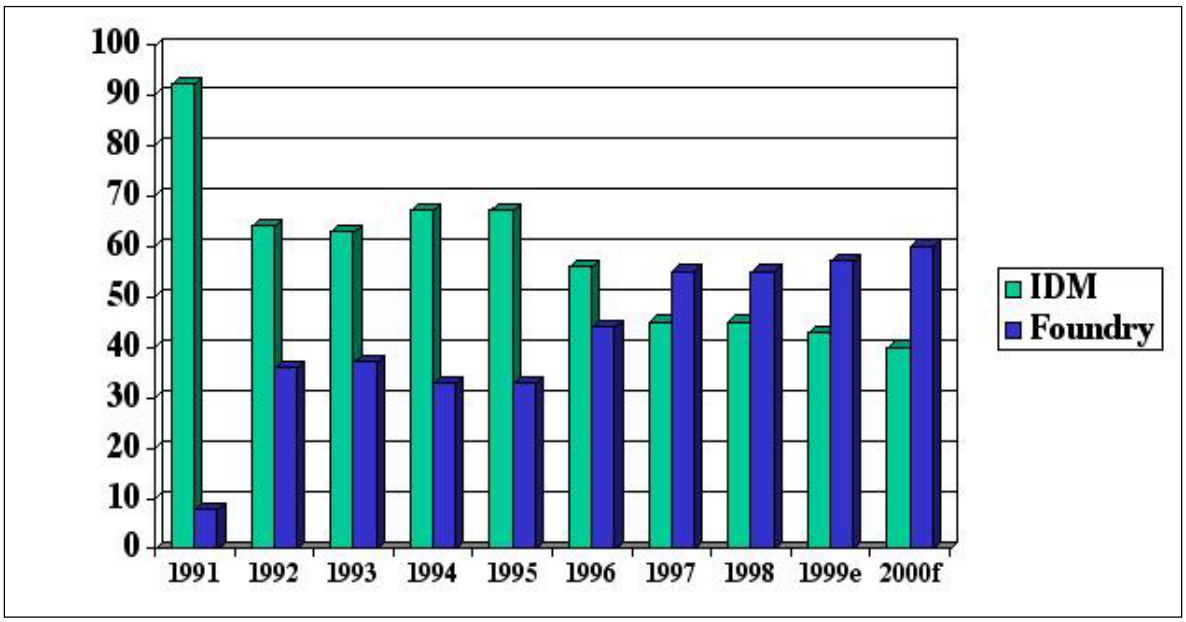
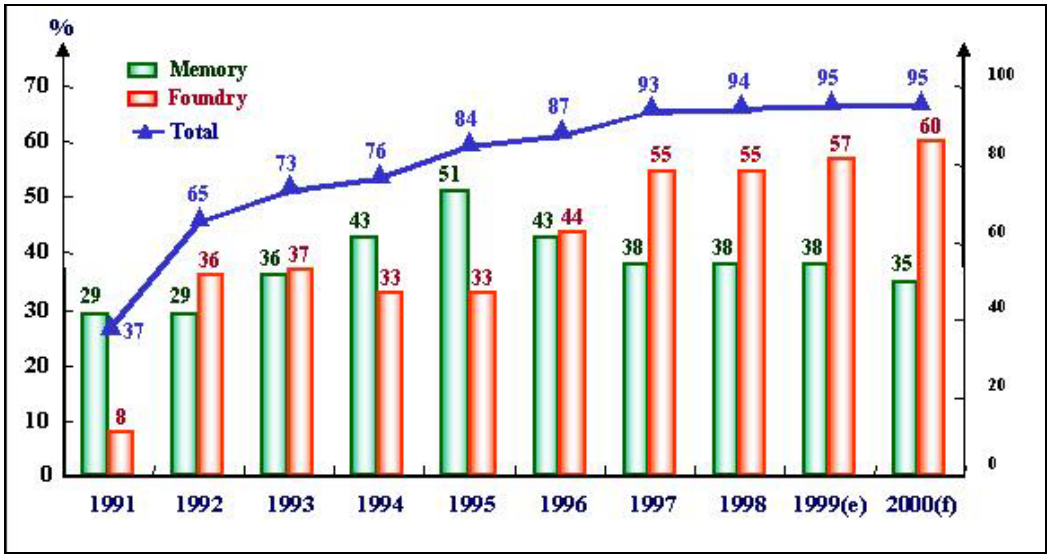
Figure 1
Foundry and IDM Production Share (%)



Source: Taiwan Semiconductor Industry Association

Figure 2
DRAM versus Foundry Production Share

Unit: percentage of total fabrication output



Source: TSIA (Taiwan Semiconductor Industry Association)

Table 1
The Concentration of Taiwanese IT Production in 2000

	Taiwanese Production Share of Top Firms	Taiwanese Production Share per Top Firm	Taiwan's World Market Share	World Market Share per Top Taiwanese Firm
Notebook Computers (2000)	78.75% (5 Firms)	15.75%	65.0%	10.24%
Desktop Computers (2000)	35.0% (3 Firms)	28.3%	22.0%	6.2%
Motherboards (2000)	54.0% (5 Firms)	10.3%	3.3%	9.0%
Monitors (2000)	44.0% (5 Firms)	8.8%	59.0%	5.2%

Source: CENS and Japanese electronic firm's market report