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Globalization for Nation-Building: Taiwan's Industrial and Technology Policies for the High-Technology Sectors

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ABSTRACT In the spectrum of East Asian technology policies from the explicitly technonationalist strategies of Korea and Japan to the MNC embracing policies of Singapore, Taiwanese policy occupies an intermediate position. Taiwan has used technoglobalist means to leverage ongoing international linkages in order to realize the technonationalist ends of enhancing the ability of domestic firms to play in global markets. These technohybrid tactics have sometimes engendered dependence on and sometimes interdependence with the outside world. The contradiction between the nation-building project and the technoglobal one is only resolved through sacrificing the technonationalist ambition of more complete control over the forefront of technology.

Key words: Taiwan, technology, technohybrid, technonationalism, technoglobalism, policy

1. INTRODUCTION: TECHNOGLOBALIST MEANS FOR TECHNONATIONALIST ENDS

Taiwan's technology policy[1] towards high-technology sectors 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 the domestic technology and industrial infrastructure in order to develop the national economy as a whole. How has Taiwan resolved this apparent contradiction in its technology policy?

In the spectrum of East Asian technology policies from the explicitly technonationalist strategies of Korea and Japan[2] 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 technonationalist 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 technoglobalist means to leverage ongoing international linkages in order to realize the technonationalist ends of enhancing the ability of domestic firms to play in global markets. These technohybrid[3] tactics have engendered a dependence on (or at least an interdependence with) the outside world that would be anathema to the technonationalism of South Korea and Japan. Thus, the contradiction between the nation-building project and the technoglobal one is only resolved through sacrificing the technonationalist ambition of more complete control over the forefront of technology.

Taiwan's hybrid mix of technoglobalist means and technonationalist 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 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. 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 that the large branded MNCs 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 overseas work experience, particularly in the U.S. information technology (IT) sector. The technology embodied in returning human capital was critical because the returnees were trained at the best U.S. research universities. They also brought back 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 foreignbased 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 electronics manufacturing operations in Taiwan and received no pressure to move out once Taiwanese achieved 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.[4] 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 Singapore-style sweetheart deals in order to lure them to Taiwan although recent policy shifts in Taiwan (discussed later on in the article) appear to push Taiwanese policy closer to the Singapore-style of wooing MNCs.

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 engage in every key activity in a given sector, the full set of the key activities in that sector. The problem with this approach 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 and private business have fallen prey to full-setism in both sectors examined in this article. 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 (dynamic random access memory) and HDD (hard disk drives). Fullsetism 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 technological policy that should not be ignored. The ability of the state to determine Taiwan's technological policy orientation has diminished over time. 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 industrial policy. The decline of the state's power relative to private enterprise has not changed the overall direction of policy. In a case that parallels Japan's, the decline of state power has not heralded a distinctly different approach to industrial 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 article 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 technoglobalist strategy for nationbuilding 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 contrast, the same strategy applied to PCs has led to development of the industry and enhancement of Taiwan's PC technology, but the Taiwanese PC makers, important suppliers to the branded firms, have few critical technologies that the branded firms cannot easily acquire elsewhere. In PCs, dependency has been the price of development.

2. HAVING IT ALL: DEVELOPMENT AND INTERDEPENDENCY IN THE IC INDUSTRY 2.1

The Development of the Industrial and R&D Infrastructure

The fundamental conflict in the early years of IC industrial 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.

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. The Hsinchu Science-based Industrial Park (HSBIP) 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. Around the HSIP, the state built up the training capabilities of local universities, particularly Qinghua and Jiaotong. Jiaotong boasts the National Nano-Device Laboratory, a very large and advanced fabrication facility for training students.[5]

2.2 Leveraging MNCs to Create a Domestic Industry

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.[6] 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.

The two main state initiatives in the IC industry led to UMC and TSMC being spun-off from ERSO. Each project not only faced political pressure that kept budgets tight, but was predicated on cooperation with a foreign MNC. The first project to acquire IC technology involved RCA transferring the technology to set up a fab (fabrication facility) in ERSO in 1976-77 and cost only US$15 million. In 1980, the fab was spun-off from ERSO to form UMC, a privately managed firm in which the state through Chiaotung Bank owned 49 percent. The firm did not represent a departure from the standard IDM model of keeping design and fabrication in-house.

The second project, the VLSI Project, aimed to bring Taiwan's IC technology up to the very large scale integration (VLSI) level of one-micron geometry in process technology and design. This controversial new plan had a budget of only US$72.5 million to be spent over six years (1983-88) (Mathews and Cho, 2000: 169). 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. Other private investors made up 24.2 percent (Mathews and Cho, 2000: 197-98, fn 20). It has also been suggested that TSMC might have needed Philips for some of the crucial IC fabrication patents that Philips owned.[7]

2.3 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 made the Taiwanese IC industry into one of the world's largest is based on interdependence between the strategic supplier of foundry services and the customers, many of whom are foreign firms. The foundry clients have to find fabrication capacity for their chips and the foundry firms have to be able to fill their fabs with client orders. The Taiwanese state and business community came to embrace this technoglobalist tactic, the foundry model, to build national industry rather than reject it as insufficient in terms of the technonational goal of technological independence.

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 feasibility of foundry model was unclear 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 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.

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 (Mathews and Cho, 2000: 172). 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.[8]

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 even as Taiwan grew to become the world's fourth largest IC producer. In Taiwan, 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. The state did not try to limit the success of the technoglobal foundry model that it had created in order to favor the IDMs, including the many new private firms that began to enter the industry in the late 1980s. Indeed, the state did not interfere with the gradual conversion of IDMs into foundries.

By 1994, 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 (IPC Interviews). 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 roughly two-thirds from 2000 onward. Many IDMs, including Taiwan's pioneering UMC, converted to the foundry model or were bought out by foundries.

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 above five percent compared to 10–15 percent of sales in large U.S. firms.[9] 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 (ITIS, 1998: VIII–15, VIII–19). Indeed, the only time Taiwanese fabrication R&D investment reached ten percent or more was during the 2001–2002 downturn when overcapacity became a major issue so capital investment shrank dramatically in absolute and percentage terms and correspondingly more was spent on R&D. With the return of growth in 2003, more capital investment was needed and R&D investment once again returned to five percent (IEK 2005: 9–19). 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. Figure 1 Percentage share of foundry and IDM in IC manufacturing

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 capacity. Philips and TSMC have a fab in Singapore, and UMC has one fab in Japan[10] and another in Singapore in partnership with Infineon.

2.4. Full-setism and the DRAM Dilemma

Despite the successes of the Taiwanese state in building an industry infrastructure and spinning off the revolutionary TSMC, 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 dynamic random access memory (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 (Mathews, 1995: 95). With their joint venture with Infineon (Siemens), 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 to develop process technologies below 1 micron-width and also created a new DRAM spin-off, Vanguard, with technology transfer from Oki.

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 (IPC Interviews). 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 TSMC's foundry capacity. TSMC has converted Vanguard to foundry production. 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 below, after frenzied investment in the mid-1990s, DRAM has declined in market share vis-à-vis foundry to roughly half of foundry's market share.[11]

2.5. The Shift to Private Initiative

After the Sub-micron Project, the state's major efforts in IC fabrication were over because the private firms (spun-off from public ITRI) were large enough to pursue research on their own. In fact, as early as the Sub-micron Project, state projects came under attack from large private firms that felt the state efforts were unnecessarily displacing their own efforts.

In the wake of a heated dispute between UMC and TSMC over which firm would own Vanguard, the Legislative Yuan cut ITRI's budget in half over anger at the perceived

waste of public funds on large private firms. The state stayed quiet for a number of years, but in the late 1990s ERSO tried to organize a new consortium called ASTRO to research future generations of fabrication technology. However, TSMC and UMC had major R&D activities of their own and secure cooperative relationship with foreign MNCs so they refused to join. This refusal doomed the project
since it was predicated on joint government-business cooperation. Figure 2 Percentage share of foundry and memory in IC manufacturing The rise of private initiative is not a defeat for Taiwan's technological development. In terms of US utility patents,
in 2001 ITRI only had 219 whereas three major private firms had more: TSMC (691), UMC (589) and Hon Hai (309). These three private firms also were ranked among the top thirty of US high-technology utility patent holders for that year (Floyd and Meyer, 2002: 19, 25, 40). Moreover, Taiwan's IC fabrication industry has received over one thousand US utility patents annually since 2000 (IEK, 2005: 9–29).

3. 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 PC firms have a superficial similarity to the IC foundries, the PC suppliers are in a more inequitable relationship with their foreign partners than the IC foundries are. The Taiwanese 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.13 During the 1980s, the share of foreign computers manufactured in Taiwan gradually declined from 57 percent in 1984 to 30 percent in 1990 (Kawakami, 1996: 6). By 1995, the figure was down to 15 percent (Hwang, 1995: 45). 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 (1996: 12–17) 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. 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 1983 (Chang, 1992: 201). In total ERSOundertook 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 (2000) argue, these OEM manufacturing firms can leverage their relationships with outsourcing partners to upgrade.14 The experience of Mitac, Acer and other firms, such as the printed circuit board 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 intellectual property (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 1986.15 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 crosslicensing arrangement with IBM.16

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 (Hsu, 1997: 73). Acer's Stan Shih stands out among Taiwan's IT entrepreneurs precisely because he was one of the few who did not go abroad for work or education. 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 Taiwan Electric Appliance Manufacturers' Association (TEAMA) and 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 fifty thousand US dollars, 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 seven notebook firms producing over a million notebooks a year (Miller, 2006: 27). By now, all the major branded computer firms, including the Japanese, employ the Taiwanese to produce notebook computers (Miller, 2006: 26).

3.2. The Glass Ceiling of OEM/ODM

Serving as OEM producers to branded international firms helped to make Taiwanese firms 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 OEM to ODM production (Schive, 2000: 2). 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 (Lee and Chen, 2000: 7). 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
(Schive, 2000; Lee and Chen, 2000; IPC Interviews).

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 PC manufacturers moved 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.

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. Notebook computers have been considered the most profitable and technologically sophisticated of Taiwan's IT products. Unfortunately, even here Taiwanese manufacturers have suffered progressive declines in their profit margins even as they have gone from forty percent of the global market in 1998 to seventy-two percent of the global market in 2004 (Miller, 2006: 27). This capture of world markets 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 from the large Taiwanese OEM/ODM firms, there are a number of large, versatile contract electronics manufacturer (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.

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.

Production abroad of Taiwanese electronics production topped fifty percent in 2000. Starting in 2000, notebook production started to move to China. By 2003, nothing but pilot production of notebooks was left in Taiwan (IPC Interviews).

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 CEMs though the Taiwanese will probably be unable to diversify into as many areas. The CEM firms' computer production is only about twenty percent of their total product portfolio.

TABLE 1

Net Profit Margins (%) for Taiwan's Major Computer Manufactures

Company 1998 2000 2002 2004

Quanta 17.8 10.3 7.6 3.7

Compal 13.2 8 6.8 3.1

Wistron 2.6 5.4 2.2 –0.7

Asustek 32.9 22.1 12.1 19.3

Mitac 4.9 3.8 3.4 4.2

Inventec 7.4 4.1 4.9 1.8

Arima 8.6 6.3 0.8 –10.6

ECS –13.8 7.2 4.5 –3.7

First Intl 0.4 0.3 –5.3 –12.3

Clevo 1.6 –4.6 1.9 3.7

Twinhead 5.6 –16.7 –11.9 –2.6

Uniwill N/A –5 –3 –0.8

Average 7.38 3.43 2 0.425

Source: Taiwan Stock Exchange Corporation, www.tse.com.tw

The logical move has been to develop communications products, principally mobile phone products. Eleven firms have received cellular phone technology, but only six have received the technology principally from ITRI and five have received it from foreign sources, principally U.S. ones.17 Private firms have shown a greater measure of independence from ITRI, given their growing absolute size and growing capabilities over time. Nevertheless, the old pattern of making international alliances, while receiving aid from ITRI, remains.

3.3. 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 hard disk drives (HDDs) and active matrix liquid crystal displays (AMLCDs). The Taiwanese state has continued to follow the leading international firms rather than setting up its own standards and also has 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 amounts of capital to fund both R&D and production capacity (Fuller et al., 2003).
The pursuit of HDD is a classic example of Taiwanese susceptibility to 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 (Noble, 2000).

4. TOWARDS TECHNOGLOBALISM?

Since 2003, Taiwan in a departure from past policy has actively begun to recruit MNCs to place R&D activities inTaiwan. This program appears to represent a move from the technohybrid to a pure form of technoglobalism. In fact, it mimics Singapore's technoglobalist policies of promoting foreign MNC R&D. Yet, this new policy is less of a move towards the technoglobalist than a move to bolster the current technohybrid model. First, the push to encourage R&D encompassed both local and foreign firms. Thus far, 39 local firms and nine foreign firms have set up these R&D
centers. Thus, in contrast to Singapore, Taiwan is still very interest in promoting its own local firms. Second, the MNCs are generally recruited to engage with local Taiwanese firms to diffuse their technologies to local firms. Indeed, MNCs interviewed said their main motivation in coming to Taiwan was the opportunity to work with the dense cluster

of Taiwanese IT firms rather than the price of Taiwan's skilled labor because the engineering costs in Taiwan are higher than other emerging economies actively recruiting MNCs, such as India and China (IPC Interviews). Moreover, a number of these firms testified that the movement of Taiwan's manufacturing offshore has not deterred them from coming to Taiwan because the design activities of Taiwan's firms primarily remain at home (IPC Interviews).

5. 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 sometimes created true interdependence and sometimes only dependence on the advanced world, but they have arguably succeeded at least as well at building the IT industry as the policies of Taiwan's more technonationalist neighbors have. The state has developed a set of domestic institutions including ITRI, the science parks, and the university system to facilitate the internal diffusion of technology acquired through these international links.

To describe Taiwan as using globalist tactics does not lessen the nation-building project behind this 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. Beyond demonstrating the potential of the technohybrid model, Taiwan's successes show us the opportunities for development when industry value chains can be segmented into discrete functions that are coordinated across corporate boundaries and geographic space. In the IT industry in the 1980s, the conditions began to ripen for segmenting the activities in the chain of production so that they could be geographically and organizationally dispersed. In other words, the activities could be coordinated across space and outside the hierarchy of a single firm or tightly controlled industrial network, such as Japanese vertical keiretsu. The Koreans and Japanese pursuing their technonationalist dreams through large, vertically integrated national champions ignored the possibilities for development through segmentation or decomposition of the

value chain. Thus, they missed the advantages of focus that went along with segmenting the value chain into discrete and narrow activities, such as TSMC's focus solely on fabrication of chips. Without the happy confluence of Taiwan's technohybrid strategy of aiming to serve as suppliers to MNCs and the decomposition of the value chain in IT, Taiwan would never have been able to enjoy the success it did as the first-mover in re-organizing IT production and creating whole new business models.

NOTES

1 In this paper, technology policy will be used in the broadest sense to encompass the set of industrial and technology policies Taiwan pursued in order to promote the high-technology sector.

2 For discussion of technonationalism, see Richard J. Samuels, Rich Nation, Strong Army: National Security and Technological Transformation in Japan (Ithaca, NY: Cornell University Press, 1994).

3 The term technohybrid in the context of technonationalist and technoglobalist strategies first appeared in Crisis and Innovation (New York: Cambridge University Press, 2003).

4 See Tianxia [Common Wealth Magazine], August 2000's list of Taiwan's 1000 largest firms.

5 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.

6 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.

7 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.

8 IPC Interviews confirmed the importance of learning through customer feedback and the foundry model as a safe
bet for customer's IP.

9 For U.S. data, see Hodges, D.A., Macher, J.T. and D.C. Mowery, "Semiconductors" in US Industry in 2000
(Washington, DC: National Academy Press, 1999), pp. 245–286. For Taiwanese data, see ITIS (Industrial
Technology Information Service), 1998 Bandaoti Gongye Nianjian [The 1998 Semiconductor Industry Yearbook]
(Taipei, Taiwan: Ministry of Economic Affairs, 1998), p. VIII–15.

10 UMC bought this fab from Nippon Steel, which is no longer a major shareholder in UMC Japan.

11 The chart below refers to memory, but the vast majority of Taiwan's memory production has been DRAM and its
offshoots so in this case memory and DRAM can be considered basically synonymous.

12 In the Taiwanese context, OEM refers to the suppliers of manufacturing services rather than the branded firms
hiring the manufacturing service firms. Outside of Taiwan, OEM usually refers to the branded firms.

13 Momoko Kawakami, Development of Small-and-Medium-Sized Manufacturers in Taiwan's PC Industry (Taipei,
Taiwan: Chung-hua Institute for Economic Research, 1996), p. 3 argues based on the Ministry of Economic
Affair's Industrial Development Bureau's Annual Report 1982–1983 that in 1979 the only PC manufacturers in
Taiwan were American ones aside from possible procurement from the small component suppliers implied by
Kawakami's data (pp. 16–17). However, at least one Taiwanese firm was involved in minicomputer Chinese
language input device production since 1974, IPC Interview.

14 Ji-ren Lee and Jen-Shyang Chen, "Dynamic Synergy Creation with Multiple Business Activities: Towards a
Competence-based Growth Model for Contract Manufacturers" in Research in Competence-based Management
Advances in Applied Business Strategy, Volume 6A (JAI Press, 2000) argues that firms can upgrade from OEM to
ODM, but, given Kawakami's evidence from the relationships between outsourcing firms 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.

15 Gregory W. Noble, Collective Action in East Asia (Ithaca, NY: Cornell University Press, 1998), pp. 139–142
claims that the head of counterfeiting of the Taipei Computer Association bought the rights to DOS, but these
rights 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
so 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.

16 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.

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

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