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Left for Dead: Asian Production Networks and the Revival of US Electronics⁽¹⁾

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I: Evolution in Electronics: From US and Japanese Leadership to the China Circle?

From the early 1970s until the mid-1980s, Japanese producers were ascendant in electronics. In short order, they had taken over consumer electronics, gained

leading world market shares in semiconductor chips, materials and equipment, and looked entirely capable of repeating the feat in computers, office systems (e.g., copiers, faxes), and customer telecommunications equipment. So worried were US policy-makers and industrialists that the avowedly laissez-faire Reagan Administration took the unprecedented step of using interventionist industrial policy to support the domestic microelectronics industry.⁽²⁾ If the rapid rates of attrition of U.S. market share had continued, US firms would have joined their European counterparts as significant players only in niches and on the margin of mass global markets.

What a difference a decade made. By 1994, US producers of silicon chips and semiconductor materials and equipment were again flourishing, having regained the dominant world position. US producers of office, communications and computer systems had reasserted product and technical leadership, with especially the latter retaining clear market dominance. As computer technology began to pervade consumer electronics, those same producers even looked to be reviving defunct US consumer fortunes. By contrast, with few exceptions, their once formidable Japanese competition appeared disorganized, dismayed and decidedly on the defensive. Indeed, US industry leaders are now so certain of continued success that many dismiss the Japanese giants as competitive dinosaurs, ill-adapted to the raucous, fast, changeable, idea-intensive electronics markets of the future.⁽³⁾

But it would be imprudent to conclude that US firms are organizationally or strategically better placed than other competitors just because they thrived in the latest round of competition: Their success is the phenomenon to be explained not the proof that those who thrived are better adapted for the future than those who did not.⁽⁴⁾ Indeed, as argued below, the recent success of US-owned firms has rested in significant part on the growing technical sophistication and competitive strength of Asian-based producers in the China Circle, Singapore and Korea. While useful to US firms in the last round of market battles with Japanese firms, Korean electronics producers like Samsung and China Circle producers like Taiwan's dominant microcomputer firm, ACER, are also formidable potential competitors. As the Asia market develops in both technical sophistication and size over the next decades, the mantle of electronics leadership could well pass from US and Japanese firms to indigenous Asian producers, especially those centered in the China Circle.

Any interpretation of the potential of the China Circle in electronics requires a clear understanding of the industry's recent competitive evolution, the principal focus here. Several competitive shifts lie behind recent Japanese troubles and American re-ascendance. Chief among these were the bursting of the domestic Japanese asset bubble, the attendant, lengthy recession in the Japanese economy, and multiple endaka (dramatic yen appreciation). Japan's electronics success was driven to a considerable degree by rapid growth in the sheltered domestic market. Rapid domestic growth afforded the stable demand to reach

scale economies, the launch market for several generations of consumer and office systems, premium prices to subsidize price competition on foreign markets, cheap capital for continuous reinvestment, and not least, quality- and feature-conscious consumers who rewarded corporate strategies built on incremental product revisions.⁽⁵⁾ Cheap capital ended when the asset bubble burst, provoking Japan's longest post-war recession. Enduring recession put an end, at least temporarily, to the domestic economy's ability to support firm strategies premised on rapid growth, and to the willingness of retailers blindly to support the producer-controlled pricing structure.⁽⁶⁾ Combined with successive endaka, the economic problems made Japanese firms increasingly vulnerable to price competition both at home and abroad.

While recession is a temporary phenomenon, the whammy of three simultaneous economic shocks is provoking enduring structural changes in strategy and behavior. Slower domestic growth for the foreseeable future and more costly capital have increased pressure on Japanese firms to scrutinize investment decisions more closely and to be more conscious of investment returns. In turn, capital and technology are likely to be turned-over more slowly in production, moderating the ability of Japanese firms to compete through aggressive manufacturing innovation and the incremental product revisions it generated. The end result is likely to be increased specialization among Japanese electronics firms as they concentrate investment in areas of core advantage, and a thorough-going industry rationalization. Indeed, the rationalization is already visible in strains on the traditional employment and subcontractor systems, and the surge of off-shore production investment into East Asia and China as detailed in the chapters by Ernst and Huchet.⁽⁷⁾

While Japan's economic problems begin to explain why Japan's electronic giants faltered in the 1990s, they do not account for the resurgence of US market and technical leadership. Two other competitive shifts are of paramount importance there--one in the market and one in production organization. The market shift encompassed both a transformation of the character of electronic systems products and a resulting sea-change in the industry's principal business strategies. Specifically, new electronics product-markets have begun to converge on a common technological foundation of networkable, 'open', microprocessor-based systems (of which, the PC is emblematic).⁽⁸⁾ Such new product markets are characterized by a predominant form of market rivalry, namely competitions to set defacto market standards--as Microsoft and Intel have done so successfully in PC operating systems and processor architectures, or as Cisco Systems has done with routers. Over the last half decade, the domestic U.S. market has been the principle launch market for such new products and the principle terrain on which the resulting standards competitions have been fought. With just a few exceptions--e.g., Nintendo in video games, Sony in 8mm video camcorders--U.S. firms have defined the products, set and controlled the

standards, and, consequently, have achieved dominant positions on world markets as US choices became global standards.

The organizational shift was, however, just as significant and in its own way permitted the new product-market strategies to succeed. The shift in U.S. firm production organization was the move away from traditional integration to network forms of organization, specifically, Asia-based production networks centered in the China Circle and Singapore.⁽⁹⁾ Their move to Asian-based production networks during the 1980s, had three significant consequences for U.S. firms. U.S. firms were able to relieve the constraining threat of competitive dependence on Japanese firms for a wide range of component technologies and manufacturing capabilities because their Asian production networks became a competitive supply base alternative to Japanese producers.⁽¹⁰⁾ Simultaneously, the networks helped to lower production costs and turnaround times while keeping pace with rapid technological progress--thereby permitting US firms to pioneer strategies of continuous innovation.⁽¹¹⁾ Finally, the networks spawned Asian-based direct competitors to Japanese firms in several of their stronghold markets (e.g., memory chips, consumer electronics, and displays).

The rest of this paper takes a closer look at the shift in production organization, the way it created an alternative supply base in Asia, and the role it played in the resurgence by US firms to product and technical leadership in electronics. The next section describes the historical development of US direct investment in electronics in Asia over the past three decades, comparing it to Japanese investment and contrasting the consequences. It also examines the indigenous complement to US firm strategies in Asia, namely the emerging networked production capabilities under the control of Overseas Chinese (OC) capital in the China Basin and Southeast Asia. The concluding section develops a production network typology to examine the respective positions of US, Japanese, and Overseas Chinese (OC) electronics firms, and concludes with speculation on whether indigenous Asia generally, and the China Circle in particular, will emerge as the next dominant force in electronics.

Before turning to those issues, however, it is appropriate to ask whether, in an industry dominated by multinational corporations (MNCs), an analytic that distinguishes between US-, Japan-, and Asia-based industries still makes sense. The analysis here presumes that the international market dynamic in most high-tech industries can still be effectively analyzed as a competition between firms operating out of largely national home bases.⁽¹²⁾ By 'home base' I mean the national market in which the majority of a firm's assets, employment and sales reside, and from which corporate control is exercised (especially control over strategy formation, corporate re-organization, new product development, finance and distribution). In most cases the home base is also the predominant locus of corporate ownership.

By that definition, very few high-tech MNCs are globally footloose. Indeed, 2/3-3/4 of the assets, employment and sales of most MNCs, and an overwhelming percentage of their best-compensated and highest-skilled jobs, are still in a

home base.⁽¹³⁾ Of the world's top 50 MNCs of all national origins, who might be expected to be the most non-national of MNCs, almost all fall in the 60-90% range of assets within the home country.⁽¹⁴⁾ Equally significant, almost all MNC firms still explicitly exercise control from their home country of origin.⁽¹⁵⁾

Given those facts, this paper's analytic sees firm strategies as systematically shaped by the logic of competition in the home market base. Domestic institutions shape a national market logic or system of production⁽¹⁶⁾ --i.e., characteristic ways of doing business and distinctive trajectories of technology development that are the basis of product differentiation on international markets.⁽¹⁷⁾ For high-tech industries, the principle domestic institutional variables include: 1) the structure of the industry in question and of its domestic market (e.g. oligopolistic, keiretsu, lead customers); 2) technology, trade and industrial policies and the political system that implements them; 3) the capital and labor market structures that condition access to those factor inputs; and 4) the local supply base which enables access to technology factor inputs.⁽¹⁸⁾

Those variables create a fabric of possibilities, a pattern of constraint and opportunity that confronts firms as they choose strategies, making some choices more likely (or less risky) and foreclosing others. Consider, for example, how U.S. antitrust enforcement denies to US firms the use of market-sharing arrangements that are routinely adopted in Japan and parts of Europe. Or consider how Japan's life-time employment system encouraged corporate strategies built on in-house training and up-skilling of technical employees. Or how 'guanxi' networks permit smaller Taiwanese family 'firms' to deal in high-risk international ventures.⁽¹⁹⁾

As such examples suggest, the home base's pattern of constraint and opportunity channels, in characteristic directions, corporate strategies and behavior and, through them, technology development. For example, a well developed venture capital market, highly flexible labor market, leading-edge military and computer industry demand, and competitive industry structure characterized by easy entry and exit, all shaped a US-based semiconductor industry with characteristic strategies and technologies based on radical product innovation.⁽²⁰⁾ By contrast, keiretsu-dominated capital and distribution, inflexible labor markets, price-sensitive consumer demand, and a panoply of industrial and trade policies, shaped a Japanese semiconductor industry with equally characteristic strategies and technologies based, in contrast to the US pattern, on incremental manufacturing innovation.

Of course, a broad range of contingent choices is always available within any given pattern of constraint and opportunity. Strategies can and do differ among firms facing similar constraints, not least because they start with different resources and actively respond to what their competitors are doing. Nor are firms inflexibly bound to the home base's particular mix of possibilities. They can seek

external opportunities or devise ways around national constraints. As the argument below suggests, U.S. firms did exactly that by creating their Asian-based production networks. In the real world of commerce, then, the home-base institutions that shape a national system of production are less independent variables in a formal analytic than systemic constraints tending to push strategies in particular directions, but without determining them.

That inherent openness of the analytic permits revision over time as evidence accrues to challenge the hypotheses it generates. Indeed, this paper suggests that regional and sub-regional production systems in electronics may be gradually supplanting national ones. This would be an unintended consequence of the Asian-based production network strategy of US firms, the sub-regional production networks it helped to spawn throughout Asia under the control of overseas-Chinese capital, and the parallel regional response of Japanese firms. Were such developments to diminish considerably the significance of the national home-base, they would obviously require revision of the approach adopted here. Until then, however, the overall working hypothesis is that for most firms the national market logic dominates international market strategies. This holds especially for the dominant Japanese electronics firms and even for the US-based MNCs who adjusted to high-tech competition by constructing production networks outside the U.S. For the U.S. firms, in important ways, the home base became more significant in the last ten years of increasing global competition than it had been earlier in the era of clearly defined national industries. As US firms regrouped and restructured, they sought renewed competitive advantage from home-based sources. Indeed, the *global* leadership of US firms was rebuilt partly on a *domestic* foundation--supportive policies, the American market's tremendous competitive ferment, and its leadership both in the networking of microcomputer-based systems and in the design, product definition, and systems architecture capabilities that created the new standards.

II: US FDI and the Creation of a Regional Supply Base

By the end of the 1970s, US electronics firms were almost completely dependent on Japanese competitors for supply of the underlying component technologies (e.g., tuners, picture tubes, recording heads, miniature motors) necessary to produce consumer electronics products.⁽²¹⁾ In most cases, thorough-going technology dependence was a first step toward market exit. It meant that US firms were far enough removed from the technological state of the art to impede new product development, and that their principal competitors could dictate time-to-market, product cost and feature quality. Under those circumstances, profits were minimal--if any were to be had at all. Consequently, by 1980 most major US firms had exited the consumer segment of the market and remaining players like GE and RCA survived largely by putting their brands on Japanese OEM production. A few short years later, even RCA and GE, who had created most of the consumer electronic technologies that Japanese firms perfected, left the business.

The loss of consumer electronics' high-volume demand eroded the US *supply base* for the other segments of the electronics industry, and threatened them with an equally, competitively constraining *architecture of supply*.⁽²²⁾ The supply base is the local capability to supply the component, machinery, materials and control technologies (e.g., software), and the associated know-how, that producers use to develop and manufacture products. The architecture of supply is the structure of the markets and other organized interactions (e.g., joint development) through which the underlying technologies reach producers. In effect, US producers of industrial electronics (e.g., computers, communications) were in danger of becoming dependent on their Japanese competitors for memory chips, displays, precision components, and a wealth of the other essential technologies (and associated manufacturing skills) that went into electronic systems.⁽²³⁾ The only alternative to increasing dependence on a closed oligopoly of rivals was to make the supply architecture more open and competitive: In conjunction with government policies and local private investors in Asia, US firms gradually turned their Asian production networks into a flexible supply base alternative to Japanese firms.

The transformation from cheap labor affiliates to alternative supply base occurred in three stages--an initial stage from the late 1960s to late 1970s during which US firms established their presence through foreign direct investments, a second stage in which their Asian affiliates developed extensive local relationships in the shadow of the dollar appreciation from 1980-1985, and a third stage from the late 1980s-early 1990s, when the technical capabilities in their regional production networks were significantly upgraded and local affiliates were assigned global product responsibilities. The US progression from simple assembly affiliate to technologically able Asian production network contrasts sharply with the development pattern of Japanese investments in the region over the same time period. A brief review of key developments in each of the three stages will highlight the differences.⁽²⁴⁾

From the late 1960s, after an earlier round of market access investments by a few large US MNCs, (notably IBM, GE and RCA), most US firms sought not market access but cheap production locations in Asia. US investment was led by US chip-makers, then consumer electronics and calculator producers, and finally, toward the end of the 1970s, producers of industrial electronic systems like computers and peripherals. Most of the U.S. investments in this first stage established local assembly affiliates. Cheap but disciplined Asian labor permitted US firms to compete on price back home and in Europe. Right from the start, then, the Asian affiliates of US electronics firms were established as part of a multinational production network to serve advanced country markets. By contrast, as Ernst suggests in his chapter, most Japanese investment into Asia in this period, led by consumer electronics and appliance makers, is aimed at serving nascent local markets behind tariff walls. Japanese investment is often turnkey, with knock-down kits exported from Japan for local final assembly and

sale in the local affiliate's domestic market. While the Japanese and US investments in this first stage are both oriented to simple assembly and superficially appear similar, the vastly different markets being served pulled their respective investments in divergent directions.

Consider the resulting logic of sunk investment for the two sets of firms. Because their Asian affiliates were integrated into a production operation serving advanced country markets, US firms upgraded their Asian investments in line with the pace of development of the lead market being served, the US market. In essence, they upgraded in line with US rather than local product cycles. By contrast, Japanese firms were led to upgrade the technological capacities of their Asian investments only at the slower pace necessary to serve lagging local markets. As local US affiliates became more sophisticated through several rounds of reinvestment, a division of labor premised on increasing local technical specialization developed throughout the US firms' global production operations. Local needs began to diverge from those elsewhere in the US firm's overall operations and affiliates sought out, and where necessary, trained local partners to meet them.

To be sure, the growth of local autonomy and relationships was constrained by overall corporate strategies (e.g. where economies of scale dictated a global rather than local sourcing arrangement), but over time US investments still led to greater technology transfer and increasing technological capabilities for locals. By contrast, stuck in developing market product cycles, off-shore Japanese affiliates benefited from no such incentives to upgrade and no need to develop local supply relationships. Japanese firms served the domestic and US markets wholly from home. Whatever their lagging Asian affiliates needed could be easily supplied from Japan. As local Asian markets demanded the marginally more sophisticated goods whose product cycles had already peaked in the advanced countries, the entire production capability for those could also be transferred from Japan. Overall, less technology was transferred, and even that remained locked up within the Japanese firm's more limited circle of relations.

Thus, during the second stage (1980-1985) US-owned assembly platforms were upgraded and enhanced technically to include more value-added, e.g., from assembly to test in chips, from hand to automation assembly techniques, from simple assembly of printed circuit boards to more complex subsystems and final assembly in industrial electronics. As they gained more autonomy, US affiliates began to source more parts and components locally (e.g., a range of mechanical parts, monitors, discrete chips and even power supplies). As US affiliates developed and as the US industry exited the consumer segment, local electronics producers in places like Taiwan shifted to concentrate more and more of their own investment (and their government's attentions) on industrial electronics as Chung Chin shows in her chapter.⁽²⁵⁾ As these developments occurred, the contour began to appear of an ever more elaborate and deepening technical division of labor between U.S. and Asian-based operations, bound together in production networks serving US firms' advanced country markets. In essence, a

new supply base was being created in Asia under the control of US and local, but not Japanese capital.

Indeed, while Asia's indigenous electronics capabilities (excluding Japan) developed in close symbiosis with the strategies and activities of American MNC firms, they were driven by local private investment and supported by government policies. Outside of Korea (where the chaebol dominated domestic electronics development), resident ethnic Chinese investors played the principal, private entrepreneurial role in the China Circle, Singapore and later in Malaysia, Indonesia and Thailand. During this period, in the NICs (and later in Southeast Asia) governments provided a panoply of fiscal and tax incentives, invested heavily in modern infrastructure, generic technology development, and the technical up-skilling of the work force, engaged in selective strategic trade interventions, and in some cases, even provided market intelligence and product development roadmaps.⁽²⁶⁾ The aims were both to plug into the developing multinational production networks in the region, and to use them as a lever toward autonomous capabilities. The result, by the end of the 1980s, was burgeoning indigenous electronics production throughout the region, with most of it, outside of Korea, under the control of Overseas Chinese (OC) capital.⁽²⁷⁾

Table 1: Taiwan Firms' 1994 World Market Share (%) in PC-Related Products⁽²⁸⁾

Motherboard	80%
Mouse	80%
Scanner	61%
Monitor	56%
Keyboard	52%
Network Interface Card	34%
Graphics Card	32%
Switching Power Supply	31%
Notebook PC	28%
Video Card	24%
Terminal	22%
Network Hub	18%
Audio Card	11%
Desktop PC	8%

Source:Market Intelligence Center/III

Not surprisingly, given its deep tie in this period to US producers, as OC electronics activity began to emerge it was concentrated in the personal computer (PC) and PC-related product-markets. In turn, the nerve-centers of OC activity in PC electronics in this era were Taiwan and Singapore, the home bases for emerging Asia-Pacific MNCs like the former's ACER and the latter's Creative Technologies.⁽²⁹⁾ Taiwanese producers were at the heart of the nascent alternative supply base. Ultimately, their position would crystallize in the 3rd period, culminating by the mid-1990s, as Table 1 shows, with significant to dominant world market shares in 14 PC-related supply categories. Singapore-based OC producers similarly began to emerge in this second period as significant suppliers of hard disk drive-related components and services, and of multimedia sound cards, PC subassemblies and PC assembly services.⁽³⁰⁾

By contrast to both the US and OC developments in this second phase, the pattern of Japanese investment led to a dual production structure under the control of Japanese firms and premised on traditional product cycles--sophisticated products were produced at home with sophisticated processes to serve advanced country markets, while lower-end products were produced with simple processes in regional affiliates to serve local Asian markets. Both sets of operations sourced from a common supply base, located largely in Japan and controlled, directly or indirectly, by Japan's major electronics companies. Where Japanese companies responded to government or commercial pressures to localize, they did so, as Ernst suggests, from within their established supply base--that is, by transplanting the operation of an affiliated domestic Japanese supplier--not by sourcing locally from the emerging Asian supply base. In short, the Japanese production networks boasted redundant investment and remained relatively closed, even as the US networks became more open and entwined with indigenous OC producers, and more specialized.

These trends were fully elaborated during the third stage, from 1985-early 1990s. At home, US firms focused scarce corporate resources more intensely on new product definition and the associated skills (e.g., design, architectures, software) necessary to create, maintain and evolve de-facto market standards. In turn, they upgraded their Asian affiliates, giving them greater responsibility for hardware value-added and manufacturing, and significantly increased local sourcing of components, parts, and subassemblies. They even contracted-out design and manufacture of some boards and components. Thus, during this period, the Asian affiliates of US firms continued to migrate from PCB to final assembly with increased automation; to increase both component production and final system value-added; and to assume global responsibility for higher value-added systems (e.g., from monochrome desktops to color notebook PCs). Their production networks extended to more and more capable local Asian producers who became increasingly skilled suppliers of components, subassemblies and, in some cases, entire systems. Even in areas like memory chips and displays where Japanese firms remained important suppliers to US

firms, there was sufficient competition from other Asian sources (e.g., Korea in memory chips) or sufficient political pressure to keep the supply architecture open.

Major US producers of PCs like Apple illustrate well these developments.⁽³¹⁾ Apple Computer Singapore (ACS) opened a PCB assembly plant for the Apple II PC in 1981. By 1983 nine local companies were contract manufacturing PCBs for the Apple IIe and Lisa PCs. By 1985 ACS was upgraded to include final assembly of Apple IIes for the world market. From 1986-89, ACS was expanded and upgraded to begin some component design work. In 1990 ACS assumed final assembly responsibility for two of three new Macintosh PCs (and PCBs for the third) and designed (locally) and manufactured associated monitors. By then, essentially all components were sourced in Asia (except the US-fabbed microprocessor)--ACS's 130 major suppliers included local firms like Gul Technologies and Tri-M (PCBs). ACS had also demonstrated that its growing technical prowess could pay competitive dividends in speeding time to market: It was able to move from designs to production roll-out in up to half the time of Apple's other facilities. By 1992, ACS assumed responsibility for final assembly for all Asia-Pacific markets, including Japan, was designing and supplying boards globally, manufacturing monitors and some peripherals, and designing chips. Over \$1 Billion was being procured annually through ACS. In 1993, ACS set up a design center for Macs for high-volume desk-top products--Apple's only hardware design center outside the US. By 1994, ACS had become the center for distribution, logistics, sales and marketing for the Asia-Pacific region, and was assembling the MacClassic II, LC III and IV, mid-range Centris, and Quadra 800 for global distribution. Regional sourcing reached \$2 billion, half from Japan (LCD displays, peripherals, memory, hard disk drives), another quarter from Singapore, \$250-500 million in Taiwan for OEM desktops, monitors, PCBs, Powerbooks, Digital Assistants, and chips. Korea's Goldstar also supplied monitors. By late 1994, ACS had begun to design the motherboard and tooling for, and assemble the multimedia system Mac LC 630 PC for worldwide export. Two new Mac products completely designed and manufactured at ACS were launched in 1995.

The value-added/local sourcing progression of other major US electronics players in Asia is broadly similar.⁽³²⁾ For example, Compaq Asia (hereafter: CAS for Compaq Asia-Singapore) established its Singapore factory in 1986 for PCB assembly of components sourced from Asia (including Japan), for desktop PCs to be final assembled in the US. By 1994, after terminating an OEM relationship with Japan's Citizen Watch, CAS was designing and manufacturing all notebook and portable PCs for worldwide consumption, and all desktop PCs for the Asia-Pacific. Similarly, Hewlett-Packard's Singapore operations evolved from assembly of calculators in 1977 to global responsibility for portable printers and Pentium desk-top PCs and servers, with local manufacturing, process design, tooling development, and chip design. Motorola's Singapore operations evolved from simple PCB assembly of pagers and private radio systems destined for the US in

1983, to world-wide mandates for design, development and automated manufacture of double-sided six-layer PCBs, for design and development of integrated circuits for disk drives and other peripherals, for some R&D, and for sourcing of at least \$500 million of parts and components within the region. Similar kinds of stories could be told for AT&T in telecommunications products, IBM and DEC in PCs and peripherals, Maxtor, Connor, Seagate, and Western Digital in hard disk drives, and for TI, Intel and National Semiconductor.

Table 2: Taiwan Firms' 1994 OEM Relations in PC-Related Products (representative sample)⁽³³⁾

OEM Producer	Buyers	Products
Acer	Apple, Fujitsu, NEC, NCR, Data General, Siemens	Notebooks and/or monitors
Delta	Apple, Compaq, IBM,	Power Supplies
Elite	DEC, IBM, NEC, Siemens	Motherboards
FIC	ATT, Dell, Unisys	Motherboards
Inventa	Apple, Compaq, Dell,	PDA, Notebooks
Lite-on	Compaq, DEC, Dell	Power Supplies and/or Monitors
Tatung	Apple, Packard Bell, NEC,	PCs and/or Motherboards, Monitors

Source: MIC/III and press accounts

As US Asia-based affiliates up-graded and specialized in this way during the third period, their indigenous OC suppliers followed suit. Table 2 gives some indication of this by examining the emergence, by the period's end, of OEM relationships with major China Circle producers. In turn, by leveraging their link into the US production networks and the global distribution capabilities thereby provided, the strongest China Circle producers began to control their own production networks. Chung Chin's chapter suggests this in showing how, in the early 1990s, intense competition and growing needs for scale-intensive investment forced a shake-out and consolidation among Taiwanese and Hong Kong-based electronics firms.⁽³⁴⁾ Firms like ACER, the Formosa Plastics Group, and Tatung began to ride herd on an extensive indigenous supply base of thousands of small and medium-sized design, component, parts, subassembly and assembly houses throughout the China Circle and extending into Southeast Asia. These firms form an intricate sub-contracting structure of affiliated and family enterprises which comprise the local production network and supply base. The numerous small firms are aligned vertically with the few larger scale enterprises that act as intermediaries for foreign MNC customers.⁽³⁵⁾ Designs and key components flow down from the

large-scale enterprises; more labor-intensive production activities flow up along the subcontract network leading to final assembly.

Table 3: Domestic vs. Off-shore Production Value of Taiwan's Electronics Industry, 1992-1995 (\$-Millions)⁽³⁶⁾

	1992	1993	1994	1995(est.)
Domestic Production	8391	9693	11579	13139
Offshore Production	973	1691	3003	4279
Offshore/Domestic(%)	11.60%	17.45%	25.93%	32.57%

Source: MIC/III

Toward the end of the third period, in response to steep rises in factor input costs in the NICs, and exacerbated by currency appreciation, these emerging OC production networks become more and more regionalized. For example, Table 3 suggests the extent to which considerable PC-related production is now being carried on by Taiwanese MNCs within the region but outside of Taiwan. As the table suggests, production outside of Taiwan but in the OC Asian networks accounted for increasing shares of total production under Taiwanese control, approaching one-quarter of the total in 1995. As Chung Chin argues in her Chapter, the off-shore activity is concentrated in certain product segments, with about two-thirds of 'Taiwanese' production of keyboards, half of power supplies, and about a quarter of monitors and motherboards now taking place outside of Taiwan. Investment targeted both Mainland China and Southeast Asia--partly a result, as other chapters suggest, of the timing of both Taiwanese and Mainland policy reforms, and partly of prudent geographical risk-spreading by OC investors.⁽³⁷⁾

In sum, by the early 1990s, the division of labor between the US and Asia, and within Asia between affiliates and local producers, deepened significantly, and US firms effectively exploited increased technical specialization in Asia. In stark contrast, up through the end of 1993, Japanese firms still controlled their Asian affiliates' major decision-making and sourcing activities from Japan. More low-end process/product technology had been off-shored, including production of audio systems (cassette recorders, headphones, low-end tuners, etc.), under-20-inch televisions and some VCR models, cameras, calculators and appliances like microwave ovens. Local Asian content had risen toward 60%, but core technological inputs like magnetrons, chips and recording heads were exclusively sourced from Japan, and the 60% 'local' content was mostly supplied by the off-shore branch plants of traditional domestic Japanese suppliers. Local design activities were invariably to tailor Japanese product concepts for local Asian markets, and global mandates for advanced products, let alone their design, development, and manufacture, were nowhere to be found outside of Japan. In contrast to US producers, for example, Japanese PC producers sourced displays, memory, some microprocessors, drives, power and mechanical components,

plastics, and PCBs from Japan (or in the case of some low-end components, from off-shore affiliates), and did PCB and final assembly, and essentially all advanced design and development in Japan. In short, Japanese firms intensified rather than rationalized their dual production structure, and, by exclusion from their production networks, failed to benefit from increasing, cheaper, and faster technical capabilities in the rest of Asia.

III: A Network Typology and the Future of Competition

In Asia today, beneath the superficial similarity engendered by aggregate trade and investment data and macro-analyses, lie distinctly different electronics production networks under the control of US, Japanese and OC multinationals. The US networks tend to be open to outsiders, fast and flexible in decision-making and implementation, structured through formal, legal relationships, and capable of changing contour (and partners) as needs change--in an image: open, fast, flexible, formal and disposable. Their activities are centered in the NICs, especially Singapore, but increasingly reach into the rest of Asia and China. By contrast, the Japanese networks tend to be relatively closed to outsiders, more cautious to make and implement decisions which are generated from Japan, and structured on stable, long-term business and keiretsu relationships--that is, closed, cautious, centralized, long-term and stable. Despite the recent surge of Japanese investment into Asia, their networks are still most definitely centered in Japan.

The respective networks also rely on distinctively different supply bases, boast different product mixes, and, most significantly, constitute very different divisions of labor. The US networks rely on an open, competitive supply architecture in which Japanese, US, Taiwanese, Singapore, Korean and other Asian firms compete on cost, quality and time-to-market and, in some cases, provide significant value-added. By contrast, the Japanese networks rely on a largely domestic and affiliated supply base with little value-added by other Asian producers. The US networks produce (and in some cases design and develop) increasingly sophisticated industrial electronics like hard disk drives, PCs, InkJet Printers, and telecommunications products. The Japanese networks still mostly produce consumer audio-visual electronics and appliances. The US networks exploit a complementary division of labor in which US firms specialize in especially 'soft' competencies (definition, architecture, design--standards areas) and Asian firms specialize in hard competencies (components, manufacturing stages and design/development thereof). By contrast, the Japanese networks exploit a division of labor with significant redundancies in which domestic Japanese operations produce high-value, high end products using sophisticated processes, and off-shore affiliations produce low-value, low-end products. The US networks exploit increasing technical specialization throughout the production process in which the Asian contribution is *maximized*; the Japanese networks exploit a value-added specialization between products in which the Asian contribution is *minimized*.

By comparison, the emerging OC networks appear to combine features of both the Japanese and US MNC approaches, with distinctive characteristics of their own. Much like the Japanese, OC networks are difficult for outsiders to penetrate. Much like the US, OC networks are fast and flexible. Indeed, industry estimates of OC network business speed peg the time from conception to execution at a fraction of that of larger MNCs burdened with formal organization and layered decision-making.⁽³⁸⁾ In some cases, OC networks can design and execute in less time than it takes the Japanese giants just to make a go-ahead decision.⁽³⁹⁾ For the Taiwanese design houses in particular, this capability is apparently built on a high-value-added foundation, macro-cell based design methodologies and libraries of already-characterized component functions that can be combined and altered to implement new concepts.⁽⁴⁰⁾ The rapid design capability then joins with the hyper-competition among subcontractors in the network to implement the new designs as fast as possible. Unlike either the US or Japanese networks, the OC networks seem especially focused on intricate division of production tasks (e.g., components and subassembly steps) that can be farmed-out all the way down to family job shops and home-workers. Individual units within the network operate at small scale with minimal capital investment requirements, and link on the informal bases of *guanxi*, that is, kinship or friendship ties. The flexibility that results, mirroring the industrial district capabilities in Italy and parts of Germany, makes it possible to increase or decrease production scale on short notice, or to enter and exit niche product-market segments, all at minimal cost and with minimal fixed investments.⁽⁴¹⁾

The best OC networks also run extremely lean in general, sales and administrative overheads where they match the best practices of MNC leaders like Hewlett-Packard (at about 10% of sales for microcomputers and printers), and are far superior to most advanced MNC performers (15%-upwards of 20% of sales).⁽⁴²⁾ Of course, such cost-minimization is inherent in the sub-contract structure of the OC production networks where affiliates and family enterprises can be squeezed (if necessary, in time-honored sweat-shop manner). In short, the OC networks appear to be insular, fast, flexible, *guanxi*-mediated, and fluid. They tend to be centered in the China Circle and increasingly focused on Mainland China. Like the Americans, the OC networks seek to exploit a highly competitive supply base and concentrate on industrial electronics. Much like the Japanese, OC networks retain in the home base high value-added products manufactured with more advanced processes, and off-shore to cheaper production locations lower value-added products assembled with simpler processes. Unlike the Japanese, however, the OC networks also self-consciously leverage increasing technical specialization through local relationships wherever possible. And unlike both, the OC network relationships are increasingly China-centered--rather than using a NIC base as the regional center, OC networks may end up with a China base as their global center, using demand and technical

know-how in the domestic China market to achieve world-class scale, costs and innovation.

As argued at the outset, the competitive consequences of the differences between US, Japanese and OC networks have been significant. The US networks relieved the constraining threat of competitive dependence on Japanese rivals by re-constituting the architecture of supply in electronics. Simultaneously, the turn to skilled but cheaper Asian suppliers helped to lower overall production costs, fierce competition within the supply base helped to reduce turnaround times, and specialization and diversity within the network permitted US producers to keep better pace than Japanese rivals with rapid technological and market shifts. Growing Asian technical capabilities freed US firms to focus their efforts (and scarce resources) on new product definition and standards competitions, systems integration, software value-added and distribution. In the bargain, the US networks helped to spawn and sustain direct Asian competition to Japanese firms in several of their stronghold markets like memory chips, consumer electronics and displays. And while OC network capabilities grew prodigiously, they did not directly challenge revived US leadership in the last round of competition. Overall, US firms not only stayed the competitive course, they prospered.

Yet, the current US position is no more a guarantee of future success than was Japan's in the early 1980s. Much depends on how Japanese firms respond to their current competitive dilemmas and on how OC firms leverage opportunities in the China Circle.

The Ernst and Huchet chapters provide evidence of nascent Japanese adjustment which, at least at first blush, appears to draw a different image from the closed network structure emphasized here. Ernst and Huchet see some evidence of increased openness and increased reliance on OC, Chinese and Korean suppliers as Japanese firms adjust to the competitive success of US and indigenous Asian producers and target the China market. Whether those changing characteristics are permanent or temporary is very much an open question, however. In 1996 there has been anecdotal evidence that Japanese networks are snapping back toward the more traditional, closed model as the yen again depreciates and as Japanese firms absorb know-how from the partners they took on in Asia. In any case, there is no evidence that the basic Japanese strategy of control of value-added through ownership has changed; nor do Japanese firms appear intent upon exploiting increased specialization in the rest of Asia wherever they can do the specialization themselves. And whatever the precise characterization, neither Ernst, Huchet nor I would expect much convergence of the Japanese and US models. ⁽⁴³⁾

They would also agree that the precise characteristics of Japan's Asia-based networks that created vulnerability over the last decade--closed, cautious, Japan-centered, long-term and stable--could be turned into competitive strengths with a dose of rationalization and a pinch of vision. Japanese firms could decide to accept slower domestic growth and the need to exploit technical capabilities in

the rest of Asia as givens. They could decide to selectively incorporate Asian producers into the family and build stable, long-term, mutually advantageous ties focused on exploiting specific technological capabilities in other parts of Asia. They could decide to invest for the long-term. They could decide to drive their growth from Asia's: If Asia becomes a launch market for new product concepts--and it's rapid growth and burgeoning wealth suggest that it must in some market segments--Japanese firms might just then be better positioned to exploit the development.⁽⁴⁴⁾

Just as big a competitive wild card is the growing electronics capability in the China Circle linked to OC investments in the US, Southeast Asia, and eventually Japan.. A competitive China Circle scenario is easy enough to describe: The combination of Hong Kong-based financial and producer services, with Taiwan-based digital product and process design, Southeast Asian component specialization, highly skilled but cheap Mainland labor, and, of course, the Mainland market, provides a tantalizing scenario for regional dominance. The OC network characteristics identified above--insulated from outside control, fast, flexible and fluid--appear to be a compelling mix for exploiting the region's possibilities. And the sheer scale of production for the mainland and, from the mainland, for overseas markets would dwarf the leverage provided by any other home market base. To this potent brew should be added the self-conscious developmental intent of governments throughout the region to nurture indigenous capabilities, and of China's to move to the technological frontier as fast as possible.

The quite significant constraints on the emergence of such a scenario should not be underestimated, however. Unlike the Americans, who have retained capability in most core component technologies and a significant though diminished position in capital goods, the OC networks remain dependent on Japanese competitors for advanced manufacturing equipment and high value-added core components (e.g., for Taiwanese producers, \$500 million of LCD displays and \$3 Billion of memory chips in 1994). Even more of a constraint, however, is continuing dependence on the American networks for microprocessor architectures, advanced product concepts, and global distribution. It is likely that the Chinese market can eventually help to break those constraints--by providing the returns to invest to relieve core component dependence, the new product concepts that can become global standards, and leverage to develop indigenous brands and global distribution channels. But that is likely to take time, probably several decades. In the interim, the China Circle will witness one of the great market battles in memory as US, Japanese and indigenous production networks vie for 21st Century advantage.

Endnotes

1. This chapter is drawn from a larger work in progress on global competition in electronics. See, Michael Borrus, *Punctuated Equilibria in Electronics:*

Microsystems, Standards' Competitions, and Asian Production Networks, forthcoming, 1997.

2. The government's support took two forms--direct financial support of \$100 million per year to the industry's manufacturing technology consortium, Sematech--or half of Sematech's annual budget--and negotiation of the US-Japan Semiconductor Trade Agreement (STA). For details, see Michael Borrus, *Competing for Control: America's Stake in Microelectronics*, (NY: Ballinger, 1988). For an elaborate analysis of the STA see Kenneth Flamm, *Mismanaged Trade? Strategic Policy and the Semiconductor Industry*, (Washington DC: Brookings Institution Press, 1996)

3. This position is argued explicitly by industry consultant William F. Finan and his academic collaborator Jeffrey Frey in their *Nihon no Gijyutsu ga Abunai: Kenshō, Haiteku Sangyō no Suitai* [Japan's Crisis in Electronics: Failure of the Vision] (Tokyo: Nikkei Press, 1994).

4. Steven Jay Gould makes this point with respect to natural selection in *Wonderful Life* (NY: W.W.Norton, 1989) at p.236.

5. For a fuller analysis, see Borrus, *Competing for Control, supra*. The domestic market served as a launch market during the late 1970s-1980s for, among other products, the VCR, Camcorder, Walkman, hand-held TV, fax machine, portable copier, and notebook PC.

6. On the latter point, see Ichiro Uchida, "Restructuring of the Japanese Economy" in Eileen Doherty, ed., *Japanese Investment in Asia: International Production Strategies in a Rapidly Changing World*, (U.C. Berkeley: Berkeley Roundtable on the International Economy, 1995).

7. On the former point, see Uchida, *supra*. As argued below--and somewhat at odds with Ernst's perspective--rationalization does not necessarily imply radical change in the way Japan's industrial firms operate. For example, some Japan scholars like Greg Noble argue that Japan's lifetime employment system appears to have survived the recent economic shocks essentially intact, with only marginal modifications. Verbal remarks of Noble at the BRIE/Asia Foundation Conference, "Competing Production Networks in Asia," April 27-28, 1995.

8. By 'open', I mean that key product specifications, especially the interface specifications which permit interoperability with the operating system or system hardware, are published or licensed and thus available to independent designers of systems or software who can produce complementary or competing products.

9. By production network I mean the organization, across national borders, of the relationships (intra and increasingly inter-firm) through which the firm accomplishes the entire value chain of production including research and development, product definition and design, supply of inputs, manufacturing, distribution, and support services. Especially significant in Asia, are supplier relationships that include subcontracting, OEM (original equipment manufacturing), and ODM (original design manufacturing) arrangements between foreign MNCs and domestic suppliers of intermediate production inputs, such as materials, tools and molds, parts and components, subassemblies, and

software--some of whom may also compete in final product markets. See the elaboration in Dieter Ernst "Networks, Market Structure and Technology Diffusion: A Conceptual Framework and Some Empirical Evidence," report prepared for the OECD, Paris, 1992

10. The next section defines the concept of supply base.

11. By 'continuous innovation,' I mean the capacity to add incremental advances in performance, functionality, or features within or between given product generations--e.g., from 75mhz to 250 mhz pentium microprocessors, or from 25mhz 386-based PCs with 4Megabytes of RAM and 100 Megabyte hard drives to 200mhz pentium-based PCs with 32 Megabytes of RAM, 2 Gigabyte hard drives and CD-ROM drives.

12. Applying and exploring the limits of this method are principle goals of BRIE research supported by the Alfred P. Sloan Foundation.

13. See the discussion in Laura Tyson, "They Are Not US," The American Prospect, (Winter, 1991), p.37ff. See also, Yao-Su Hu, "Global Corporations Are National Firms with International Operations", California Management Review, Winter, 1992, p.107ff. Of course, the debate addressed by these articles was popularly launched by Robert Reich in "Who is Us?" Harvard Business Review, (Jan.-Feb., 1990) p.53ff. More generally, the recent collection by Dennis Encarnation and Mark Mason, ed., *Does Ownership Matter?* (NY and London: Oxford University Press, 1995) supports the persistence of important differences among multinational firms based on national origin.

14. See "A Survey of Multinationals" The Economist, March 27,1993, p.6-7, citing United Nations data. The major exceptions are oil companies (because oil fields tend to be located abroad) and small country multinationals like Nestle, Unilever and ABB (because their markets are located abroad)--and the latter would fall into the 60-90% range if Europe was treated as their home base. By that measure, the most non-oil MNC is IBM, with about 50% of assets outside of the U.S. But because half of its assets are still concentrated in the U.S., even IBM can be said to have the U.S. as its home base.

15. This conclusion is easily reached from industry conversations and even a quick perusal of the annual reports of the 1000 largest US and 1000 largest non-US firms. More generally, the evidence in John Dunning's comprehensive work on MNCs supports this conclusion, as does Michael Porter's work. See, John Dunning, *Multinationals, Technology, and Competitiveness*,(London: Unwin Hyman, 1988); Michael Porter, *The Competitive Advantage of Nations*, (London: MacMillan, 1990).

16. My colleague Stephen Cohen coined the concept of national market logics in Borrus, Cohen, et.al, "Globalization and Production," BRIE Working Papers, #45 (Berkeley: BRIE, 1991).

17. For a discussion of this concept of technology trajectories see Michael Borrus, "The Regional Architecture of Global Electronics: Trajectories, Linkages and Access to Technology" and the sources cited there, in Peter Gourevitch and Paolo Guierrieri, eds., *New Challenges to International Cooperation: Adjustment of*

Firms, Policies, and Organizations to Global Competition, (San Diego: UCSD, 1993).

18. For one effort to elucidate some of these variables--the state, labor relations and financial systems--as part of a formal analytic explaining national economic development, see John Zysman, "How Institutions Create Historically Rooted Trajectories of Growth," *Industrial and Corporate Change*, V3#1, 1994, 243-283. Some of the variables described above are similar to those used by Michael Porter, *Competitive Advantage*, *supra*, however, to different ends in a decidedly different, albeit complementary, analytic.

19. On the 'guanxi' network concept see Gary G. Hamilton, "Competition and Organization: A Reexamination of Chinese Business Practices," paper prepared for the IGCC Conference *The China Circle: Regional Consequences of Evolving Relations Among the PRC, Taiwan, and Hong Kong-Macao*, Hong Kong, December 8-10, 1994

20. For a fuller discussion of this US-Japan comparison, see Borrus, *Competing for Control*, *supra*, at chapters 4 and 5.

21. See the discussion of sequential increasing supply dependence in consumer electronics in Consumer Electronics Sector Working Group, *MIT Commission on Industrial Productivity*, "The Decline of U.S. Consumer Electronics Manufacturing: History, Hypotheses, Remedies," December, 1988.

22. For an extended discussion of the supply base and architecture of supply concepts, see Borrus, "The Regional Architecture of Global Electronics," *supra*.

23. For the broad range of major component technologies involved, see the discussion in Borrus, *Ibid*.

24. The characterization of US FDI is based on the BRIE US Electronics FDI database, compiled from public sources and maintained by Greg Linden, supplemented by industry conversations, and reviewed by senior managers with Asia responsibility from most of the firms mentioned in the text. The characterization of Japanese electronics FDI in Asia which follows is consistent with, and in part draws on data and detail in the chapters by Ernst and Huchet, as well as from Ken-ichi Takayasu and Yukiko Ishizaki, "The Changing International Division of Labor of Japanese Electronics Industry in Asia and Its Impact on the Japanese Economy," *RIM, Pacific Business and Industries*, V1, #27, 1995, p.2-21. See also the relevant chapters in Doherty, *Japanese Production Networks*, *supra*.

25. On the progression from consumer to industrial electronics in Taiwan, see also Scott Callon, "Different Paths: The Rise of Taiwan and Singapore in the Global Personal Computer Industry," *Japan Development Bank Discussion Paper Series*, #9494, August, 1994. More generally, on the development of Taiwan's information technology industry, see Kenneth L. Kraemer and Jason Dedrick, "Entrepreneurship, Flexibility and Policy Coordination: Taiwan's Information Technology Industry," (Irvine: Center for Research on Information Technology and Organizations, 1995).

26. There were, of course, tremendous variations in the role played by state policy, and in the policies themselves, in the different countries of the region. In highlighting a few commonalities, I do not mean to slight those differences. The active role played in general by governments in the region has been explored in detail in a variety of scholarly works. See, e.g., Robert Wade, *Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization*, (Princeton: Princeton University Press, 1990); Stephan Haggard, *Pathways from the Periphery: The Politics of Growth in the Newly Industrializing Countries*, (Ithaca: Cornell University Press, 1988). More recently, see the excellent contributions in Andrew MacIntyre, ed., *Business and Government in Industrializing Asia*, (Ithaca: Cornell University Press, 1994).

27. In focusing on OC electronics producers, I am ignoring the significant regional investment by the Korean Chaebol who emerged during this period as major, region-wide producers of consumer electronics and components. See, e.g., Martin D. Bloom, "Globalization and the Korean Electronics Industry," *Pacific Review*, v.6 #2, 1993.

28. The Table is drawn from a presentation prepared by Tze-Chen (T.C.) Tu, Director of Taiwan's Market Intelligence Center (of the Institute for Information Industries), "Upgrading Taiwan's IT Industry--New Challenges and the Role of International Cooperation," at the BRIE-Asia Foundation Conference, *Competing Production Networks in Asia: Host-Country Perspectives*, San Francisco, April 27-28, 1995.

29. This picture is perhaps a bit at odds with the emphasis in the rest of this volume on the importance of Hong Kong as a force for China Circle integration: Hong Kong was at best a distant third most important NIC site for MNC or indigenous electronics production. Moreover, its relative importance declined as investment spread into southeast Asia and Mainland China--though Hong Kong undoubtedly played an important role in helping to channel Taiwanese investment onto the Mainland during the third period, described below.

30. Callon, *ibid.*

31. Based on press accounts, company annual reports and SEC 10K filings as compiled by Greg Linden in the BRIE Asia FDI Database. See Linden, "Apple Computer East Asian Manufacturing Affiliates," November 7, 1994, unpublished summary.

32. For Compaq, see Linden, "Compaq East Asian Manufacturing Affiliates," November 7, 1994, unpublished summary; for Hewlett-Packard, see Linden, "Hewlett-Packard East Asian Manufacturing Affiliates," November 9, 1994, unpublished summary; for Motorola, see Linden, "Motorola East Asian Manufacturing Affiliates," November 7, 1994, unpublished summary.

33. Presentation by Tze-Chen (T.C.) Tu., *supra*, supplemented by press reports.

34. As she shows, the resulting industry concentration was most visible in Taiwan's largest domestic product sectors, notably monitors, PCs and PCBs, where the top ten indigenous producers now account for over 70% of the market.

35. For elaboration on the following, see, e.g., G.S.Shieh, "Network Labor Process: The Subcontracting Networks in Manufacturing Industries of Taiwan," *Academia Sinica, Bulletin of the Institute of Ethnology*, #71, Spring, 1991; Brian Levy and Wen-Jeng Kuo, "The Strategic Orientation of Firms and the Performance of Korea and Taiwan in Frontier Industries: Lessons from Comparative Case Studies of Keyboard and Personal Computer Assembly," *World Development*, v.19,#4, 1990. I have also drawn on an excellent paper by one of my graduate students, Fu-mei Chen, "From Comparative Advantage to Competitive Advantage: A Case Study of Taiwan's Electronics Industry," unpublished manuscript, May 21, 1994.

36. Presentation by T.C. Tu, *supra*.

37. The Taiwan straits crisis of 1996 does not appear to have substantially influenced the willingness of Taiwanese electronics firms to invest on the Mainland, though it undoubtedly reinforced their desire to spread the risk by simultaneously investing into Southeast Asia.

38. Representative estimates range from Apple's judgment that its Singapore operation can move a new product into production in half the time of its other operations, to Ming Chien, Chairman of FIC, who estimates that motherboards can be completely changed out (with all attendant alterations to the rest of the system) in Taiwan in 2-3 weeks vs. up to a year in the US. On the former, see Singapore *Business Times*, 11/27/90 p.14; on the latter, see Callon, "Different Paths," *supra*.

39. Louis Kraar, "Your next PC could be made in Taiwan," *Fortune*, August 8, 1994, p.90ff, inferring from Dataquest estimates.

40. See Callon, "Different Paths," *supra*, citing interviews in Singapore. Structured IC design approaches were pioneered in the US at Universities like Berkeley and CalTech, where many OC engineers were formally trained.

41. On European industrial districts, see the work on flexible specialization, notably, Michael Piore and Charles Sable, *The Second Industrial Divide: Possibilities for Prosperity*, (NY: Basic Books, 1984).

42. Based on industry discussions.

43. So long as Japanese, US, and OC firms continue to be driven by very different domestic linkages, strategies, industrial structures, and policy, capital market and labor market influences, their network differences are likely to persist even if they converge in competitive purpose.

44. In fact, the opportunity to drive development out of Asia is already appearing in a set of significant potential product markets. These include broadcast media where firms like HongKong's TVB and Murdoch's Star TV are pioneering direct broadcast TV transmission, software where indigenous concepts could lead in new directions, and segments of the wireless communication markets where, for example, Motorola projects that China will pass the US to become its largest market for pagers in the next few years.

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