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New Firm Formation and Technical Upgrading in the Taiwanese Semiconductor Industry: Is Petty Commodity Production Still Relevant to High-Technology Development?

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Introduction

Over the past decade, many political scientists, economists, sociologists, anthropologists, and economic geographers have proposed that there has been a resurgence of regional economies (Piore and Sabel 1984; Sabel 1989; Best 1990; Blim 1990; Scott and Storper 1992). They argue that the concentration of interconnected specialist firms in a region constitutes collective strength for global competition. Most of these researchers focus on agglomerations of small- and medium-sized enterprises (SMEs) that specialize in different but related phases of production in an industry. The vertically disintegrated industrial system prevails in Taiwan's IC (Integrated Circuit) sector, one of the most prominent high-technology industries. Taiwan's IC industry is not dominated by a small number of vertically integrated large corporations, but by a great number of small firms that target certain market niches and collaborate under different roofs (Mody and Wheeler 1990; Mathews 1997). One of the advantages accompanying this industrial system is the easy formation of new firms. The system allows new firms to focus on development of new product ideas, without disturbing other phases of the production process. Furthermore, economies of scope, rather than economies of scale, reduce production costs for participating firms. In addition to the static advantage of cost-saving, the integration of interconnected independent firms creates the possibility of mutual adjustment within the system. This allows firms to handle abrupt crises flexibly.

The process of new firm formation and the method of technological learning in Hsinchu are critical for the rethinking of Petty Commodity Production (PCP) in the globalizing knowledge economy, which is characterized by flexible specialization and industrial clustering (Cooke 2002). Firms' competitive advantage in the new competition era comes not from ruthless cost reduction, but from competence in nimble adjustment of production chains. In the new competition, firms' technological capability for innovation is the key weapon (Best 1990). This is particularly the case for high-technology industries. As PCP is usually connected with preindustrial, domestic, and outdated technology, will it still be relevant to the new economy? If it still works, then in what sense and aspects? Is it just a survival strategy for peripheral sectors, such as Taiwanese SMEs, or part of the ingredients of core competence in the high-technology battlefield? How will Taiwan's small high-technology firms survive and prosper in the global competition, which is controlled by key advanced giants? This research will demonstrate that the decentralized industrial system of SMEs in the Hsinchu region builds up complementary connections with Silicon Valley in technology and industry. Through these connections, an overseas Chinese technical community plays the key role in technology transfer. In a sense, the interpersonal relationships and incarnate trust characteristic of the PCP world could serve as channels of ideas, particularly for tacit knowledge, which could not be transferred in printed formats. Moreover, this chapter will demonstrate that the PCP networks can be institutionalized to render technology transfer and starting up easy and constitute the backbone of the formal cross-border technology agreements and licensing.

In the next section, we will elaborate on the industrial structure and its governance mechanisms to flesh out the social dimensions of Taiwanese IC industrial system. Then we will illustrate the strategies Taiwan's IC SMEs adopt to upgrade their technical levels. Among them, the connection with the high-technology hub, Silicon Valley, is particularly critical. We will argue that thick social ties and industry associations are key mechanisms in the cross-border connections. Finally, we will reflect on the role of PCP in the globalizing knowledge economy, and argue for the growth potential of PCP in the modern capitalist world, as the cross-border technical communities between Hsinchu and Silicon Valley demonstrate.

The Sources of New Firm Formation

Taiwan's IC industry consists overwhelmingly of specialized small- to medium-sized firms. Unlike huge vertically integrated conglomerates, IC firms in Taiwan operate around a finely detailed division of labor. By 1999, Taiwan hosted more than 230 IC firms, including 100 design houses, 5 in mask making, 21 fabrication firms, 42 in packaging, and 33 in testing. Almost all of the important firms, including the top ten design houses, and all of the fabrication and mask-making firms, are located in the Hsinchu-Taipei Corridor (ITRI 2000). The largest one is the Taiwan Semiconductor Manufacturing Corporation (TSMC) whose initial funding, partly from government initiative, was $145M. Its sales revenues reached $1.6 billion in 1998 and $2.4 billion in 1999. By 2000, TSMC employed 14,000 people (including overseas operations).

New IC firm formation has been phenomenal since the HSIP (Hsinchu Science-based Industrial Park) was established in 1980. As just shown, the sources of new firm formation basically came from the local public lab spin-offs and from Silicon Valley returnee start-ups.

Spin-offs from Public Lab

Recent researches (Liu 1993; Chang, Shih, and Hsu 1994) attribute the success of Taiwan's semiconductor industry to the spin-offs during the different stages of the public lab, ERSO development. Each phase represented the government's successive efforts to upgrade Taiwan's IC manufacturing technological capability. United Microelectronics Corporation (established in 1980) was seen as a successful example of government initiative in international technology transfer. From technology selection to capital formation, plant buildup, and personnel training, ERSO fostered teamwork to incubate the new company. Among these, personnel transfer was the most critical factor in the spin-off process. To enhance UMC's technology absorption capabilities, ERSO directly transferred experienced staff engineers to the new company.

Transferred personnel included the manufacturing supervisor, testing manager, sales manager, quality control manager, and circuit design manager. Almost the entire ERSO pilot plant was transformed into a new venture. The flow of experienced manpower from ERSO to UMC, as well as from other private companies, became a main feature of the local labor market in Taiwan's IC industry. Through the process of job hopping, people and embodied technology traveled and diffused around the industrial circle, and ERSO was often chosen as the starting point. During the second stage of personnel movement from UMC, new IC companies began to proliferate in the HSIP (Figure 8.1). UMC also provided a model of a successful start-up, encouraging ventures in the burgeoning IC business.

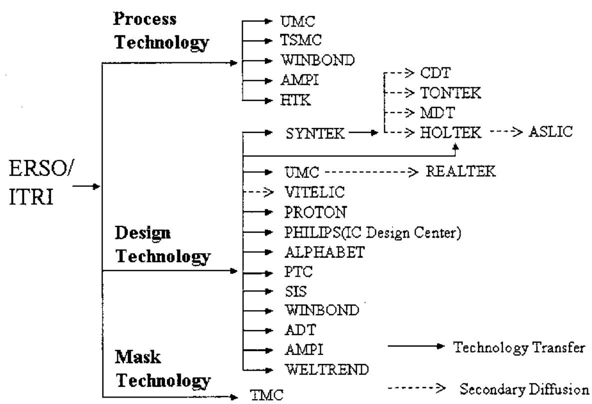

Figure 8.1. The Genealogy of ERSO Spin-offs

In the area of IC design, ERSO also contributed to the establishment of some new design houses. Syntek Design Technology was initiated in 1982 by a former manager of ERSO's IC design department. Based on design technology transferred from RCA, through ERSO channels, Syntek was able to design consumer specific ICs to meet market demand. Other IC design houses in the HSIP such as Holtek Microelectronics, Silicon Integrated Systems, and Weltrend Semiconductor were all founded by people trained in ERSO.

In the process of spin-off, it is the connections between the engineers that lower the barrier to entry of the high-technology business, and different combinations of talented people create the divergent IC specialist firms, and constitute a sound industrial system. The key to the social connections lies in the colleague and classmate relations among high-caliber engineers. In other words, despite recognition that the state leads in the birth of the Taiwanese IC industry, it is the dense networks among the group of engineers that constitute the backbone of the flexible labor market and facilitate new firms capable of racing in high-technology frontiers.

Silicon Valley Returnees

Another group of industrial initiatives in the HSIP came from overseas Taiwanese returnees. Most of them came back with plenty of experience and training at midcareer from such companies as IBM, Intel, AT&T, and Hewlett Packard. Once they assembled the required funds, they were capable of recombining their ideas and capital to create their own fortunes.

Miin Wu of MXIC (Macronix International Corporation) and Mr. Alex Au of Mosel-Vitelic exemplified this trend in the semiconductor industry. Wu was a Stanford graduate who had worked in Intel and VLSI (Very Large Scale Integration) Technology for several years before returning to Taiwan. He recruited thirty-eight people from Silicon Valley to join the new company and stressed new product development, rather than simply importing technology. The thirty-eight engineers and their families moved back to Taiwan to start MXIC in 1989. Work experience in Silicon Valley enabled Wu to understand market trends for flash memories, which has proven to be MXIC's major product line. The story of Au is similar. He worked at Fairchild before establishing a design company in Silicon Valley. Afterward he moved the company back to Taiwan to exploit the production capacity there. Mosel-Vitelic was the first local venture in Taiwan that was able to design its own DRAM (Dynamic Random Access Memory).

Nicky Lu of Etron Technology is another example of the returnee entrepreneur. Lu was one of the key designers of IBM's 4- and 16-Mbit DRAMs before he founded Etron in the HSIP, bringing the IBM design team intact from Silicon Valley. Etron then landed a plum contract to design part of the state-funded Submicron project. As well, a number of small independent design houses were established or managed by Silicon Valley returnees, such as the key chipset maker, VIA Technologies, and SRAM

(Static Random Access Memory) maker, ISSI (Integrated Silicon Solution Incorporated). These small firms specialized in market niches that were closely connected to the working experience of the founders. For example, VIA Technologies was transformed from the Symphony Company, a small design house in Silicon Valley previously acquired by Winbond. VIA's president, Wen-chi Chen, worked at Intel before he joined Symphony and then transferred a team back to Taiwan to enter the chipset business. The Formosa Plastics Group was VIA's main financial supporter and the group was also the major founder of FIC (First International Corporation). Thus, it was easy for VIA and FIC to cooperate. Chen's working experience allowed VIA to take advantage of early access to the new CPU (central processing unit) specifications defined by Intel. This helped VIA to design chipsets quickly and accurately matching the demands of the new CPU specs.

As Steve Hsieh, the former director-general of the HSIP, observes, "without these engineers and scientists returning from the United States, the HSIP would be half empty. These are experienced people with advanced knowledge in their fields, and they are very good vehicles for technology transfer. I don't think we could find this caliber of engineers and managers from local companies, at least not yet" (Zhuang, 1996: 201–202).

The waves of new firm formation in Taiwan's IC industry provide the metabolism for the emergent industrial system, and maintain the system's competitiveness on technology frontiers. However, the key to the competitiveness of Taiwan's IC industry comes not from the individual innovative firm itself, but from the collective capabilities of the industrial system of SMEs. In other words, the social division of labor between the IC SMEs, rather than the scale economies of certain firms, constitutes the competitive edge and renders the decentralized system flexible in meeting global challenges. In the next section, we will demonstrate that the social ties that integrate the social division of labor among Taiwanese IC firms basically lie in the interpersonal relations and in the engendered transnational technical communities (Saxenian and Hsu 2001).

Industrial Organization of Taiwan's IC Sector

Social Division of Labor

A finely detailed division of labor exists among Taiwanese IC firms. In addition to a few full-service companies who design as well as fabricate their own brand products,[1] there exist more than two hundred thirty small- to medium-sized independent IC firms specialized in different stages, such as design, mask production, testing, and packaging, in the production process.

Specialization is critical to the growth of Taiwan's decentralized industrial system of high-technology SMEs. Take IC manufacturing as example. Taiwan Semiconductor Manufacturing Corporation (TSMC), the well-performing IC foundry, provides state-of-the-art processing services for domestic as well as foreign IC firms. The establishment of TSMC was an innovative achievement. TSMC was set up to concentrate on manufacturing for other companies, not to compete with them in selling chips. TSMC was conceived as a pure foundry firm, and this idea has proven to be a lucrative one.

According to Morris Chang, the chair of TSMC,

> the concept of a specialized foundry was feasible because of two considerations. First, in comparison with other IC manufacturing companies who own wafer fabrication capacity, we are the preferred partners of many IC firms since we manufacture no product under our own brand name, and thus have no conflict of interest with them. Put simply, the environment for competition with our customers does not exist.[2]

Second, Chang points that "the feasibility of a pure foundry is based on the consideration that the expenditures required to build a new state-of-the-art wafer fab easily exceed one billion dollars. Thus, for small- to medium-sized design houses, the service TSMC provides can eliminate their need to invest in money-consuming facilities, allowing them to focus on quickly getting their product to market."

TSMC provide versatile technologies to satisfy the demands of its different customers. To do this, TSMC modularizes the receipt of each new technology so that it can quickly integrate in different ways, in accord with the requirements of each customer. TSMC also employs a mini-environment manufacturing system (a kind of wafer isolation technology), that allows it to add capacity by setting up a machine next to one that is already in operation. In fact, TSMC was the first major semiconductor company to commit to 100 percent mini-environments in its fabs. Besides the flexible technologies and modular system employed by TSMC, effective integration with patron IC firms requires close communications in the IC manufacturing process. To enhance integrated operations, TSMC seeks many ways to cooperate with its customers, in addition to standard foundry agreements. For example, TSMC will choose some potentially prosperous IC design houses and provide them with guaranteed foundry capacity and sales. According to Tseng, the CEO of TSMC,

> to help new start-up design companies shorten their product time to market, TSMC is glad to cooperate with them by reserving some foundry capacity for their use. We believe the strength of TSMC does not reside in TSMC itself, but in the growth of the design companies and TSMC together. If a design company possesses growth potential, no matter how small they are now, we'll definitely arrange our capacity for them.[3]

Basically, TSMC's customers can enter the IC production chain at any one of three points in the IC fabrication process. Customers can provide TSMC with masks, database tape, or a netlist, (description of the connectivity of an electronic design) and will receive untested wafers, probed die, or finished, tested and packaged ICs. In other words, customers play the role of both designer and buyer. This leads to a quite intimate relation between TSMC and its customers. To ensure design compatibility and better yields, TSMC and its customers need a seamless transfer of data between them. Frequent meetings and on-site technical support can help to quickly overcome unexpected delays and barriers in the transfer process. "To satisfy our customers, cooperative communication becomes pretty important. More often than not, our R&D staff engineers have to work directly with the designers from our customer companies, maybe in our place, maybe in theirs. Anyway, we have to maintain intimate relations, otherwise, we'll never get things done," Tseng of TSMC added.

Collaborative ties exist not only between the design houses and their fabrication partners, but also between them and their customers. In contrast to big vertically integrated firms, which use their own R&D divisions, high-technology SMEs rely more on their contacts with customers as sources for innovation. Many companies report that they have kept some "critical" customers with whom they frequently meet and exchange information. The concept of "critical" is based primarily on the quick dissemination of new product ideas from the customers to the designers. Sam Lin, the president of Weltrend Semiconductor, a specialized monitor IC design house, illustrated this concept as follows.

> When a new idea emerges, our critical customers discuss it with us first. They are experienced people in the marketing of electronic products, thus they have accumulated a lot of experience and a "market sense" about new product trends. Once they find a profitable product idea, we are the first to be informed, and after intensive communication, we decide together whether to enter the new product line or simply give it up.

Integration: The Building of a Collective Industrial System

As just illustrated, Taiwan's IC industry takes advantage of flexible specialization by the social division of labor among the small independent firms. However, to depict Taiwan's IC industry as a detailed division of labor is only one side of the full story. Integration of the various stages of work is another part of the mechanisms that get production systems to operate smoothly (Sayer and Walker 1992). Three mechanisms of integration are identified in Taiwan's IC industry:

Social Ties of Integration. First of all, the social ties between the owners, engineers, and employees of local companies facilitate formal agreements and informal information exchange within the IC industrial circle. Past experience working together in ERSO or in Silicon Valley provides a foundation for further cooperation. Gorden Gau of Holtek Microelectronics emphasizes the role of ERSO experience in business operations: "Basically we never cooperate with strangers. We will only consider ex-colleagues from ERSO as partners. The cooperation is based on the principle of reciprocity. We provide our foundry service to some of our friends in the design companies, while they come out with some new product designs. Mutual trust prevents the leakage of product secrets." Though such kinds of foundry agreement involve formal contracts, the social fabric between the transacting partners is usually the element that keeps the agreements operable.

Trust lubricates transactions and renders opportunism ineffective (Williamson 1985). Trustworthiness can represent itself in rapid response and accurate quality. Trust-based transactions also occur in relationships between IC designers and their customers. Many design companies reported that their relationships with critical customers lasted for more than five years.[4] Some of these relationships began and continued from the time the design houses started up their business. Often, the supplier-customer relationships could be both professional and personal as they last for a long time enough, and frequent visits become part of the high-technology people's lives. When asked "will face-to-face communication be replaced by other advanced methods of telecommunication like E-mail?" Ching Hu, the president of E-Cmos Corporation, responded:

> You can use email to clear up the technical part of a product development or the written part of a business contract. Email functions quite well in these things. But you can't do business in this way. Without trust, you cannot get things done. To create trust, you have to meet your business partners or customers in person. Only by doing so, you can enhance and revise the mental image of your customers and incubate the feelings of trustworthiness.[5]

In the process of trust breeding, traditional face-to-face communication is believed to enhance trustworthiness, even in the technologically dynamic IC industrial sector.

More importantly, common working experiences lubricate informal, everyday technical cooperation. This kind of cooperation includes the use of friend's equipment, engineering solutions, and even product ideas. The phenomena were mentioned repeatedly by the CEOs of several companies. For example, Ching Hu reported that when he started business, because of the small size of his own company, he went to MXIC (whose president was Hu's buddy in Silicon Valley) to use their workstations to run programs. Nasa Tsai, vice president of Mosel, reports that suggestions from friends are an important ingredient in finding engineering solutions. Sometimes the social network expedites information exchange. When some firm develops a new product or transfers new technology, the information will soon spread throughout the whole HSIP by way of personal contacts. This benefits the IC companies that are challenged by short product cycles. In fact, the informal exchange of information among engineers helps diffuse technology and upgrade the technology level of the IC industry as a whole.

Integration by Investment. In addition to the social fabric of integration, cross-investment is another formal means of integration of the various stages of IC production. Investment can be seen as the expansion of ownership and control between different firms. Through partial or whole ownership, some IC firms, particularly the relatively big ones, participate in or control another firm's business. By doing so, they are able to assure smooth operation of the IC production process without risking the rigidity of vertical integration. For example, most of those new packaging and testing companies received a portion of their investment capital from other IC companies. Just to name a few: UMC invests in Caesar and More Power, Winbond invests in Talent and Chantek, and MXIC in Caesar. The new joint investment projects also include a new packaging firm set up by VISC, (Vanguard International Semiconductor Corporation) Winbond and Mosel, a new foundry company is initiated by Syntek (a design house), and SIS (Silicon Integrated Systems) participating in the establishment of VISC. Though these new subsidiaries sometimes serve as subcontractors to buffer high season demand for their parents, they remain independent and do not exclusively subcontract with their parent companies.

The key to cross-investment is the aim to build up partnership between the different stages of the IC production system. Within the process, the role of venture capital in the initiation of new firms, particularly small design houses with specialized product niches, is of growing importance. Some of the venture capital, such as Dr. Ding-hua Hu of Champion Consulting Group, is managed and controlled by IC experts who watch the industry closely. They are involved in business plans, assessing financial requirements, market analysis, management recruitment, and initial public offerings. Venture capital companies have extensive personal networks of investors, qualified engineers, government officials, universities, and public R&D institutes. They are able to play a catalytic role in the mobilization of resources to help new firms.

The Local Labor Market. Industrial agglomeration facilitates the formation of local labor markets (Storper and Scott 1993). Local labor pooling, in turn, reinforces the trend toward industrial localization (Krugman 1991). In the case of the HSIP, the agglomeration of high-technology firms draws a swarm of competent engineers into its orbit. Some come from ERSO, some from Silicon Valley. Entry-level engineers come from the neighboring universities and from other colleges in Taiwan, and the HSIP is reported to be one of the most popular working locations for graduating students. Information matching job opportunities and qualified engineers flows easily within the HSIP. According to the president of a design house, "Sometimes a job vacancy appears in the morning, and is filled by the afternoon. You might meet your buddy and neighbor who work across the street, to convince him to hop seats (change jobs)."[6] He continued by describing the relationships between departing employees and his company.

> Even when employees leave our company, they usually transfer to other firms which specialize in the supply of services we require. These services include computer equipment, design tool imports and design subcontracting. We see these departures as an expansion rather than elimination of the strength of our company. Thus, when these ex-employees come back to use our computers for debugging, they are quite welcome.

Technical cooperation proliferates as personal networks spread. More importantly, a repository of specialized industrial skills and capabilities is formed within the social networks in the HSIP. This further attracts investment, and the recruitment of more talented people.

At the same time, experienced engineers move backward and forward among the IC firms in the HSIP. The mobility of middle-level engineers, like production engineers, design engineers, and equipment engineers is quite fluid in the HSIP. The establishment of new firms, above all the design houses, correlates highly with the fluidity of the local labor market (Hsu 1999). The mobility of experienced labor allows small start-up IC firms to recruit key engineering personnel during early phases of growth.

The Effect of Decentralized Industrial System

The vertically disintegrated industrial structure benefits each part of the production system by engendering external economies and by enhancing firm proliferation. Moreover, the pattern of vertical disintegration enhances flexibility, enabling the production system to adapt to abrupt crises. The low overheads of the fabless design houses allows them to respond to outside shocks quickly, and to expedite product changes without being dragged down by considerations of fab (fabrication plant) capacity utilization. The responsiveness of the people, emanating from such factors as hands-on management, efficient information flows, and proximity to customers, can give firms a distinct advantage.

Take the incident of Intel's "expansion into the chipset market" in 1994 as an example to illustrate this point. In August 1994, Intel announced it would expand its chipset and motherboard (primary circuit board of a computer) business.[7] Before then, Intel focused on the heart of the PC, the Central Processing Unit (CPU), and left the supporting chipset business to other specialist companies. Among these chipset makers, Taiwan claims three of the world's top five. Intel's invasive action, based on its capability to define new CPU specs and hence those of supporting chipsets, caused a 25 percent sale drop for Taiwan's chipset makers in 1995. The relationship between Intel and Taiwan's chipset design companies has changed dramatically. In the past, Intel would release chipset spec documents to its strategic partners, mostly Taiwan's chipset makers. But now it is no longer open to other companies.

Intel has forced these chipset makers to change their product and management strategies swiftly. VIA Technologies, for example, has chosen to cooperate closely with its customers, particularly First International Computer, one of the largest motherboard companies in Taiwan, to develop chipsets to match BEDO (Burst Extended Data Output) DRAM, and to upgrade the efficiency of the whole system. By doing so, VIA was able to remain competitive in product development without fighting directly with Intel. The incident also pushed VIA into aggressively searching for breakthroughs in system–on-chip design. Accordingly it collaborated with S3 Graphics in Silicon Valley, whose CEO has a collegial relationship with VIAs, to develop the second-generation graphic chip in 1999. Moreover, VIA purchased the CPU department of National Semiconductor to become the third CPU maker, besides Intel and AMD, in early 2000, and posed a serious challenge to Intel's hegemony in CPU business. As a small IC design specialist, VIA responded to the crisis by promptly adjusting its product development, and cooperated with outside competences to enter new fields. Particularly, it took advantage of the transnational connection between Taiwan and Silicon Valley in high-technology industries. In fact, the collaborative relations between Taiwan and Silicon Valley empowered the firms in the two regions to compete in the highly unstable world market. Through the cross-border partnership buildup, Taiwan's

IC firms kept technically upgrading and fostered small start-ups to exploit economic niches.

The Transnational Collaboration with Silicon Valley

Mutual adjustment and experience sharing of the decentralized industrial system are critical for Taiwan's IC SMEs in order to increase flexibility, but it is also important to keep the system open to outside resources in order to avoid locking in obsolete technologies and maintains its learning momentum (Grabher 1993). In other words, it has to be a localized industrial system within a global industrial network (Amin and Thrift 1992). An open industrial system will continuously upgrade technical levels and develop new products through the establishment of networks. Taiwan's IC industry benefited from the cross-border connection since the initial stage in the 1970s. Taiwan's government launched the IC technology transfer deal with RCA, and further fostered the first local IC firm, UMC (Mathews 1997). From then on, Taiwan's public laboratory and private firms had continuously recruited high-caliber overseas Taiwanese engineers or set up listening posts in Silicon Valley, the most innovative hub of the informatics sectors, to tap into the newly developed industrial technology and management knowledge.

The growing integration of the technical communities in the two regions has created new patterns of cross-regional collaboration (Saxenian and Hsu 2001; Hsu and Saxenian 2000). In some cases, collaboration occurs between the specialized divisions of a single firm. This includes start-ups like Macronix (a Flash Memory IC Maker based in Hsinchu with design center in Silicon Valley) and ISSI (a SRAM maker based in Silicon Valley with manufacturing division in Hsinchu) as well as larger, more established companies like Acer (the largest PC maker headquartered in Taiwan with a division in Silicon Valley). In these cases, the division managers are well connected in the local labor market and technical community and also have close, trust-based working relationships with their colleagues in the main office. This allows them to avoid many of the problems that corporations have when they seek to acquire technology in foreign locations like Silicon Valley. They need to be able to integrate into local social networks to gain access to technology and market information, while simultaneously being able to communicate quickly and effectively with decision makers in the headquarters.

More frequently the cross-regional collaborations involve partnerships between specialist producers at different stages in the supply chain. The relationship between Taiwan-based semiconductor foundries and their Silicon Valley equipment manufacturers is a classic example. Steve Tso, a senior vice president in charge of Manufacturing Technology and Services at TSMC worked at semiconductor equipment vendor Applied Materials in Silicon Valley for many years before returning to Taiwan. He claims that his close personal ties with senior executives at Applied Materials provide TSMC with an invaluable competitive advantage by improving the quality of communication between the technical teams at the two firms, in spite of the distance separating them.

The interactions between TSMC and Applied engineers are continual, according to Tso, and, for the most part, must be face-to-face because the most advanced processes are not yet standardized and many of the manufacturing problems they are confronted with are not clearly defined. Tso reports that he travels to Silicon Valley several times a year, and that teams of TSMC engineers can always be found in the Applied Materials' Silicon Valley facilities for training on the latest generations of manufacturing equipment. Engineers from Applied, likewise, regularly visit TSMC. He argues that this close collaboration helps TSMC develop new process technologies quickly while avoiding the technical problems that frequently arise when introducing new processes. It also keeps them abreast of the latest trends in equipment design.[8]

While Silicon Valley and Hsinchu remain at different levels of development and are differently specialized, the interactions between the two regions are increasingly complementary and mutually beneficial. As long as the United States remains the largest and most sophisticated market for technology products, which seems likely for the foreseeable future, new product definition and leading edge innovation will remain in Silicon Valley. However, Taiwanese IC SMEs continue to enhance their ability to design, modify, and adapt as well as to rapidly commercialize technologies developed elsewhere. As local design and product development capabilities improve, Taiwanese companies are increasingly well positioned to take new product ideas and technologies from Silicon Valley, and to quickly integrate and produce them in volume at relatively low cost.

However, the transnational connection is not governed by a number of big multinational corporations (MNCs). Neither does it exist in a socially neutral environment of market transactions.

Instead, Taiwan's global links with the Californian technology hub unfold in several ways: Taiwan's companies recruit overseas engineers, they set up listening posts in Silicon Valley to tap into the brain power there, or successful overseas engineers return to Taiwan to start up their own businesses. All of these possible links are established smoothly not just on an individualistic base, but with the mediation of overseas organizations, since the experienced engineers such as Steve Tso need to be able to integrate into local social networks to ensure gaining access to technology and market information and to absorb them effectively (cf. Hsing 1997; Hamilton 1996; Kao 1993).

The Hsinchu-Silicon Valley connection suggests that the growth of social and economic ties between individuals and firms in the two regions enhances the performance of *both* Silicon Valley and Hsinchu. The key actors in this story are a transnational community of U.S.-educated Taiwanese engineers who have the language skills and experience to operate fluently in both regions. Their dense social and professional networks foster two-way flows of technology, capital, know-how, and information between the United States and Taiwan, supporting entrepreneurship in both regions while also providing the foundation for formal interregional business relations like consortia, joint-ventures, and partnerships. Just as the social structures and institutions *within* these regions encourage entrepreneurship and learning at the regional level, so the creation of a transnational technical community facilitates collaborations between individuals and producers, particularly the high-technology SMEs, in the two regions and supports a mutually beneficial process of reciprocal industrial upgrading. These interregional relationships support entrepreneurial success in both regions by supporting joint problem-solving and complementary innovation (Sabel 1989). And like the relationships between specialist SMEs and their suppliers in the industrial districts, these interregional networks cannot be understood purely as market transactions or as "commodity chains" linking independent firms in different locations (Gereffi and Korzeniewicz 1994.) Rather, the economic ties are dependent upon a social structure and culture that foster openness and cooperation between producers in geographically distant regions. Close, trust-based relationships among the transnational community of Taiwanese engineers are thus an essential precondition for the flexible collaboration needed to adapt and survive in today's fast-paced competitive environment.

Petty Commodity Production and Taiwan's High-Technology Industries

Although the scale of operation of Taiwan's IC industry is relatively small in comparison with its Korean or Japanese counterparts, most of the IC design houses and manufacturers are still ventures of millions or billions of dollars, and employ hundreds or thousands of people. In what sense can Taiwanese IC ventures be considered to be PCP? Despite Hill Gates's (1979) observation that the experience of early industrialization in 1960s was in association with the household-based PCP model, it is still not clear if the PCP model could apply to the high-technology sectors, which seems unsuitable in light of level of scale and technology. It seems ridiculous to parallel the fantasy of the IC fabrication facility with the dilapidation of the furnace of the blacksmith. Also it is unambiguous that the high-technology development does not match the confinement of PCP concept, which is usually referred to a domestic mode, tributary, proto-industrial, self-employed, and informal economies (Gates, this volume). Does it mean that the idea of PCP is just outdated, and doomed to be insufficient in explaining high-technology sectors in the knowledge economy? Not necessarily.

Since today's high-technology industries are characterized by their products, markets, and technology being continually redefined and exceptionally short product cycles, the challenge becomes keener for these firms to be able to locate partners quickly and to manage complex business relationships across cultural and linguistic boundaries (Scott and Storper 1992; Castells 1996). In the new environment, flexibility becomes the catchword of the competitive advantage, and cluster of the specialist firms is better positioned in the battlefield to enhance the collective capabilities of adjustment (Best 1990). The key to success in the rapid-changing market lies in the capabilities to identify the right people (know-who), and to accordingly fix the right technologies and products (know-how), as more innovations are human-embodied and team-working (Amendola and Gaffard 1988). Under the circumstances, social ties, such as the overseas Chinese technical communities, enable the small producers to tap innovative expertise and to gain access to manufacturing capabilities and skills across long distances. Even the large corporations, such as TSMC and Applied Materials, take advantage of interpersonal relationships to render technical cooperation and knowledge transfer smooth. Instead of seeing the PCP model as irrelevant to current high-tech development, this chapter asserts that the personalistic relations of production enhanced the adaptability and innovation of the decentralized industrial system of Taiwanese high-technology SMEs.

Nevertheless, one caution should be made here. In spite of arguing against the grain that the PCP model could play a key role in the development of high-technology industries by boosting new firm formation and by promoting technical upgrading, this chapter argues that the effective social ties sector comes from the technical communities, such as classmate and colleague relationships, whose members share the same professional identities in solving technical problems with information exchange, rather than from kinship and other primary relationships, which most PCP studies focus on (cf. Niehoff 1987; Sheih 1992; Ka 1993; A. Smart 1999). The difference matters as kinship-incubated goodwill can render the coordination and allocation of resources between transacting firms easy and economical, but the capabilities needed for industrial upgrading is less likely to be found within the connection. This research implies that Taiwanese high-technology start-ups can be seen as a variant form of PCP because they are driven by knowledge and technology, and therefore the founders and leaders of each firm need to be actively involved in the hands-on technical aspects of the firm's production. Thus, the division between ownership and production is less apparent in even well-capitalized firms, creating similarities with petty capitalism in other contexts.

Conclusion

Most international business studies take the large multinationals, which possess tremendous technological capabilities and deep pockets, as the central players in the global battlefield (Dicken 1998). Even research concerning late-industrialization in East Asian NICs (Newly Industrializing Countries) focuses on the emerging business groups, such as Korean Chaebol (Amsden 1989). Against the grain, Taiwan's high-technology SMEs in IC industry demonstrate a story of what permits David to defeat Goliath. The keys to the puzzle of overturning the scale disadvantage and leveling the field lies in the developmental state's midwifery, the decentralized industrial networks, and transnational technical connection in the growth of Taiwan's IC industry. We conclude with the following points.

First, although Taiwan's state did foster the IC industry at the initial stage, as its Korean counterpart did (Mathews and Cho 2000), it took different strategies to get the job done. In Korea, the state targeted the *chaebol*, the big industrial giant, to enter the risky industry, with generous banking loans and market protection. Taiwan's developmental state, as just shown, did not choose specific big firms, but provided infrastructures (the ERSO and the HSIP) and subsidies (tax breaks and cheap land), to encourage the formation of spin-offs. In this sense, the state played the role of demonstrator to show private capital the profitability of the seemingly risky business, and lowered the entry barrier for the IC start-ups by subsidies, rather than by playing the role of omnipotent planner as in the Korean case. The divergent strategies led to differing industrial landscapes: while Korean IC industry was dominated by a few key giants like Samsung, Taiwan's IC industry was composed of hundreds of small to medium enterprises (SMEs) who benefited from the demonstration effect.

Second, Taiwan's late-industrializing firms could not only benefit from the institutional embeddedness of the local developmental state, but also from tapping into the transnational connection with the Overseas Chinese technical community. It is well recognized that social and institutional embeddedness exists on the local level (Granovetter 1985; Scott 1988). The story of Taiwan's high-technology SMEs system explores the possibilities of transnational embeddedness in the evolution of the late-industrialization process. Shared language and cultures do help producers, even those located at great distances, gather information about people, capital, and other resources within the community. In other words, such social ties fulfill the need of "know-who" in the learning economy in which the social dimension is the key and often ignored issue in the constitution of competitiveness (Lundvall 1996). In this case, social solidarity derives from common educational and professional experiences among engineers and scientists who have studied and worked together. These professional networks can facilitate economic transactions and managerial and technological learning for the networked industrial system of high-technology SMEs in Taiwan.

Finally, this research also reflects on the literature of the PCP model. It recognizes that the interpersonal ties become more, rather than less, critical in the governance of the disintegrated industrial system and simultaneously remain flexible and competitive in the high-technology industries. From this viewpoint, this chapter argues that the PCP style still contributes to the growth of high-technology industries in Taiwan, through close and transnational networks of people-embodied technology and information flow, and keeps Taiwanese decentralized high-technology industrial system open to the state-of-art technologies and improving on technological frontiers. Despite economies of scale that operate against the PCP, and raise barriers to entry (Harrison 1994), the vertical disintegration of Taiwanese high-technology industries allows the SMEs to cooperate and learn from each other, based on the interpersonal connections that are nurtured by associational embeddedness. As a result, Taiwanese high-technology industries are praised as “the Silicon Valley of the East” (Mathews 1997), and surpass their major late-industrial rival, South Korea, which is noted for the dominance of a small number of conglomerates, the *chaebols* (Levy 1988; Dedrick and Kraemer 1998; Ernst 1998). All in all, in contrast to the modernist expectations, the PCP model is alive and well in the knowledge-based economy.

Notes

1. Before the mid-1990s, these full-service companies include UMC, HMC, (Hualon Microelectronic Corporation) Winbond, Holtek, Ti-Acer, MXIC, and Mosel. Basically, all of them have their own design departments and in-house fabrication facilities, though they sometimes subcontract a portion of overcapacity fabrication work to other companies. However, UMC became a foundry specialist by spinning off its design department in 1995. The same strategy was adopted by HMC. Moreover, Holtek merged with UMC and turned out to be its fourth foundry fab, and Ti-Acer merged with TSMC. Therefore, only three full-service firms retained their organization figuration as the industry evolved.

2. Morries Chang, interview, October 23, 1995.

3. Fang-Churng Tseng, interview, November 11, 1995.

4. This data agrees with interviews conducted at several design companies in the HSIP. Bear in mind that most of the design houses did not exist until 1988, the year TSMC began operations.

5. Ching Hu, president of E-Cmos Corporation, interview.

6. Ibid., October 13, 1995.

7. The reason behind Intel’s vertical integration strategy is not clear. It is generally believed that Intel’s intention to expand the sales quanti-

ties of its Pentium CPU caused this action. Because the Pentium CPU needs matching chipsets to work, and because the performance of current chipsets is not able to meet Intel's expectations, Intel decided to internalize chipset making (ERSO 1995)

8. Steve Tso interview, in Hsinchu, March 15, 1999.