Industry Studies Association

INDUSTRY STUDIES ASSOCATION
WORKING PAPER SERIES

Modular Production's Impact on Japan's Electronics Industry

Chapter Two in Recovering From Success: Innovation and Technology Management in Japan
Edited by D. Hugh Whittaker and Robert Cole, Oxford University Press, forthcoming.

By

Timothy J. Sturgeon
Industrial Performance Center
Massachusetts Institute of Technology
Cambridge, MA 02142
and
Institute for Technology, Enterprise, and Competitiveness (Center of Excellence)
Doshisha Management School
Kyoto, Japan

2006
Industry Studies Association
Working Papers

WP-2006-04
http://isapapers.pitt.edu/

Modular Production's Impact on Japan's Electronics Industry[1]

Chapter Two in Recovering From Success: Innovation and Technology Management in Japan, Edited by D. Hugh Whittaker and Robert Cole, Oxford University Press, forthcoming.

Timothy J. Sturgeon

Global integration has accelerated the worldwide flow of knowledge and information, causing societies to become embedded in one another in complex ways, even as they retain their distinctive characters. This chapter examines the process of global integration through the lens of national industrial models – the collection of routines and strategies generally shared by corporate managers in a particular society. Some might question the notion of national industrial models, rightly pointing to diversity among firms based in a specific society. All Japanese firms, for example, are not the same (Suzuki, 2004). I would agree with Berger's (2005) assertion that managers face 'open pathways' and so can and do choose a range of strategies. Nevertheless, societies continue to have distinct cultures, institutions, and histories, and so differences persist in the face of global integration in ways that profoundly shape corporate strategy. In the course of sustained field research on the locational and organization strategies of more than 500 firms in a variety of industries and countries conducted by a team of researchers at the MIT Industrial Performance Center during the period 1999-2005, such national characteristics were evident.[2] At the same time, the managers interviewed were clearly making choices based on what they perceived

[1] This chapter is based on research funded by ITEC (COE) at Doshisha University, Kyoto, and the Alfred P. Sloan Foundation. The field research was conducted by the author, other members of MIT's Globalization Study Team (see http://ipc-lis.mit.edu/globalization/main.html) and Yoshiji Suzuki of Doshisha University. Clair Brown and Gregory Linden at UC Berkeley, Martin Kenney at UC Davis, and Mon-Han Tsai and Kazushi Nakamichi at ITEC, provided important insights and valuable support, as did Jun Kurihara of the John F. Kennedy School of government at Harvard University. Hugh Whittaker and Robert Cole provided helpful suggestions for improving the text. All responsibility for the final text, of course, resides with the author.

[2] At the time of this writing MIT's Globalization Study Team had conducted 622 field interviews in 19 countries, including 42 interviews with managers of electronics companies in Japan.

companies in other societies to be doing. It is this process of outside pressure, reflection, and response that is at the heart of this chapter's analysis.

As a window into the process of global integration, the chapter develops a stylized account of Japanese electronics firms' response to a new organizational model emanating from the United States, the Modular Production System. The account is stylized both because it is intended to tell a general story about the Japanese electronics industry and because we are required to omit firm-specific data collected during our field interviews to protect the personal and corporate confidentiality of our respondents. There were many differences as well as similarities in the strategies chosen and concerns expressed during our interviews, and an analysis of these differences would doubtless be fruitful, but my aim here is to highlight areas of agreement and similarity.

The Evolution and Circulation of Industrial Models

Industrial models consist of a range of norms, practices, routines, and tendencies. As such, they are always stereotypical, and firms vary widely in how closely they hew to the stereotype. Nevertheless, industrial models have been characterized at a variety of levels. Some have coalesced at specific historical moments across a wide range of countries, such as the post World War II 'social contract' between labour and capital that emerged in the United States, Europe, and Japan in the post-World War Two period, albeit in different forms. Others have been associated with groups of countries, individual countries; industries in specific countries; regions within countries; and even individual large firms. The core idea that has emerged from this work is that alternative viable forms of industry and corporate organization can co-exist within capitalism (Berger and Dore eds., 1996).

But what of the notion that global competition and integration accelerate the degree to which industrial models influence one another? There is a rich body of literature in this area as well, from work that documents the rise and uneven geographic spread of 'financialization,' the increased responsiveness of publicly traded firms to pressure from financial analysts and large institutional investors (Lazonick and O'Sullivan, 2000; Williams, 2000); to research on how the collection of 'best' industrial practices known as Lean Production (Womack, Jones, and Roos, 1990) have been differentially adopted and adapted by managers from different societal home bases and in different industrial sectors (e.g., Abo, 1989: Liker, Fruin, and Adler, 1999).

The central message here is that industrial models are not static, but evolve with time, and that the pace of transformation tends to accelerate when practices are transferred from one society to another. The Japanese Production System, for example, emerged in the 1950 and 1960s as Japanese firms adapted the principles of 'Fordist' mass production to the constraints of the post World War Two Japanese economy, namely small markets, scarce capital, and limited consumer spending power (Sayer, 1986). Because of the success of Japanese firms in the 1980s, some of the key principals of the Japanese Production System in turn had a profound impact on the organization of industrial production in the United States and Europe in the 1990s. But the elements of Lean Production were introduced into societies with very different institutional structures and industrial histories, and so the process has been one of adaptation and transformation rather than simple imitation and adoption.

There is now a rich literature on how the Japanese Production System has been adopted and adapted differentially in various industries, companies, workplaces, and stages of the value chain (e.g., Abo, 1989; Kenney and Florida, 1993: Liker, Fruin, and Adler, 1999; Holweg and Pil, 2004). American firms did respond to the Japanese Production System, and the MIT book that codified its elements as 'Lean Production,' *The Machine That Changed the World*, was extremely influential among managers in the automotive industry and beyond. North American investments by Japanese firms in the 1980s and 1990s also did much to expose managers and workers at American suppliers to key elements of the Japanese Production System. These lessons resulted in an increased focus on quality at American firms, achieved through systematic and continuous defect reduction programs and reduced in-process inventories, at least in final assembly (Cole, 1999). In the realm of industry organization, however, the value chain elements of Lean Production that admonished lead firms to ask more from their suppliers dovetailed with other forces in the United States that were both driving and enabling increased outsourcing. I will refer to the industrial model that emerged from this process as the Modular Production System.

Value Chain Modularity as a Response to the Japanese Production System

Outsourcing became extremely popular in the United States in the1990s, and it was driven by some of the same motivations that exist in Japan: the search for greater flexibility in the face of increased international competition and market volatility through the transfer of fixed assets and inventory to suppliers. A close lead firm-suppler relationship was a key aspect of the Japanese Production System. Japanese lead firms tend to be relatively vertically integrated, and when suppliers are heavily used, they are more likely to be highly dependent on one or a small number of key customer firms. Buyer-supplier relationships have traditionally been canted towards affiliates of the same industrial group, or *keiretsu*. The qualification process for new suppliers (Japanese and non-Japanese) can be extremely lengthy. Lead firms may make equity investments in their suppliers and can in some cases come to dominate them financially.[3] Lead firms often provide the required technical assistance and financial support to help affiliated suppliers adopt asset-specific production technologies, inventory management, capacity planning, and quality control systems. These tight linkages between lead and suppliers have been identified as a source of competitive advantage for Japanese firms (Dyer, 1996).

While in the United States outsourcing grew beyond anything that had been imagined in Japan, one striking difference was that relationships with suppliers did not change their adversarial tone, but retained much of their arms-length, short-term, and contractual character (Helper, 1991). Nevertheless, the challenges of transferring and coordinating complex and sensitive information along the supply-chain, reducing in-process inventories, and ensuring quality remained. Here American industry drew on its

[3] Although this pattern of cross-holding has been quite strong historically, the *keiretsu* structure has loosened considerably in the past decade or so, in part driven by the efforts of foreign investors, such as Renault, to drive down the cost of components. See Lincoln, chapter 12, in this volume.

long history of *systems integration*, 'the art of conceiving, designing, and managing the development of large systems involving multiple disciplines and many participating organizations' (Sapolsky, 2003: 31).[4]

Elsewhere I and others have characterized the new model that emerged in the United States during the 1990s, in part as a response to Lean Production and in part as a response to home-grown pressures to 're-engineer' the corporate landscape, as the 'Modular Production System.' It is based on value chain specialization, formalization of value chain linkages, and an increase in the scale and global reach of each horizontal segment — or 'module' — of the value chain.[5] In modular value chains distinct breaks in the chain of activities tend to form at points where information regarding product and process specifications can be highly formalized. As in modular product design, activities tend to remain tightly integrated and based on tacit linkages within functionally specialized value chain nodes. Between these nodes, however, linkages are eased by the application of widely agreed-upon protocols and standards. Discreet nodes of tacit activity can reside within divisions of the same firm, but only when activities are outsourced can scale economies build up beyond the level of the firm (Langlois and Robertson, 1995).

According to Pavitt (2003), the robustness of systems integration in the face of growing complexity in the realm of commercial products has been enabled by advances in information technology, especially computer simulation technologies that reduce the cost of experimentation and technological search. This has enabled the development of simplified and codified methods for transmitting detailed product and production information along the value chain. Specifically, the key business processes that have been

---

[4] Systems integration developed as a formal practice in the United States during the Cold War in response to a need to coordinate the invention, development, production, deployment, and maintenance of increasingly complex and exotic weapons and aerospace systems. Projects to create complex weapons systems such a ballistic missiles, early warning radar systems, and nuclear submarines were so large and interdisciplinary that detailed knowledge required to deign and produce all of the sub-systems were far beyond the scope of knowledge and expertise contained within any single military branch, firm, university labouratory, or other single organization. Someone had to make sure the systems worked as intended. At first, the task of systems integration fell to a few aerospace contractors, government agencies, and specially created non-profit agencies, but over time, the approach and methods of systems integration migrated to the private sector as private military contractors gained experience with the approach and systems engineering and management became established, if much maligned, academic disciplines by the 1970s (Johnson, 2003).

[5] Baldwin and Clark 2000; Sturgeon, 2000, 2002; Takeishi and Fujimoto, 2001; Langlois, 2003; Principe et al, 2003; Gereffi, Humphrey, and Sturgeon, 2005; Sturgeon and Lee, 2005.

computerized are product design (e.g., computer aided design), production planning and inventory and logistic control (e.g., enterprise resource planning), as well as various aspects of the production process itself (e.g., assembly, test and inspection, material handling). Furthermore, the Internet has provided an ideal vehicle for sharing the data generated and used by these systems. Such technologies and practices are at the core of the Modular Production System. It is the formalization of information and knowledge at the inter-firm link, and the relative independence of the participating firms that gives value chain modularity its essential character: flexibility, resiliency, speed, and economies of scale that accrue at the level of the industry rather than the firm (Sturgeon and Lee, 2005).[6]

Value chain modularity introduces risks as well as benefits for participating firms. Responsiveness may suffer as contracts are hammered out. There is potential for intellectual property and other sensitive information about product features, pricing, production forecasts, and customers to leak to competitors through shared suppliers. The ability of lead firms to innovate and design successive product generations may suffer from the atrophying of manufacturing and component knowledge, a problem that has been referred to by Chesbrough and Kusunoki (2001) as the 'modularity trap.' Reliance on standard interfaces may lead to the use of standard components, leading in turn to a loss of product distinctiveness. Shared and overlapping inventory resident in supplier organizations can lead to distortions and tracking problems that introduce waste.

How the risks and benefits of the Modular Production System balance out depends, like all things in business, on execution. Both lead firms and suppliers must perform their respective tasks well, anticipate problems before they occur, and deal with them effectively when they inevitably do. One unavoidable issue is that independent firms in buyer-supplier relationships often have competing interests.

In sum, there appears to be no single best way to organize production. Takeishi and Fujimoto (2003) argue that firms and industries that make products with integral

---

[6] The high volume of non-price data flowing across the inter-firm link differentiates modular value chains from simple markets. Because of this complexity it is not unusual that additional engineering and coordination be required. The hand-off of product and process specifications between firms need not be perfectly clean, but only relatively so for modular value chains to function.

product architectures[7] tend to have integral value chains, while firms and industries that make products with modular product architectures tend to have modular value chains. But value chain architecture is not always a function of design architecture. As Baldwin and Clark (2000) have shown, there are many cases in which break points in modular value chains have been willfully engineered. While products with highly modular design architectures such as the personal computer certainly make value chain modularity more likely, even a single modular link in the flow of activities, such as the link between an integral design and manufacturing, can unleash the dynamics of value chain modularity. In addition, firms such as Autodesk, Cadence, and Mentor Graphics have aggressively created new opportunities for value chain modularity by developing and marketing design automation tools that produce files in standard format. The degree of modularity in a given chain of activities thus involves a large measure of strategic choice, and is not a simple function of design architecture. The question, then, is how well a given industrial model fits with the product, industry, and larger institutional and competitive factors that influence firm strategy.

What is clear is that national-scale institutions heavily influence managerial choices related to industry organization. For example, corporate responses to intensified competition and market volatility depend on the strength of worker protection and how well the institutions of new firm formation function at the level of the nation-state. In the United States, volatility is high, not only because globalization and technological change displace workers in vulnerable industries, but also because worker protection laws are relatively weak and labour unions have been in serious decline for decades (only 8.5% of the United States private sector workforce is unionized). On the other hand, the financial and regulatory mechanisms that support entrepreneurship and corporate restructuring are very strong, and so volatility has spurred the formation of new kinds of businesses that focus on the pooling and rapid redeployment of workers and machines. Today, lead firms in the United States can lease almost anything, from workers to trucks to entire factories, by making a phone call to Adecco or Ryder or Solectron. These large, specialized suppliers have arisen in direct response to increased volatility. In countries

[7] Products with integral architectures have tight design interdependencies with components and subsystems of which they are comprised.

where worker mobility is lower, such as Japan (Brown et al, 1997), the infrastructure and motivation for new firm formation tends to remain underdeveloped, and so volatility is weakly translated into industry re-organization and modular suppliers of pooled resources have not emerged.

In the American electronics industry, value chain modularity took shape during the late 1980s and early 1990s. Because many established firms had in-house manufacturing and components divisions, this change required the break-up of vertically integrated corporate structures and the aggregation of cast off activities in suppliers. Hewlett Packard and IBM led the way, selling most of their worldwide manufacturing infrastructure to contract manufacturers such as Solectron and Flextronics, or spinning off internal divisions as merchant contract manufacturers, as IBM did with its Toronto manufacturing complex in 1997, creating the contract manufacturer Celestica. Another source of growth in contract manufacturing was increased business from newer firms that never built up internal manufacturing divisions, such as the Internet switch company Cisco and the computer workstation and server firms Sun Microsystems and Silicon Graphics.

Circuit board and final product assembly work was mostly transferred to contract manufacturers based in North America, specifically the big five 'electronics manufacturing services' (EMS) firms Flextronics, Solectron, Sanmina-SCI, Jabil, and Celestica, while the assembly and even some of the design of notebook computers went to 'original equipment' and 'original design' (OEM and ODM) contract manufacturers based in Taiwan, such as Quanta, Compal, Inventec, Hon Hai (Foxconn) and the various contract manufacturing arms of Acer. By the end of the1990s, much of the manufacturing capacity of the Taiwan-based contract manufacturers had shifted to Mainland China, and the big five United States-based contract manufacturers had established a global-scale network of factories (Sturgeon and Lester, 2004). At the level of components, the 1990s was a time of rapid growth among 'fabless' semiconductor design firms as well as the semiconductor foundries that serve them, such as the Taiwan-based TSMC and UMC, as well as IBM (Linden and Somaya, 2003). Thus, by the end of the 1990s, the Modular Production System in the United States electronics industry had become fully developed and global in scope.

Competitive Challenges to Japan's Electronics Industry at the End of the 1990s

Value chain modularity came to the attention of Japanese electronics firms in the late1990s, triggered by the fantastic growth of the Internet and the huge demand for data communications and Internet-enabled enterprise computing equipment that came with it. American firms are leaders in nearly all Internet-related electronics hardware and software product categories; Cisco Systems and Juniper Networks in Internet routers and switches; IBM and Sun Microsystems in powerful computer servers; Dell in personal computers; EMC in storage arrays; Microsoft and Netscape in Internet browsers; Yahoo! and Google in Internet portals and search engines; Amazon and E-Bay in Internet retailing and auctions; and Accenture, Price Waterhouse, McKinsey, and IBM in Internet-enabled corporate computing networks. Japanese electronics firms are focused on components, stand-alone consumer electronics devices, and proprietary enterprise computing systems that connect client sites through private leased data lines.[8]

The sudden rise of the Internet, and almost complete lack of any driving role for Japanese electronics firms in this rise, combined with severe financial losses, initiated a period of questioning in the Japanese electronics industry. Cisco Systems, based in California, jumped to an early lead in the market for Internet (TCP/IP) protocol switching equipment. Through a combination of technological excellence and a shrewd and efficient acquisition strategy Cisco managed to accrue and maintain an 80% market share in Internet routers while continuing to drive innovation in the field (Mayer and Kenney, 2004). As they rushed to learn about the Internet, Japanese firms looked to Cisco and saw some very striking features. First, Cisco relied almost entirely on third-party systems integrators such as Accenture and McKinsey for the creation of fully functional Internet-enabled data networks and enterprise computing systems. Even more striking from the Japanese point of view was that Cisco did not directly produce its own equipment, but relied on contract manufacturers such as Solectron and Flextronics. Cisco's success was based on its 'platform leadership' (Gawer and Cusumano, 2002), that is, its ability to

[8] See Cole, chapter 2, for a detailed account of the Japanese response to the Internet and the weakness of Japanese firms in the network equipment sector.

drive the standard-setting process through technological and market leadership while leveraging the capabilities of its suppliers and customers. The major Japanese electronics firms, on the whole, are much more vertically integrated, with in-house design and manufacturing of many sub-systems and components.

In 2001 competition from American firms in modular production networks formed only part of the challenge facing Japanese electronics firms. Korean firms such as Samsung, LG Electronics, and Hyundai are highly vertically integrated. Similar to Japanese firms, large Korean electronics firms tend to follow the 'components plus products' strategy; they manufacture and sell components on world markets, and use their most advanced components first in their own branded products to the degree possible. Until the late 1990s, Japanese companies followed the 'flying geese' strategy of licensing older component technologies to less capable firms in Korea and Taiwan and moving to newer technologies without much worry, but by 1999 Korean firms, especially Samsung and LG, began to close the gap in specific consumer electronic and component markets, such as mobile phones, digital cameras, digital televisions, computer monitors, high capacity memory chips, and flat panel displays.

In Japan, intensified competitive pressure from both the United States and Korea fostered the widespread impression that Japanese electronics firms were losing pace. This, along with losses at several firms in 1998, focused managerial attention on the practices of rival firms and fostered the consideration of radical shifts in strategy. The build-up of the Internet bubble, and its bursting in 2001, whipsawed Japanese electronics firms along with the global industry, not because Japanese firms were driving innovation in the field, but because they were significant suppliers of components, personal computers, and computer peripheral equipment, the sales of which were being driven by the expanding Internet. As a result, the near moratorium on IT spending that followed the excesses of the Internet bubble deeply affected Japanese firms along with the rest of the industry. But the losses posted in 2001 and 2002, while very large, were this time accompanied by even greater losses at the North American firms that had been most caught up in the mania of the Internet boom, such as Lucent, Nortel, JDS Uniphase, and Solectron. Table 3-1 summarizes the financial performance of the largest 10 Japanese electronics firms during the period 1997-2004.

3. 1. Net Income (Loss), Largest Ten Japanese Electronics Firms, 1996-2004, $M

Firm name	1996	1997	1998	1999	2000	2001	2002	2003	2004
Matsushita	1,228	764	107	898	376	(3,427)	(160)	374	545
Sony	1,243	1,812	1,409	1,098	152	123	948	785	1,527
Fujitsu	411	46	(107)	385	77	(3,064)	(1,002)	441	297
NEC	827	387	(1,190)	94	513	(2,499)	(202)	364	632
Toshiba	598	60	(109)	(252)	871	(2,035)	152	256	429
Hitachi	800	41	(2,652)	152	946	(3,876)	229	141	480
Canon	839	970	862	633	1,215	1,342	1,566	2,446	3,200
Mitsubishi	76	(864)	(351)	224	1,131	(625)	(97)	398	663
Sharp	433	202	36	253	349	91	268	539	716
Sanyo	157	101	(204)	195	366	11	(506)	119	(1,599)
Top 10	6,612	3,517	(2,199)	3,681	5,995	(13,959)	1,196	5,862	6,892

Source: Company reports

Notes: Except for Canon, dates are approximate calendar years ending on March 31 of the year following the year listed. US dollar figures were derived from average currency "ask" prices for the period April 1 of the year listed through March 31of the following year. Currency pricing was obtained from http://www.oanda.com.

The Response to Modular Production: a New Japanese Model?[9]

This section examines the strategic responses of Japanese electronics firms to Modular Production in the period 2000-2004, responses made in the context of the competitive and financial challenges discussed in the previous section. Our interviews reveal that Japanese electronics firms have been strongly influenced by Modular Production but that they have, unsurprisingly, resisted certain aspects of the model while adopting and adapting others. What emerged most powerfully in our interviews was the depth and scope of the questioning taking place within the highest levels of Japanese electronics firms. One respondent summed up the situation in the late spring of 2001 in this way:

[9] This section is based on several rounds of interviews with top managers at Japan's largest electronics firms, conducted by the author, other members of MIT's Globalization Study Team (see http://ipc-lis.mit.edu/globalization/main.html) and Yoshiji Suzuki of Doshisha University. The interviews were semi-structured in that the same themes were covered, were conducted at the respondent's office, and typically lasted 1-2 hours. The names of the firms and managers are withheld for reasons of confidentiality. The respondents typically, but not always, occupied high-level decision-making positions at their firm.

> Mega-competition means we are facing strong companies with narrow core competence, such as Micron and Dell. Such single-function players are very strong. We are an all around diversified player so we cannot fight such players with agility. We have convened a series of one-day meetings to determine how to survive. (Japanese electronics executive, June, 2001)

The dilemmas and contradictions facing the largest Japanese electronics companies were great during the interview period, as they continue to be today. Japanese electronics firms are highly diversified and have large numbers of employees both in Japan and abroad. For firms selling enterprise computing systems, key customers in Japan, which prominently include national and local governments, are demanding IT systems comprised of the best hardware and software in the world, and since such systems now must be Internet-compatible or even Internet-based, this often means using elements created by non-Japanese companies. For firms selling consumer electronics products and electronic components, competition is intense from low-cost producers with modular value chains, such as Dell in personal computers, and with high levels of vertical integration, such as Samsung in mobile phones and flash memory chips. These pressures prompted decision-makers at Japanese electronics firms to consider new strategies to rapidly acquire or develop new competencies, increase specialization, and relocate in-house operations to low-cost locations such as China. At the same time, the managers we spoke to agreed that it would be politically and strategically impossible to enact the layoffs that would be required if radical restructuring was taken too far.

The bursting of the Internet bubble in early 2001 led Japanese managers to step back from the brink of radical transformation. The 'dot.com' crash dramatically exposed some apparent weaknesses of the Modular Production System. As a result of over-anticipating demand, Cisco was forced to liquidate $2.2 billion of finished and in-process inventory, largely held by its contract manufacturers. The company cut 8,500 jobs and posted its first loss in its 11 years as a public company ($2.69 billion) in the third quarter of 2001 (Niece, 2005). Over the next few years Solectron, Cisco's most important contract manufacturer, suffered a total of $6.5 billion in losses and laid off nearly a third of its global workforce of 60,000.

However effective these developments were in driving Japanese firms back to their traditional industrial model, managers at Japanese electronics firms have nevertheless made significant breaks with past practices. Only key components, such as system-on-a-chip (SoC) — known in Japan as LSI — semiconductors, leading-edge flat panel displays, high-capacity batteries, and advanced memory chips are to be produced in Japan, either in-house or in joint-ventures with other Japanese firms. In-house final assembly in Japan is largely being limited to high-cost models with advanced features. Low-end products are to be produced offshore, especially in China, either by affiliates or by Taiwanese contractors. Divestiture of old, unprofitable, and unrelated businesses and products lines has accelerated, though these moves comprise only an incremental step toward downsizing and specialization. Increased specialization, increased complexity, and the continued importance of foreign component sales has led to increased outside purchasing and higher dependence on global markets for a wider variety of inputs, including technology inputs.[10] The remainder of this section presents evidence of these changes, and their limits, in three areas: alliances, outsourcing, and information technology and communications services.

Alliances

The renewal of traditional strategies at Japanese electronics firms has a high price. The fast pace of technological change in the technologies that underlie key components has required a spate of new investments in leading-edge factory production in Japan (see table 3-2 for some examples). The high cost of many of these new investments has convinced managers to forge an unprecedented set of production-sharing alliances. Seven of the twenty-five factory investments listed in Table 3-2 involve more than one firm. The shift in thinking about alliances is captured by the following statements made by the same top manager in 2001 and 2002:

> We have a terrace-house style management where we exchange ideas with people in the same house, so we don't want to sell our factories to other people.' (Japanese electronics executive, June, 2001) 'We're thinking of a smaller terrace house now. And we're also thinking about having good neighbours.' (same Japanese electronics executive, July, 2002)

[10] For example, most large Japanese electronics firms have licensed processor cores, a modular block of design code (or 'IP block') for inclusion in SoC semiconductors, from the British firm Advanced RISC Machines Ltd. (ARM) as a way to stimulate business in Europe, where ARM technology amounts to a *de facto* standard for embedded communications equipment.

3. 2 Examples of recent and planned electronics factory investments in Japan

Firm Name	Kind of factory	Location	Investment ¥ B	Planned opening
Renesas Technology (Hitachi – Mitsubishi joint venture spin-off)	semiconductors (system LSI)	Hitachinaka, Ibaraki	200	latter half of2005
Elpida Memory (Hitachi – NEC joint venture spin-off)	semiconductors (DRAM)	Higashihiroshima, Hiroshima	500	latter half of2005
NEC Electronics	semiconductors (system LSI)	Tsuruoka, Yamagata	100	latter half of2005
Toshiba	semiconductors (flash memory)	Yokaichi, Mie	270	latter half of2005
Fujitsu	semiconductors (system LSI, ASIC)	Kuwana, Mie	160	first half of2005
Renesas Technology (Hitachi – Mitsubishi – NEC joint venture spin-off)	semiconductors (system LSI, flash memory)	Kagami, Kochi	200	undecided
Matsushita	semiconductors (system LSI)	Uozu, Toyama	130	latter half of2005
Sony	semiconductors (microprocessor)	Isahaya, Nagasaki	200	first half of2005
Sony	semiconductors (CCD)	Kyushu (undecided)	100	undecided
Sharp	semiconductors (flash memory)	Fukuyama, Hiroshima	50	first half of 2006
Oki	semiconductors (undecided)	Kiyotake, Miyazaki	100	undecided
Toshiba Matsushita Display Technology	liquid crystals for cellular phones	Kawakita, Ishikawa	50	April, 2006
Sharp	liquid crystal displays for TVs	Kameyama, Mie	150	June, 2006
IPS	liquid crystal displays for TVs	Mobara, Chiba	110	2nd Q, 2006
Toshiba-Canon	SED displays	Taiji, Hyogo	180	January, 2007
Matsushita (Panasonic)	plasma displays	Ibaragi, Osaka	60	April, 2004
Matsushita (Panasonic) - Toray	plasma displays	Amagasaki, Hyogo	95	September, 2005
Fujitsu Hitachi plasma display	plasma displays	Kunitomi, Miyazaki	85	latter half of 2006
Pioneer	plasma displays	Tatomi, Yamanashi	26-27	September, 2004
Konica Minolta	polarizing film for liquid crystal displays	Kobe, Hyogo	30	autumn, 2006
Fuji film	film for flat panel displays	Kikuyo, Kumamoto	100	December, 2006
Dainihon insatsu	film for liquid crystal panels	Kitakyushu, Fukuoka	30	end of 2006
Toppan insatsu	film for liquid crystal panels	Hisai, Mie	50	October, 2006
Sumitomo Chemical	polarized plates	Niihama, Ehime	10	autumn, 2006
Asahi glass	glass plates for liquid crystal panels	Takasago, Hyogo	25	autumn, 2006

Source: Nikkei Shinbun, various dates

In contrast to the technology and standards development deals forged with American and European firms in the 1980s, most of these recent agreements have been between Japanese firms. In some cases the deals are simple technology development and patent sharing deals between firms with complementary assets and capabilities. In other cases firms have combined component divisions and spun them off as separate companies. In still other cases firms have purchased the divisions of other firms to gain control over needed components or to build larger, more viable divisions, especially in the face of volatile global markets and fierce competition (e.g., DRAMs). Of the greatest interest and significance are eight deals listed in Table 3-3 that involve joint factory investments, where partner firms share output. Such deals require significant investment that heighten risk and make withdrawal difficult. Alliances of this kind create shared factory space, and shared risk. They move the Japanese electronics industry in the direction of Modular Production in that large fixed investments are pooled and shared by a number of industry players. But in this case the number of firms sharing capacity is limited to the members of the alliance, which is typically two, and in a few cases, three firms.

Overall, this restructuring activity is leading the Japanese electronics industry on a path toward greater specialization, concentration, and fixed capital sharing. These are the same goals that American firms have sought as they have moved toward the Modular Production System, albeit pursued in somewhat different and more partial way. Table 3-3 provides some examples of recent restructuring in the Japanese electronics industry, including mergers, spin-offs, acquisitions, and alliances.

3. 3. Examples of recent restructuring in the Japanese electronics industry

Partners (% share)	Year announced	Products	Type of deal
Sony – Konica - Minolta	2005	digital still cameras (SLR)	joint product development
Matsushita - Olympus	2005	digital still cameras (SLR)	joint product development
Hitachi - Matsushita	2005	flat panel displays (plasma)	joint R&D, production, marketing and intellectual property sharing
Hitachi (50%) – Matsushita (23.4%) – Toshiba (23.4%)	2004	flat panel displays (liquid crystal)	joint production
NEC - Pioneer	2004	flat panel displays (plasma)	sale to Pioneer
Seiko Epson (55%) – Sanyo (45%)	2004	flat panel displays (liquid crystal)	merger and spin off
Toshiba - Mitsubishi	2004	semiconductors	sale to Mitsubishi
Sharp - Sony Ericsson	2004	software for cellular phones	joint development
Casio (51%) – Hitachi (49%)	2003	cellular phones	joint product development, design and purchasing

Konica - Minolta	2003	cameras, printers, and copiers etc	merger
Fujitsu	2002	flat panel displays (liquid crystal)	spin off of division
Hitachi (55%) - Mitsubishi (45%) (Renesas Techology)	2002	semiconductors (system LSI)	merger and spin off of R&D, product development, production and marketing
Mitsubishi – NEC – Hitachi (Elpida Memory)	2002	semiconductors (DRAM)	merger and spin off of R&D, product development, production and marketing
Toshiba (60%) – Matsushita (40%)	2001	flat panel displays (liquid crystal)	joint production
NEC	2001	semiconductors (network applications)	spin-off
Sony – Toshiba - IBM	2001	semiconductors (system LSI)	joint product development
Matsushita - NEC	2001	software for cellular phones	joint product development
Matsushita - Toray	2000	flat panel displays (plasma)	joint venture
Fujitsu - Hitachi	1999	flat panel displays (plasma)	joint production
Toshiba (50%) – Canon (50%)	1999	flat panel displays (SED)	joint R&D and production
NEC (50%) – Hitachi (50%)	1999	semiconductors (DRAM)	merger and spin off of R&D, product development, production and marketing
Mitsubishi - Matsushita Electronic	1998	semiconductors (system LSI)	joint product development
Toyota Jido Shokki (50%) – Sony (50%)	1997	flat panel displays (liquid crystal)	joint venture

Source: Trade press publications and Nikkei Shinbun

Outsourcing

In the realm of outsourcing as well, Japanese electronics firms have taken a partial step in the direction of Modular Production. Dense interactions between design and manufacturing is one of the hallmarks of the Japanese Production System, and much criticism was leveled at the tendency at American firms' to "throw designs over the wall" to manufacturing (Kenney and Florida, 1993). But this was one lesson of Lean Production that went largely unheeded in the United States. On the contrary, one of the most significant challenges to the traditional Japanese system posed by Modular Production is the notion that manufacturing can be entirely separated from product development. Were American firms simply misguided or had technology enabled new ways of organizing the value chain? One respondent put the question this way:

> Traditionally we thought that if we don't keep manufacturing, we can't keep our core technological competence. US firms threw that out. This is the central question. For 'analog' manufacturing, where you have the in-house accumulation of technology, [outsourcing] is dangerous. For 'digital' manufacturing, [outsourcing] is OK. But does digital equipment

> eliminate the accumulation of manufacturing expertise? This is one of my questions. We need at least to keep experimental pilot plants in Japan. For manufacturing technologies, like miniaturization, there is real Japanese strength. What will US core competence be if all their manufacturing goes? New technology must combine various technologies and expertise within the company. The question is: can we throw manufacturing out of this mix totally? (Japanese electronics executive, July, 2001).

The general strategy in Japan has been to keep the production of leading edge products in-house but embrace outsourcing for high-volume, price-sensitive products such as low-end personal computers, mobile phones, and previous generation video game consoles. But instead of American contract manufacturers, Taiwan-based contract manufacturers have received the lion's share of these new orders from Japanese firms. Taiwanese contract manufacturers were thought to have access to lower cost capital and be willing to tolerate lower returns on investment than Japanese firms. Taiwanese manufacturers of commodity flat panel displays, personal computers, and mobile phones are especially popular. Some use of Taiwan's semiconductor foundries (TSMC and UMC) was reported as well. Japanese managers have confined the use of contract manufacturers to older and simpler products and components because of the engineering time required to transfer specifications and because they fear the leakage of intellectual property. One respondent put it as follows:

> Some of our products require special components and finishes. If we used a Taiwanese [contractor], we would also use them as parts vendors, and we'd have to teach them about this [advanced process], and we don't want to — it would take too much of our engineering time. Eventually they will be able to do everything, but we don't want to teach them so quickly. It's a constant decision to figure out how much of our resources to invest in teaching them as opposed to the cost of doing it ourselves. Moreover it leads to the leakage of our intellectual property. Eventually they catch up — but maybe we can delay that (Japanese electronics executive, October 2004)

This statement reveals a deep ambivalence about outsourcing that has not been as evident in American electronics firms, which tend to deal with such problems by codifying complex product specifications and punishing suppliers that try to compete with them by withdrawing business. While not unheard of, American companies have had no appreciable problems with IP leakage to rivals via shared suppliers. Managers of Japanese electronics firms, in contrast, have largely opted to continue traditional strategies that seek to develop and leverage synergies within their organizations. As one respondent put it:

> In can be an advantage to have both components and [final products] in-house; we can use advanced components in our own products first and introduce new features faster. If manufacturing is outsourced, 100% of the strength of Japanese companies will die. Launching new models quickly is the key. If we don't have a manufacturing function, we will not be able to launch new products based on new [in-house] technologies, such as batteries, LCDs, and semiconductors, nor could we make modifications to existing products. The ability to make incremental modifications on the factory floor is important. Dell doesn't create. They will have a hard time creating new products because they depend on outside [contract manufacturers] that have no unique technology. Making parts and products is important. When products are commodities, then using [contract manufacturers] is OK, but advanced products are better made in-house. (Japanese electronics executive, June 2001)

Still, it was recognized that the benefits of this strategy were declining with the increased ability to codify product and process information that has come with digititzation. One respondent put the problem this way:

> With digital technology it becomes easier to gain the capability to manufacture. It's easier to make personal computers than televisions. Everyone can buy the technology. The machines embody the instructions. It's no longer a 'black box'; the Japanese advantage when it used to be that way is eroding. For example, the Koreans can simply buy the machines and have the technology. (Japanese electronics executive, July, 2001.)

On the other hand, in some areas the increasing consolidation of functionality enabled by digitization has created new technical challenges and a greater need to integrate product and component design efforts. The Japanese managers we spoke with believed this to be especially true in the case of system-on-a-chip semiconductors.[11] As one respondent put it:

> United States companies specialize in a core competence, a piece of the value chain. We do it all: system LSI, [product] design, manufacturing, production equipment, and marketing.

[11] This is in contrast to American lead firms, which commonly source their SoC semiconductors externally or do the logic design in-house and outsource the remaining design and fabrication tasks (Greg Linden, personal communication, September 2005).

> The main business [of our division] is to manufacture digital audio-visual products. To do this we must co-develop with our semiconductor group. We can put all of our knowledge about system design into the LSI design. The system LSI made by a specialist may not work as well or fit as well within the final product. In the past we could buy key components from the outside, but now system LSI determines everything so we buy these from inside. But this is the exception. Other components can be bought from the outside. (Japanese electronics executive, October 2004)

Another respondent listed the benefits of in-house system-on-a-chip semiconductor production as:

> 'Speed, cost, and intellectual property protection.' 'When outside vendors are used, roadmaps are leaked to competitors. Inside we don't have that problem.' (Japanese electronics executive, October 2004)

Our interviews suggest that by 2003 the questioning on the topic of outsourcing had led only to modest changes. One of the main difficulties was the work force reductions that would be required for more radical restructuring.

> If we got rid of manufacturing, we'd have to get rid of 50% of our workforce. We couldn't survive if we did that because other stakeholders, like the governments who procure our services, couldn't accept our doing such a thing. (Japanese electronics executive, July, 2002)

Severe workforce reductions were also seen as problematic because of their effect on morale. As one respondent put it:

> We can't just fire people, because if we did, we couldn't keep the others. This is the Japanese way of business; we can't just adopt the American way. We have to make full use of Japanese people. If we fire the laggards, the talented promising people will think about their own future and also leave. They would think that [our company] is not a good place to work. We are building up some outside companies like real estate and maintenance to absorb excess people, but all this has to happen slowly. We are thinking of cutting some businesses, but this must be done gradually, according to the Japanese way. (Japanese electronics executive, June, 2001)

To sum up, Japanese firms appear to have settled on a mixed model in the realm of outsourcing. Advanced components and products are to be produced in-house or in joint ventures, and older, simpler, and non-strategic components and products lines are to be outsourced. While this strategy might seem clear and decisive on its face, it provides no real guidance on how far to take outsourcing. What comprises a core technology, a key component, or advanced product? How soon should advanced process technologies be transferred to outside suppliers? It was recognized that the definition of core competencies and key components would shift over time. One respondent summarized this point as follows:

> In regard to outsourcing, we have a mixed model. We make key components in-house. We must choose these key components carefully and engage in constant search and revision. What is considered key will change over time. Then, we must choose our real high tech collaborators; firms that can provide specialties and have special R&D capabilities. (Japanese electronics executive, October, 2004)

What this suggests is that Japanese electronics firms face the same strategic challenges that their foreign competitors do and have similarly moved in the direction of Modular Production, in most cases for older product lines but in other cases with the aim of developing high-level technological collaborations. But even in the case of older, non-strategic products, the migration of in-house production to low-cost locations, especially China, was mentioned at least as often as outsourcing. What is clear is that the degree and speed of these changes are limited in the Japanese institutional context. The following statement sums up this point well:

> Suppose we do away with all of our plants and fire all of our workers If we were driven to this we might do it, but in Japan you can't do this. It is our policy to protect [manufacturing workers'] jobs. It is part of our mission as a company. So we must continue to develop products that cannot easily be outsourced. Putting parts together is the job of a trading company. We are not a trading company. This is why we cannot do what Apple computer has done [externally sourcing the components and assembly of its iPod digital music player]. (Japanese electronics executive, March, 2004)

Information technology and communications services

As they lost money in the late 1990s, Japanese electronics firms with the breadth to supply large-scale corporate computing systems saw a solution to their financial woes through growth in the service side of their business, following IBM's long success in this area. An expanding information technology and communications (ITC) services business is attractive in many ways, not least in its potential to absorb a large number of employees in high-value-added, knowledge-intensive work. But customized ITC systems and IT-enabled business services tend to require a deep and thorough understanding of the end user's line of business and close collaboration to identify and fulfill the buyer's needs. Such 'domain knowledge' is typically industry-specific, requiring knowledge that is applicable only to relatively narrow 'vertical' markets, so there is an obvious knowledge gap.[12] Japanese electronics firms have very little experience providing ITC services outside of Japan. There is, moreover, a great deal of competition in the realm of ITC services, both from other integrated electronics hardware and software firms such as IBM and from services-only consulting firms, such as Accenture, Price Waterhouse, and McKinsey.

Competing with foreign ITC service firms even in Japan has proved difficult, and Japanese electronics firms have found that their product lines and service offerings are not considered serious contenders. One reason for this is Japanese electronics firms' continued bias toward using their own products for the ITC systems they sell. The provision of advanced ITC services to Japanese customers, but especially to global clients, introduces a contradiction with the traditional Japanese way of doing business. Japanese electronics firms, when providing complete ITC systems to clients, produce and thus have an incentive to supply a full range of their own hardware products, from components to PCs to servers to large computers to networking equipment, as well as software. With the deployment of global-scale data communications systems, and especially since the rise of interoperability based on Internet, or TCP/IP, protocols, it has become much easier and in some cases necessary to integrate hardware and software from a variety of vendors. In fact, many customers, even in Japan, believe that their systems should be built from best products available. It has been very difficult for Japanese electronics firms to adopt this model, not least because of strongly held notions about the learning synergies between various components of large complex systems. In addition, sales forces have little or no experience selling products from outside vendors,

[12] See Rtischev and Cole (2003) for an analysis of the not always wise penchant of large Japanese firms to try to use expanding businesses to absorb redundant labour.

and may well have incentive structures that discourage this practice. One executive explained this dilemma as follows:

> Five to seven years ago, there were no cases of United Sates [firms'] success in selling [IT systems] in Japan, but today, even local governments are choosing whoever has the best integration package. If we try to sell only our own products we'll lose business. We do have one case where we sold a big system integration solution with no in-house products. It included only American-made hardware and software. Our engineers on that project asked, 'What company am I working for?' But pure systems integration like this is profitable. (Japanese electronics executive, July, 2001)

Debates about shifting from manufacturing to services at Japanese electronics firms have apparently been quite intense. For now, it seems as if the integrated approach has won the day. This is captured well by the following three statements made by the same high-level Japanese electronics executive:

> July 2001: Now we want to change from a hardware to a software and services solutions business, so we need more differentiation to fit customers in every country. Will turning away from manufacturing create weakness? We are struggling to find an answer. Even on government programmes, we can't do it ourselves and so we are using some American firms as sub-contractors. Accenture, Mckinsey, and Price Waterhouse and others have a very good business in Japan and can win bids over us. Our engineers make full use of our products first. So customers prefer to go with American companies because they'll provide integrated packages using the best components from a variety of vendors. Our engineers are trying to integrate products from Cisco and others but sales and engineering issues force them to use our own products, so we lose some bids.
>
> July 2002: There are two different views at our company. Some say we should simply be good at choosing the best components, but others say anyone could package them in the same way. They would be standardized parts, so anyone could do the same thing. Where's the competitive advantage for us then? With no differentiating hardware, there is no way of succeeding in a pure software/services business. How would we make profits in such a business? In this view, we need to maintain advanced hardware capabilities.
>
> October 2004: Service companies cannot expect to make profits. We found we cannot make money from just software services. Even IBM is facing losses from its system integration business. Competition is too tough in being a pure provider of services. Therefore my opinion now is that we need to keep making all the necessary hardware in our company. Some

> people in our company said we should lead in services and software and use the best hardware we can find whether it's ours or another company's. Gradually we realized that the company that produces the key hardware in-house can provide customers with the confidence and security they need.

Conclusions

The failure of Japanese electronics firms to participate fully in the Internet-fueled growth in the global electronics industry during the late 1990s triggered a period of questioning among the top executives in Japan's leading electronics firms. At the time, the Modular Production System emanating from the United States seemed to be providing American firms with significant competitive advantages. Moreover, the key features of the Modular Production System provided a direct challenge to a host of the most cherished strategies of Japanese electronics firms. In Modular Production, manufacturing capacity is pooled in specialized contract manufacturers, freeing lead firms to engage in 'open innovation' (Chesbrough, 2003) by specializing in specific aspects of technology development and system architecture while depending on outside firms for complementary system elements. The goal of 'platform leaders' (Gawer and Cusumano, 2002) in the Modular Production System is to attain early market dominance to set standards in emerging technologies, thereby forcing 'partner' firms to create products, subsystems, and components that comply with the standards they set. These strategies clash with the strongly held belief among Japanese managers that competitive advantage comes from design collaboration within a diversified organization, tight feedback between internal design and manufacturing, and the first-use of internally developed components.

The bursting of the Internet bubble in 2001, and the ensuing inventory and financial problems at firms closely associated with Modular Production such as Cisco and Solectron, affirmed the skepticism of Japanese managers regarding the model. Our interviews after 2003 suggested that the pressure for radical moves away from manufacturing had lost momentum and that traditional strategies of vertical integration were being reasserted, especially for advanced products and technologies. In addition, financial performance at many large Japanese electronics companies improved in 2004, driven in significant degree by rising demand from Japanese customers with booming sales to China for products such as steel, ships, and heavy machinery. Only the threat from Korea failed to diminish.

So the period of intense questioning came to an end, at least temporarily, as decisions were taken to deepen traditional strategies, especially for advanced products and technologies. Japanese electronics firms continue to have shallow, tactical alliances with foreign firms, and have reasserted their vertically integrated approach by investing in a new round of factory construction — in Japan — for key components such as system-on-chip semiconductors, advanced flat panel displays, high capacity batteries, and high-performance memory chips. There have been partial but significant steps taken in the direction of Modular Production in the form of increased specialization, outsourcing of low-end products, and shared factory investments in Japan, but wholesale restructuring has been resisted, at least for now.

However slowly it may be moving, restructuring at Japanese electronics firms is indeed underway, and most large firms reported reductions in their global workforces by 10-15% since the late 1990s, mostly through attrition. Still, this restructuring is proceeding under the substantial weight of existing organizational routines, investments, and workforces, and is being driven by contradictory pressures. As a result, Japanese electronics firms are simultaneously shedding and protecting jobs, getting out of old business lines and adding new ones, opening their sourcing networks and investing in new in-house component plants, and expanding some facilities and shrinking or closing others, both off- and on-shore, in an effort to rebalance their organizations. While it is too early to determine how successful these changes will be, or if they will add up to a new and distinct industrial model in the end, there are a host of new challenges and opportunities that now face Japanese electronics firms given their recent experiments with joint technology development, production alliances, relocation, and global outsourcing. Whether Japanese electronics firms can simultaneously and quickly shed non-core business, develop new software and service competencies, and carry the weight of the substantial new component manufacturing investments, many of which are being made in the context of new and completely untested alliances, is unknown.

Finally, what do recent trends in the Japanese electronics industry tell us about the global circulation of industrial models? First, firms can and do react to external pressures for change, but in a complex and increasingly integrated world, there are multiple models that are viable at any given moment, and even if a particular model is quite popular, firms receive mixed signals from the outside. For Japanese electronics firms, challenges have come not only from the Modular Production System, but also from Korean firms such as Samsung and LG Electronics, which remain highly vertically integrated. Second, the resistance to radical change is typically quite high, so changes tend to be introduced in piecemeal fashion. It is this process of partial application, experimentation, and reversal, however, that could work to create a new model, one well adapted to the industrial history and institutions of Japan as well as to the exigencies of global markets.

References:

Abo, Tetsuo ed. 1994. Hybrid Factory: The Japanese Production System in the United States. Oxford and New York: Oxford University Press.

Albert, Michel. 1991. Capitalism vs. Capitalism. NY, Four Wall Eight Windows.

Baldwin, Carliss, and Clark, Kim. 2000. Design Rules. Cambridge, MA: MIT Press.

Berger, Suzanne and Ronald Dore, eds. 1996. National Diversity and Global Capitalism. Ithaca NY: Cornell University Press.

Berger, Suzanne et al. 2005. How We Compete: What Companies Around the World are Doing to Make it in the Global Economy. New York, NY: Doubleday.

Brown, Clair; Reich, Michael; Ulman, Lloyd; and Nakata, Yoshifumi. 1997. Work and Pay in the United States and Japan. New York, NY: Oxford University Press.

Chesborough, Henry. 2003. Open Innovation; the New Imperative for Creating and Profiting from Technology. Boston, Massachusetts, Harvard Business School Press.

Chesbrough, H. and Kusunoki, K. 2001. 'The Modularity Trap: Innovation, Technology Phase Shifts, and the Resulting Limits of Virtual Organizations.' In Nonaka, L. and Teece, D. (eds.), Managing Industrial Knowledge. London, Sage Press, 202-230.

Cole, R. (1999), *Managing Quality Fads: How American business learned to play the quality game*, New York: Oxford University Press.

Dore, Ronald. 1986. Flexible Rigidities: Industrial Policy and Structural Adjustment in the Japanese Economy 1970-1980, Stanford University Press, Palo Alto.

Dyer, Jeffery. 1996. 'Does Governance Matter? *Keiretsu* Alliances and Asset Specificity as Sources of Competitive Advantage.' Organization Science, 7(6) 649-666.

Gawer, Annabelle, and Cusumano, Michael. 2002. Platform Leadership; How Intel, Microsoft, and Cisco Drive Innovation. Boston, Massachusetts, Harvard Business School Press.

Gereffi, Gary; Humphrey, John; and Sturgeon, Timothy. 2005. 'The Governance of Global Value Chains.' *Review of International Political Economy*12(1), 78-104.

Hall, Peter and Soskice, David eds. (2001). Varieties of Capitalism. Oxford, Oxford University Press.

Helper, Susan 1991. 'How Much Has Changed Between U.S. Automakers and Their Suppliers?' *Sloan Management Review*, v. 32, Summer, pp. 15-28.

Holweg, Mattias, and Pil, Frits. 2004. The Second Century; Reconnecting Customer and Value Chain through Build-to-Order. Cambridge, Massachusetts: MIT Press.

Johnson, Stephen. 2003. 'Systems Integration and the Social Solution of technical Problems in Complex Systems.' in: The Business of Systems Integration, Prencipe, Andrea; Davies, Andrew; and Hobday, Mike (eds.), Oxford; Oxford University Press. 35-55.

Kenney, Martin and Florida, Richard. 1993. Beyond Mass Production: The Japanese system and Its transfer to the United States. Oxford and New York: Oxford University Press.

Langlois, Richard, 2003. 'The Vanishing Hand: The Changing Dynamics of Industrial Capitalism,' *Industrial and Corporate Change* 12(2): 351-385 (April).

Langlois, Richard, and Robertson, Paul. 1995. Firms, Markets, and Economic Change. Routledge: London and New York.

Liker, Jeffery; Fruin, W. Mark; and Adler, Paul (eds.). 1999. Remade in America; Transplanting and transforming Japanese Management Systems. Oxford and New York: Oxford University Press.

Linden, Greg, and Somaya, Deepak. 2003. 'System-on-a-Chip Integration in the Semiconductor Industry: Industry Structure and Firm Strategies,' *Industrial and Corporate Change* 12 (3): 545-57

Mayer, David and Kenney, Martin. 2004. 'Economic Action Does Not Take Place in a Vacuum: Understanding Cisco's Acquisition and Development Strategy.' *Industry and Innovation*, Volume 11, Number 4, 299–325, December.

Niece, Jennifer. 2005. 'Cisco's first glitch.' Journal of Business Research. 58: 1003–1005.

Pavitt, Kieth. 2003. 'Specialization and Systems Integration: Where Manufacturing and Services Still Meet.' The Business of Systems Integration, Prencipe, Andrea; Davies, Andrew; and Hobday, Mike (eds.), Oxford; Oxford University Press. 78-94.

Principe, A, Davies, A., and Hobday, M, (eds.) 2003. The Business of Systems Integration. Oxford, UK.

Rtischev, D. and R. E. Cole (2003), 'Social and Structural Barriers to the IT revolution in High-Tech Industries,' in J. Bachnik (ed.) *Roadblocks on the Information Highway*, Landham, MD.: Lexington Books.

Saplosky, Harvey. 2003. 'Inventing Systems Integration.' in: The Business of Systems Integration, Prencipe, Andrea; Davies, Andrew; and Hobday, Mike (eds.), Oxford; Oxford University Press. 15-34.

Sayer, A. 1986. 'New Developments in Manufacturing: the Just-in-Time System,' *Capital and Class*, 30, pp. 43-72.

Sturgeon, Timothy and Lee, Ji-Ren (2005), 'Industry Co-Evolution: Electronics Contract Manufacturing in North American and Taiwan' In: Berger, S. and Lester, R. (eds.), Global Taiwan: Building Competitive Strengths in a New International Economy. New York, London: M.E. Sharpe. 33-75.

Sturgeon, Timothy and Lester, Richard. 2004. 'The New Global Supply-base: New Challenges for Local Suppliers in East Asia.' Chapter two in Global Production Networking and Technological Change in East Asia, Shahid Yusuf, Anjum Altaf and Kaoru Nabeshima (eds.), Oxford: Oxford University Press.

Sturgeon, Timothy, 2000. 'Turn-key Production Networks: The Organizational Delinking of Production from Innovation' in: New Product Development and Production Networks; Global Industrial Experience, edited by Ulrich Jüergens, Springer Verlag, Berlin, New York, pp. 67-84.

Sturgeon, Timothy, 2002. 'Modular Production Networks. A New American Model of Industrial Organization,' *Industrial and Corporate Change* 11(3):451-496.

Suzuki, Yoshiji, 2004. 'Structure of the Japanese Production System: Elusiveness and Reality.' Asian Business & Management, 3:2, 201-219.

Takeishi, Akira, and Fujimoto, Takahiro 2001. 'Modularization in the Auto Industry: Interlinked Multiple Hierarchies of Product, Product, and Supplier Systems.' International Journal of Automotive Technology and Management, 1;4, 379-396.

Williams, Karel 2000. 'From Shareholder Value to Present-day Capitalism.' *Economy and Society.* 29:1 February: 1–12

Womack, J., Jones D., and Roos, D. 1990. The Machine that Changed the World. New York: Rawson Associates.