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High-technology restructuring in the USA and Japan

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Abstract. In this paper, the comparative responses of the USA and Japan to the rise of new high-technology industries are examined. The United States pattern mainly revolves around the rise of high-technology districts like Silicon Valley and Route 128 which comprise dense networks of small entrepreneurial firms and other related institutions. Despite its tremendous innovative capabilities, this pattern generates significant costs (that is, high turnover of labor, chronic entrepreneurship, and an emphasis on breakthrough innovations at the expense of manufactured products) which are not sufficiently recognized by proponents of the flexible specialization or 'simple flexibility' thesis. The Japanese approach to restructuring is contrasted as one of 'structured flexibility' where large corporations perform important 'system governance' functions in the linking of manufacturing and innovation and act as focal points in just-in-time production complexes. Japan's pattern of 'structured flexibility' overcomes many of the limitations of high-technology organization in the USA.

Introduction

The advanced industrial countries are in the midst of a dramatic process of technological and institutional restructuring. This involves the rise of new technologies and industries—semiconductors, computers, computer software, industrial automation, and biotechnology—which are setting in motion a sweeping pattern of 'creative destruction' and industrial renewal. It also entails the emergence of new ways of organizing work, new ways of organizing enterprises, and new ways of organizing transactions among firms. Silicon Valley in California and Route 128 around Boston with their dense networks of entrepreneurial firms are two, frequently cited examples of high-technology restructuring. For a growing number of scholars, the critical dimension of current restructuring lies in the triumph of flexibility over older, less flexible forms of industrial organization (especially, Piore and Sabel, 1983; 1984; Scott and Storper, 1987; Storper and Scott, 1988a; 1988b; Scott, 1988a; also, Harvey, 1988; Leborgne and Lipietz, 1988; Moulaert and Swyngedouw, 1988; Schoenberger, 1988).

Most of the current explanations for high-technology restructuring are based almost exclusively on the cases of the USA and Western Europe, without so much as a cursory examination of Japan. This is surprising because Japan has emerged as a fierce competitor for world leadership in high-technology. A recent study indicates that Japan holds an unquestioned advantage over the USA and Europe in twelve out of twenty-four important semiconductor technologies, with the USA and Japan at parity in eight others, and the USA leading in just four (USDSB, 1987). In 1987 alone, the USA ran a $700 million semiconductor trade deficit with Japan (Dataquest Inc., 1988b). Other reports indicate that Japan is catching up rapidly in computers (Anchorduguy, 1988) and biotechnology (Yoshikawa, 1987) as well as in science and technology more generally (Okimoto and Saxonhouse, 1987; Saxonhouse, 1988).

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A study by the US Office of Technology Assessment (USOTA, 1988a) indicates that Japan has a leading position in the new superconductor technologies. The 1980s have seen Japan's high-technology trade surplus with the United States grow from $4 billion to more than $20 billion (see figure 1).

In this paper we explore the very different responses to high-technology restructuring taken by the USA and Japan. Our basic argument can be summarized as follows. The approach of the United States is mainly one of 'simple flexibility', revolving around high-technology districts like Silicon Valley in California and Route 128 around Boston. These new industrial districts mostly comprise tight networks of small entrepreneurial firms (as well as some large ones), research universities, venture capitalists, and other actors.[1] Japan's approach is one of 'structured flexibility', where flexibility exists within highly structured institutional relationships. Large firms play a central role in this system by fostering high degrees of integration across industries and functioning as 'anchors' or 'hubs' for extensive just-in-time complexes of high-technology producers. In doing so, they perform important 'system governance' functions, replacing the atomistic and 'helmless' industrial organization of US high-technology districts.

It is important at the outset to distinguish our concept of 'structured flexibility' from the 'simple flexibility' thesis associated with Piore and Sabel's concept of flexible specialization (Piore and Sabel, 1983; 1984; Sabel, 1982; 1988; Sabel et al, 1987), and Storper and Scott's (1988a; 1988b) more explicitly geographic concept of 'flexible industrial districts'. Although our aim here is not to add to the general critique of the simple flexibility thesis (see Gertler, 1988; Williams et al, 1987), we are concerned with its limits as a generalizable model for high-technology

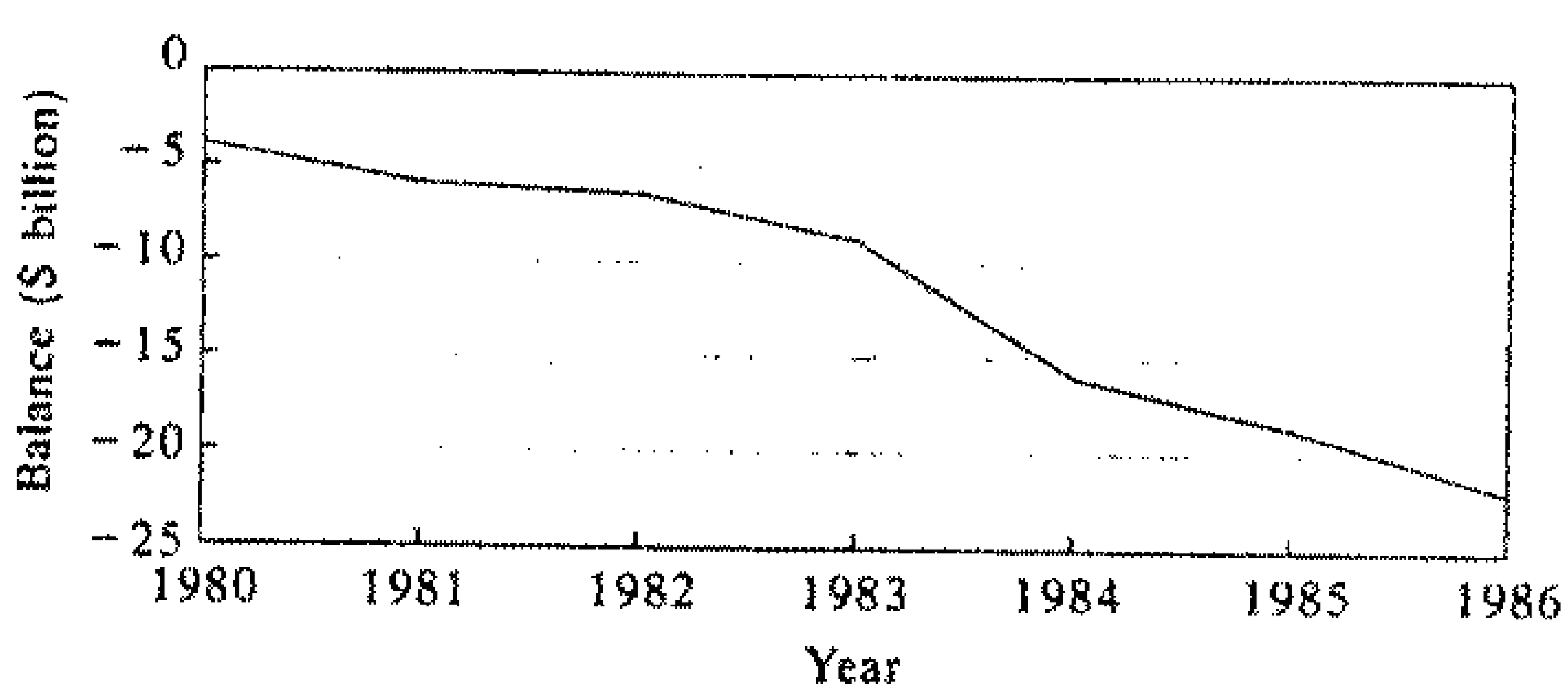

Figure 1. The US high-technology trade deficit with Japan. Source: NSF, 1987.

[1] Large firms like IBM and AT&T are important components of high-techology industry in the USA, but they function to a large extent independently of high-technology districts. Although a number of large firms in the USA remain major high-technology producers (for instance, IBM in computers, and Motorola and Texas Instruments in semiconductors), many others (like General Electric) devote the lion's share of their high-technology effort to military applications. Despite the fact that a few such companies remain important in the manufacturing industry, most have lost their impact, in terms of innovative output, to newer entrepreneurial entrants. In fact, the major innovations in the three leading high-technology sectors (semiconductors, computers and biotechnology) have disproportionately come from venture-capital-backed start-ups: for instance, Fairchild Semiconductors, Intel, and LSI Logic in semiconductors; DEC, Apple Computers, Compaq Computers, Cray Research, and Sun Microsystems in computers; and Genentech and Amgen in biotechnology. Of course, many such companies have evolved into large companies, and still retain linkages in established high-technology districts. A number of other important companies like Hewlett Packard also come from entrepreneurial origins and retain close linkages within high-technology districts. In this regard, high-technology in the USA might be thought of as comprising two relatively autonomous subsystems—high-technology districts and established companies—with the former's importance increasing dramatically over time. In this paper, we focus on high-technology districts as the primary response to high-technology restructuring in the USA.

restructuring. For us, too much emphasis has been placed on the cooperative and collective aspects of flexible districts. In contrast to the overly positive image fostered in some of the literature (especially Piore and Sabel, 1984), high-technology districts like Silicon Valley are beset with problems of chronic entrepreneurship, high turnover of labor, jungle-like competition, and a worsening separation of innovation and production, or 'mental' and 'manual' labor.

We advance the concept of 'structured flexibility' to capture more adequately Japan's approach to high-technology restructuring. Despite an explicit attempt by Sabel (1988) to extend the model of simple flexibility to Japan, that model provides an inadequate explanation for Japanese restructuring. 'Structured flexibility' refers to the integration of a number of dimensions of the new flexibility identified in high-technology districts within a highly structured and stable institutional framework.

There are five basic dimensions to Japan's structured flexibility. (1) Large companies are active in multiple high-technology industries, avoiding the fragmentation and splintering found in US high-technology. (2) Participative organization of work allows large Japanese companies to integrate mental and manual labor in a better way. (3) Close internal linkages between innovation and manufacturing within these same companies allows them to achieve powerful technological synergies. (4) An organized process of quasi-disintegration takes shape around large Japanese companies; this is more orderly than the market-oriented vertical disintegration of US complexes. (5) Just-in-time production complexes anchored by large companies result in linkage patterns which are quite stable and allow for intense information exchange.

As a result, Japan embeds many of the elements of participative work organization and interfirm linkages found in flexible districts like Silicon Valley within a much more stable set of institutional relationships. The explanations for such differences are found in the different geographies, different institutional legacies, and different social forces at work in the USA and Japan. In presenting our arguments, we draw upon a variety of primary data sources including industry studies by Dataquest, Arthur D Little, Standard and Poor, and Dodwell, trade journal reports, and detailed interviews with industry participants and analysts in the USA and in Japan.

High-technology restructuring in the USA

Recent work has made important progress in explaining the dynamics of high-technology restructuring in the USA (Dorfman, 1983; Florida and Kenney, 1988a; 1988b; Malecki, 1987; Miller and Cote, 1985; Saxenian, 1985; Scott and Storper, 1987; Stohr, 1986; Storper and Scott, 1988a). In this work high-technology complexes like Silicon Valley and Route 128 are interpreted in terms of the complimentarities and synergistic relationships which exist between technology intensive businesses, research universities, industrial research centers, venture capital, and related factors.

A number of theorists use the concept of 'flexibility' to explain a variety of dimensions of high-technology restructuring (Moulaert and Swyngedouw, 1988; Piore and Sabel, 1984; Sabel, 1988; Scott, 1988a; Storper and Scott, 1988a; 1988b). The geographic synthesis developed by Storper and Scott combines elements of the spatial-division-of-labor approach (Massey, 1984; Storper and Walker, 1983; 1989), Scott's own work on the role of transaction costs in geographic organization (Scott, 1988a), Piore and Sabel's work on flexible specialization (1983; 1984), and the continental 'regulation' school of political economy (Aglietta, 1979; DeVroey, 1984; Lipietz, 1987; Noel, 1987) to offer a compelling interpretation of the dynamics of flexible production complexes (a significant subset of these are high-technology districts). For Storper and Scott (1988a; 1988b), such complexes represent a new post-Fordist form of industrial district characterized by high degrees of vertical disintegration and dense interfirm transactional activity. External linkages among small firms and the tight clustering of them replaces the internal hierarchy of large corporations (Scott, 1988a; Williamson, 1985). Figure 2 provides a schematic depiction of linkage patterns in flexible districts. These new industrial relationships are in turn embedded in deep social structures and institutional forms that contribute to the constant reskilling and circulation of human labor power, a steady pace of technical advance, and a more general pattern of self-reinforcing growth or reproduction.

The simple flexibility model for high-technology restructuring in the USA is supported by a variety of empirical evidence. Recent studies of high-technology industrial organization in the USA contain two general conclusions: (1) new high-technology industries comprise large numbers of small entrepreneurial enterprises and a few older, established companies (for work on semiconductors, see Braun and MacDonald, 1982; Ferguson, 1988a; 1988b; for biotechnology, see Kenney, 1986a; for computers, see Dorfman, 1987; Flamm, 1987), and (2) these companies tend to locate close together in a few geographic enclaves (Markusen et al, 1986; USOTA, 1987). Premus (1982), by means of a survey, found a variety of factors to be important to the location decisions of high-technology firms: proximity to universities, local labor-market characteristics, wages, infrastructure, and climate. Malecki's (1985) enterprise-level analyses of four important high-technology sectors: computers, computer programming, semiconductors, and medical instruments, found strong agglomerations of new business formations with low levels of dispersion occurring over time and only among larger enterprises. Florida and Kenney (1988a) show dense concentrations of venture capital around high-technology agglomerations. Statistical models developed by Markusen et al (1986) indicate that although high-technology industries exhibit high degrees of agglomeration, it is hard to isolate empirically any strong causal factors for high-technology agglomeration. The consensus view in the literature is that high-technology agglomerations arise when a variety of complimentary factors coincide which comprise a high-technology infrastructure and that only a very limited number of places possess such an infrastructure (Florida and Kenney, 1988a; 1988b; 1988c; Malecki, 1987; Scott and Storper, 1987).

Although the underlying determinants of the innovative capabilities of high-technology districts (or regional technical capacities) have not yet been sufficiently conceptualized in the literature, it is possible to extrapolate a series of explanations for the spatial concentration of innovative activity. On the one hand, constant interactions between end-users and suppliers (Von Hippel, 1988) and a steady flow of information between enterprises enhances human resources and helps to give

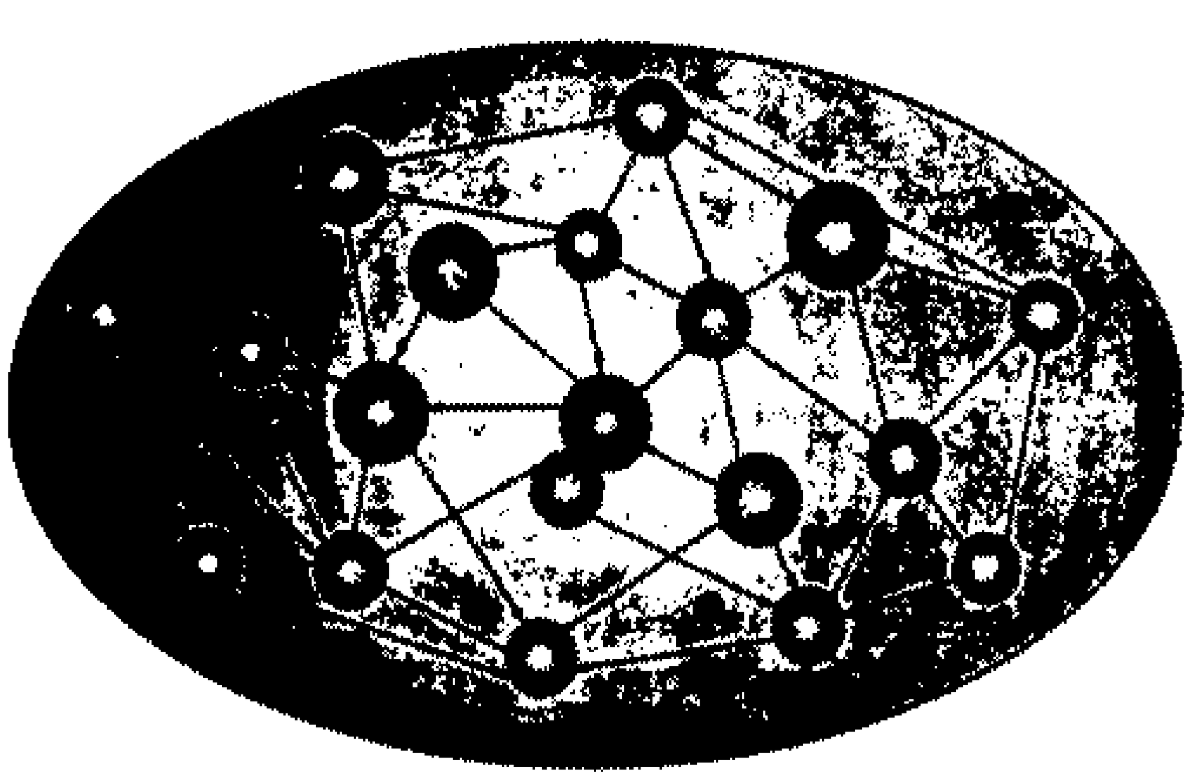

Figure 2. Linkage patterns in a flexible high-technology district.

rise to an economic environment distinguished by learning and innovation. On the other hand, an established climate of entrepreneurship plus the availability of venture capital enable unique combinations of technological and managerial talent to be brought together in new business-formations (see Freiberger and Swaine, 1984; Wilson, 1985). The combination of these factors enables workers, firms, and entire complexes to respond quickly to external stimuli and/or to changing market conditions, generating a constant flow of innovations.

Limits of high-technology districts

Although the proponents of the 'simple flexibility' model of high-technology restructuring do recognize a few of the limits of flexible districts, they tend to minimize their negative implications. In doing so, they leave us with a very one-sided picture of high-technology restructuring in the USA. The emphasis in the literature is on the serious consumption-side problems of low-wage jobs or labor dualism (Scott and Storper, 1987), escalation of housing prices, and urban congestion (Saxenian, 1985). Still, this literature neglects deep-rooted problems in production which limit the effectiveness of districts, like Silicon Valley, to respond to high-technology restructuring.

The organization of high-technology firms and complexes reflects a systemic neglect for manufacturing and the incremental improvements in products and processes that can come from it. On the one hand, the organization of work in many high-technology companies essentially recreates the separation of mental and manual labor found under Fordism. High-technology work is typically organized in two tiers: mental labor is performed by well-paid engineers who work in participative environments, and manual labor is done by production workers who perform repetitive, unskilled tasks in conditions similar to those of Fordist industry (Cho, 1985; Saxenian, 1981). As a wide variety of studies have shown, high-technology production workers are poorly paid (Siegel and Borock, 1982) labor under oppressive, near 'sweatshop' conditions (Cho, 1985), are mostly nonunionized (Kassalow, 1987), and are subject to frequent layoffs (Rogers and Larsen, 1984). On the other hand, many high-technology start-ups concentrate exclusively on research and development and do not engage at all in direct manufacturing, externalizing the division between mental and manual labor. For example, most new semiconductor start-ups, such as Altera, Brooktree Corp., Vitelic, Chips and Technologies, and Weitek are development-only companies that are entirely dependent upon outside manufacturers (Hayashi, 1988). Indeed, offshore subcontracting is increasingly common among high-technology firms in the USA (see Scott, 1987; Scott and Angel, 1988). A recent report by Dataquest Inc. (1988b), a leading high-technology market-research firm in the USA, found that roughly half of all semiconductor companies subcontracted some part of their manufacturing offshore. The strict divisions between mental and manual labor and between the sites of innovation and production are clearly reflected by Donald Valentine, a leading Silicon Valley venture capitalist.

> "Silicon Valley and Route 128 are worlds of intellectual property, not capital equipment and production. Most of the employees of U.S. high technology live in southeast Asia" (interview by authors, April 1988).

In creating this division, high-technology enterprises essentially forfeit the ability to capitalize on shop-floor innovations and/or to create synergies between innovation and production. Cohen and Zysman (1987; 1988) correctly identify some of the problems that come from the delinking of manufacturing and innovation (also, see Gomory and Schmitt, 1987; Thurow, 1987). Beyond this, high-technology restructuring in the USA is premised upon the false notion that innovation only takes place upstream in formal R&D settings and hence that only a small group of technologists can provide the source of new ideas and new economic value. This view completely discounts the innovative role played by manufacturing workers who frequently possess intimate knowledge of the actual production process. In sharp contrast to this view, recent studies point out that manufacturing workers are an important source of downstream innovation (especially Hayes et al, 1988).

Although the literature on high-technology districts implies that the relation-ships between mental and manual labor and/or innovation and production can be reconstituted between firms, the consensus in the literature on organizational learning indicates that such relationships are significantly more effective when they are internalized within organizations (see Aoki and Rosenberg, 1987; Arrow, 1962; Lieberman, 1987; Rosenberg and Steinmueller, 1988; Tilton, 1971). The need for close internal linkages is especially important in high-technology fields, like semiconductors, where the production process is the site of constant adjustment. Tilton makes this point quite explicitly in his landmark study of innovation in the semiconductor industry:

> "Although some learning readily becomes general knowledge and thus a public good, much is either applicable to a particular operation or can be transferred to another facility only with technical assistance from the firm having the know-how. Consequently, a large portion of the benefits produced by learning accrues to the firm doing the learning" (Tilton, 1971, page 86).

As a consequence, high-technology firms in the USA continue to pioneer new technical advances, but they increasingly lack the capacity to capture the full economic rewards of their innovations. This focus on technological entrepreneurship appears to be turning the USA into a 'breakthrough economy'—one which lacks the ability to follow through on many of its most promising innovations (Florida and Kenney, 1990). In a recent paper, Nelson elaborates on this dimension of the US high-technology system:

> "Once competition mounts, US firms shift resources elsewhere, labor is laid off and does not acquire skills and US firms are disadvantaged when sustained efforts are needed for survival" (Nelson, 1988, pages 32-33).

More significantly, high-technology districts in the USA are distinguished by destructive levels of chaos and competition. Indeed, there is increasing concern that the USA has fallen victim to a pattern of 'chronic entrepreneurship' (Ferguson, 1985; 1988a; 1988b). Figure 3 illustrates one dimension of this process, showing the accelerated pace of semiconductor start-up activity during the mid-1980s.

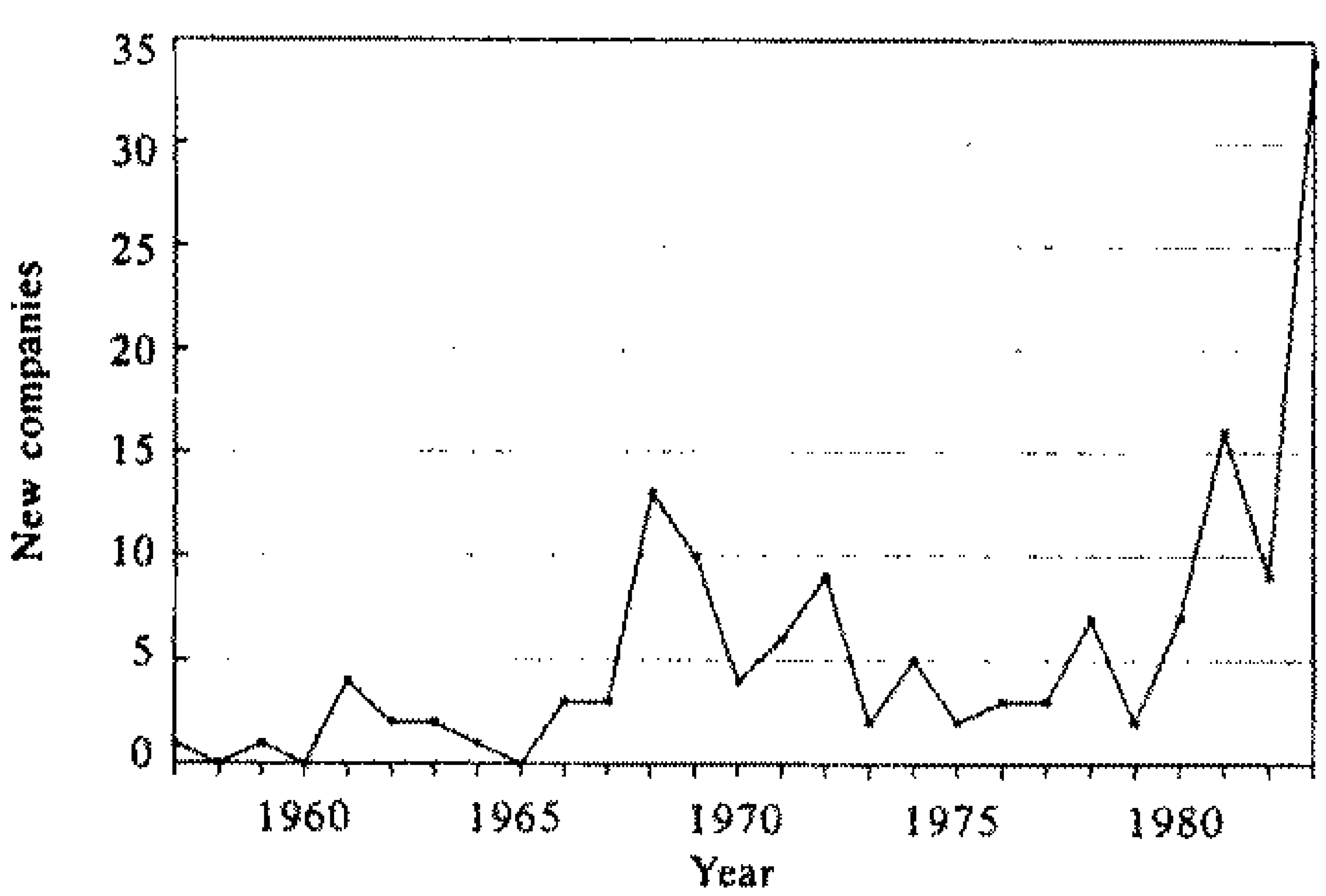

Figure 3. The formation of semiconductor companies, 1957-1983. Source: Rice, 1987.

Our interviews with leading high-technology executives and venture capitalists in the USA indicate that a large number of new start-ups are formed by defections of key researchers or even entire research groups. Rather than being internalized within stable companies, technological innovation is itself externalized in a series of start-ups or 'splinters' from established companies. Ready availability of venture capital exacerbates this splintering process by resulting in a proliferation of 'me-too' companies, escalating competition, and devastating shakeouts, as occurred in the personal computer and computer disk-drive industries (Sahlman and Stevenson, 1985). Chronic entrepreneurship is causing US high-technology to fragment and splinter, making it hard to build stable companies which are competitive over the long haul. A recent report on the state of the US semiconductor industry observed:

> "The US semiconductor producers and their equipment and material suppliers are disaggregated and have little tradition of cooperation and mutual support. In the fact of encroachment by large Japanese industrial groups, substantial segments of the US information infrastructure are at risk of being acquired by Japanese firms or disappearing altogether" (Howell et al, 1988, page 12).

Taken as a whole, the US response to high-technology may be relatively 'inefficient', giving rise to high levels of business failure and severe misallocations of resources.

Structural limits

Perhaps the most significant limitation of high-technology districts lies in their inability to transform the broad technological-institutional landscape of Fordism. Scott and Storper, like Piore and Sabel, see high-technology districts as a linear progression beyond Fordism. In doing so, they fail to consider adequately the way that high-technology districts have themselves been shaped by Fordism's limits, and how they in turn have generated serious limitations of their own. Theorists as diverse as Marx, Schumpeter (see Rosenberg, 1976; 1982), Lipietz (1987), Freeman (1987), Freeman and Perez (1988), and Olsen (1982) have all pointed out, older institutions create rigidities which inhibit their responses to social, political, and economic forces and also constrain the formation of new institutions.

The concept of institutional rigidity is especially useful in understanding flexible districts as a constrained response to high-technology restructuring. Under Fordism, research was organized in a manner which reflected many of the elements of assembly-line organization, making it virtually impossible for established industries to nurture new high-technology industries (Graham, 1985; Hounshell and Smith, 1989; Mowery, 1984; Noble, 1977; Reich, 1985; Wise, 1985). Researchers were separated into disciplinary specialties and placed in research facilities which were isolated from manufacturing. The dispersal of production facilities and the concomitant relocation of research laboratories to campus-like suburban settings during the 1960s and 1970s only exacerbated these rigidities (Malecki, 1979). The separation of mental and manual labor on the shop floor was mirrored by the separation of the sites of innovation and production more broadly.

High-technology restructuring in the USA can only be understood in the context of such rigidities. The microlevel response was the emergence of entrepreneurial start-ups (which created participative work environments for engineers and managers but ignored production workers), whereas the macrolevel response was the rise of high-technology districts. Despite their innovative prowess, these firms and districts emerged at the geographic and institutional periphery of Fordism, and thus have had a minimal impact on Fordism's broader institutional structure. In doing so, they have recreated a number of Fordism's limits (that is, the separation of mental and manual labor) and have generated some limits of their own (that is, chronic entrepreneurship). Simply put, high-technology complexes represent a constrained, partial, and limited response to restructuring—one which leaves the broader Fordist landscape of the USA essentially unperturbed.

High-technology restructuring in Japan

Japan's response to high-technology restructuring has been much more thorough and systemic. Japanese high technology grew up for the most part within large companies. In fact, Japanese industry never developed a full-blown Fordism, but embarked on a unique non-Fordist path (Kenney and Florida, 1988). The early rise of non-Fordist forms of industrial organization (that is, participative work organization) and spatial organization (that is, 'just-in-time' supplier relations) made it possible for the Japanese system to develop a much more comprehensive response to high technology.

Beyond Fordism

Japan's non-Fordist approach overcomes the separation of mental and manual labor found under US Fordism, transforming shop-floor laborers into 'smart workers'. Workers have significant input in shop-floor issues and work is organized to facilitate decentralized decisionmaking. Workers are organized in self-managing teams and rotate among jobs. They also do most immediate quality control, make suggestions on how to improve manufacturing processes, and have significant discretion on how they do their jobs. The revolutionary way work is organized in Japan systematically enhances skills, promotes problem solving on the shop-floor, and enables large firms to internalize many important learning effects (Aoki, 1984a; 1984b; 1986; 1987; Dore, 1986; Koike, 1984; 1987; Shimada and MacDuffie, 1986; Shirai, 1983). In addition, Japan's manufacturing system is characterized by 'just-in-time' supplier relationships (Asanuma, 1985a; 1985b; Monden, 1983; Sayer, 1986; Sheard, 1983; Swyngedouw, 1987). This well-articulated 'network form' of spatial organization is more structured and organized than the atomistic linkages of high-technology districts in the USA.

The rise of non-Fordist arrangements was the product of Japan's unique historical legacy. Like Western Europe and the USA, postwar Japan went through a prolonged period of domestic institution-building which came to be reflected in its unique 'class accord' between capital and labor (Gordon, 1985; Kenney and Florida, 1988; Moore, 1983; Muto, 1984). An important result of this accord was the establishment of a system of tenure guarantees or so-called life-time employment for workers in large manufacturing companies. In return, these workers gave up more radical demands for 'production control', ceding management significant control over the organization of production. Institutionalization of long-term employment ultimately helped create a pattern of labor force stability. This gave firms tremendous incentives to invest in workers since it was uncommon for workers to leave. As a result, firms were able to create large stocks of knowledge within their work force, transforming Japanese companies into 'learning organizations" (Aoki and Rosenberg, 1987; Hayes et al, 1988).

Structured flexibility and high-technology restructuring

Japan's non-Fordist structure enabled its corporations to avoid many of the institutional rigidities that plagued North American and European Fordism, setting the institutional context for its unique approach of high-technology restructuring. Japan's approach to high-technology restructuring can best be characterized as 'structured flexibility'. Large firms are a central component of the highly structured institutional framework of Japanese high-technology. The next few sections focus on five dimensions of structured flexibility: (1) the multiple-industry orientation of large high-technology firms, (2) reintegration of mental and manual labor in large companies, (3) tight integration of innovation and production, (4) quasi-disintegration, and (5) well-articulated 'just-in-time' production complexes.

Multiindustry orientation of large high-technology firms

High-technology industry in Japan is given explicit structure by large firms that play important roles across multiple high-technology sectors. In Japan, the same companies that make semiconductors also make personal computers, supercomputers, telecommunications equipment, electronic instruments, and industrial robots, as well as mass-market consumer-electronics goods (like televisions and stereo equipment) that provide ready outlets for microelectronic components (Ferguson, 1988a; 1988b; Gregory, 1983; 1986; Okimoto et al, 1984; Steinmueller, 1986; USOTA, 1983).

Large diversified Japanese electronics corporations—Fujitsu, Hitachi, Matsushita, Mitsubishi Electric, NEC, and Toshiba—are major players across a variety of high-technology sectors: computers, semiconductors, and advanced manufacturing, as well as being major consumer-electronics companies. As table 1 shows, these six firms account for more than two-thirds of the Japanese market for a variety of semiconductors and integrated circuit products, 58% of the market for general purpose computers, 48% of the personal computer market, and 43% of the office computer market, along with 60% of the market for computerized machine tools and 40% of the industrial robotics market. When we combine the market share of these firms with the market share comprised by other large Japanese electronics companies, this pattern of cross-industry dominance becomes even clearer. Large Japanese electronics firms do focus on slightly different business areas—for example, Fujitsu on large computers, NEC on telecommunications, and Toshiba on consumer-oriented high technology—but all have multiple lines of business. This stands in sharp contrast to severe fragmentation of US high technology.

Tremendous cross-industry scope gives large Japanese companies important advantages in both technological innovation and downstream manufacturing. The integration of high technology and consumer products within the same companies makes it much easier for new technical developments to diffuse into mass-market goods, and for the production and sale of mass-market goods to fuel additional innovations (Ergas, 1987; Freeman, 1987). The end result is a substantial cross-

Table 1. Percentage share in the domestic (Japanese) market for the major Japanese electronics corporations. Sources: DMC, 1985a.

	Six corps[a]	Other corps[b]	Total
Semiconductors and integrated circuits			
linear	70	0	70
bipolar	66	6	72
MOS	66	0	66
Computers			
general purpose	58	17	75
personal	48	12	60
office	43	7	50
Advanced manufacturing			
computerized machine-tools	60	20	80
industrial robots	41	33	74

[a] Fujitsu, Hitachi, Matsushita, Mitsubishi Electric, NEC, and Toshiba.
[b] Examples of firms in this category include Sony, Sanyo, Sharp, and IBM-Japan.

fertilization in the development and implementation of technological innovations. Japanese technology analyst Gene Gregory summarizes the advantages of this.

> "Japanese integrated circuit manufacturers have a special and often decisive advantage in the diversification of downstream equipment manufacture including a wide variety of computers, communications equipment robots, medical equipment, home appliances and audio-visual equipment—which make possible rapid and extensive integrated circuit applications. Through their extensive network of central laboratories and factory applications engineering, Japanese electronics manufacturers are able to speed the diffusion of new semiconductor technology, obtaining at once important economies of production and important advantages in downstream product innovation" (Gregory, 1983, page 15).

Reintegrating mental and manual labor

Participative work organization allows large Japanese companies to overcome the separation of mental and manual labor. There is now a sizeable literature which recognizes the importance of shop-floor participation, information transfer, and learning-by-doing in Japanese high-technology (Imai et al, 1984; Koike, 1984; 1987; Nonaka, 1988a; 1988b; 1988c; Rosenberg and Steinmueller, 1988; Shimada and MacDuffie, 1986). Japanese companies essentially see all workers as 'smart workers'. The role of smart workers is especially noticeable in the semiconductor industry, where Japanese production lines evolve constantly as production workers and engineers work together to make them more efficient. James Koford, research director at LSI Logic, a leading custom-semiconductor company, aptly characterizes the relationship between the organization of work and the innovative capacities of the Japanese semiconductor industry.

> "Japanese semiconductor facilities have state-of-the-art equipment. They have the best manufacturing equipment. And, there are thousands of workers using that equipment and busily tweaking aspects of everything to make the whole process better, more efficient" (interview by authors, April 1988).

As Jaikumar (1986) has shown, participative work organization also makes it easier for Japanese companies to deploy new automated technologies as smart workers have the capabilities needed to maximize the effectiveness of these technologies.

Production and innovation

The Japanese response to high-technology restructuring is characterized by tight internal linkages between production and innovation (Aoki and Rosenberg, 1987; Clark, 1984; Eto, 1985; Hull et al, 1985; Imai et al, 1984; Kagono et al, 1985; Ohmae, 1985). Rotation of people between research and manufacturing is common. It is typical for Japanese research scientists to spend the first decade or so of their career engaged in long-term research at central laboratories and then to be deployed in manufacturing facilities where they function as 'carriers' of particular projects and technical knowledge (also, see Westney, 1987; Westney and Sakakibara, 1985). At NEC, for example, approximately 50% of research personnel are rotated between operating divisions during their initial ten years with the company; after 20 years, about 80% have rotated.

Moreover, product development proceeds in terms of a series of 'overlapping development phases' (Imai et al, 1984). This is in sharp contrast to the USA where projects are simply handed 'over-the-wall' from one specialized group to the next. In Japan, projects evolve gradually as, for example, researchers are slowly replaced by product development specialists, and product development specialists later give way to manufacturing experts. This process creates tremendous knowledge-sharing and learning as members of each group participate in all phases of the project

(Hayes et al, 1988; Imai, 1986; Imai et al, 1984; Kline, 1985). The Japanese pattern of phasing ensures continuity, results in powerful technical synergies, and creates deep personal linkages between research and manufacturing. In addition, Japanese research laboratories and manufacturing plants are located in close proximity, mainly in the greater Tokyo area, promoting close interaction (Nishioka and Takeuchi, 1987). Japanese companies have not chosen to decentralize either of these important activities.

Industrial linkages and 'quasi-disintegration'

Japan's high-technology industries are characterized by highly structured 'just-in-time' linkages between parents and their subsidiaries, suppliers, and subcontractors, similar to those found in the automobile industry (Sayer, 1986; Sheard, 1983; Swyngedouw, 1987). Large firms play an important role here as a focal point for these multitier linkage systems. Large corporations use a variety of mechanisms to integrate subsidiaries and suppliers into production complexes: cross-ownership, spatial proximity, information exchanges, and personnel sharing. Large corporations function as 'anchors' or 'hubs' for these complexes, helping to orient and define linkage patterns. Figure 4 provides a schematic depiction of this organized tier-system of industrial linkages. These highly structured relationships stand in marked contrast to the atomistic linkages found in US high-technology districts (figure 2).

The concept 'quasi-disintegration' provides a useful way to understand industrial linkages in Japanese high technology. Despite their surface similarity, there is a significant difference between the concept of 'quasi-disintegration' advanced by Aoki (1987) and the idea of 'vertical disintegration' associated with Scott (1988a). According to Aoki, Japanese high-technology industrial organization takes on aspects of:

> "... 'quasi-disintegration' in that a highly integrated form of business organization is in effect avoided and the parent firms or prime contractors retain a considerable degree of control over their subsidiaries or subcontractors. This quasi-disintegration is certainly different from the spinning-off of venture business firms from established large firms recently observed in Western countries since the initiative for the move is in the hands of the larger firms" (Aoki, 1987, page 287).

Table 2 (see over) sheds light on the historical evolution of 'quasi-disintegration' in Japan. Adapted from Aoki (1987), it gives measures of 'quasi-disintegration' in terms of the ratio of supplier investments to total paid-in capital, for a variety of manufacturing industries. This ratio increased dramatically from approximately 10.7% in 1965 to 44.0% in 1984 for all manufacturing industries. For the Japanese electronics industry, which includes both high technology and consumer

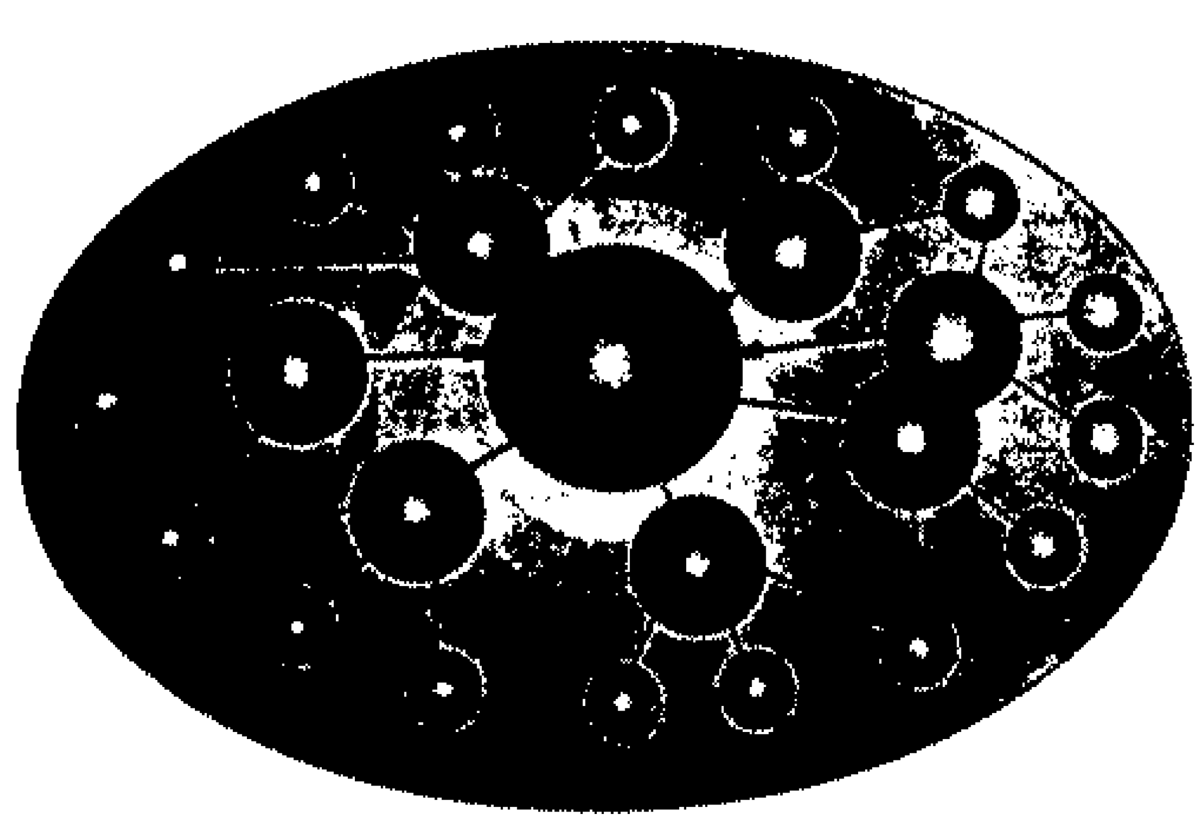

Figure 4. Linkage patterns in a just-in-time high-technology complex.

electronics, the ratio of supplier investments to paid-in capital rose from around 13.8% to 72.6% over that period, an increase of more than 58%.

Clearly, a general trend toward 'disintegration' is characteristic both of Japanese and of US high-technology. However, it is the 'quasi' aspect that makes the Japanese case so interesting, combining the joint advantages of independence and integration. Disintegration in the USA is largely an ad hoc, market process. Japanese quasi-disintegration is more organized and structured. It enables large corporations actively to spin out new technologies or products into semiautonomous companies. The classic example of this is Fujitsu's spin-off, Fanuc, which is now one of the world's leading manufacturers of industrial robots. Under this process, spin-off companies retain close linkages to their corporate parent. The parent, for example, provides financing for the new venture, retains significant ownership in it, and ensures a permanent outlet for its products.

The role of industrial linkages in Japanese restructuring can be further clarified by looking at the extensive subsidiary/supplier networks in high-technology electronics. Table 3 shows ratio of the number of parent plants to various types of subsidiaries: majority owned or affiliated subsidiaries, partly owned subsidiaries, and loosely affiliated subsidiaries for the six major high-technology electronics companies. Quasi-disintegration is evident in the high degrees of parent ownership among these subsidiaries, which often function as major suppliers to parent company plants. Hitachi, for example, has 729 satellite companies including 46 majority owned subsidiaries, 530 partly owned equity affiliates, and 153 loosely affiliated subsidiaries. Matsushita has 463 satellite subsidiaries, Toshiba has 412, Mitsubishi

Table 2. Quasi-disintegration in Japanese industry: the ratio (expressed as a percentage) of Japanese supplier investments to the total paid-in capital, 1965–84. Source: Aoki, 1987 (adapted from Nikkei Electronic Data System corporate data files).

Industry	Year					Change
	1965	1970	1975	1980	1984	
All industries	10.7	16.3	24.2	29.1	37.2	27.2
Manufacturing	10.9	16.4	25.4	32.3	44.0	33.1
Automobiles	12.5	28.1	32.3	40.3	85.5	73.0
Electronics	13.8	20.0	37.7	56.9	72.6	58.8

Table 3. Parent–subsidiary linkages in Japanese electronics firms. Sources: DMC, 1985a.

Firm	Parent co. (N_p)	Subsidiaries				$\frac{N_p}{N_s} \times 100$[a]
		majority owned	partly owned	loosely related	total (N_s)	
Fujitsu	16	46	34	80	160	10.0
Hitachi	37	46	530	153	729	19.7
Matsushita	38	82	270	111	463	12.2
Mitsubishi	32	24	109	71	204	12.2
NEC	7	88[b]	34	64	186	26.6
Toshiba	26	32	182	192	412	15.9
Total	156	318	1159	671	2154	–
Mean	26	53	193	112	359	13.8

[a] The ratio of the number of parent companies to the total number of subsidiaries, expressed as a percentage.
[b] Includes forty-four wholly owned subsidiary NEC plants.

has 204, NEC has 186, and Fujitsu has 160 satellites. Taken together, there are 2154 satellite subsidiaries to 156 core plants—an overall ratio of subsidiary to parent plant of 13.8 to 1. As these data are limited to major subsidiaries and affiliates, they do not give an accurate picture of the dense networks of secondary and tertiary suppliers in high-technology electronics. An example from the automobile industry can provide rough approximation of the degree of underestimation imparted by these limited data. Toyota's 11 parent plants and 176 primary subsidiary/suppliers are surrounded by 4000 secondary suppliers and 30000 tertiary suppliers (Cusumano, 1985; DMC, 1985b).

We have recently begun a research project examining linkages in the Japanese software industry. At the surface level, this industry looks like a good candidate for the 'industrial district' model or 'simple flexibility' model. It is populated by more than 3000 firms (JETRO, 1985; Kuwahara, 1986) and is tightly clustered in Tokyo (Nishioka and Takeuchi, 1987). Preliminary findings from our study of software linkages indicate that the software industry does not fit the 'simple flexibility' model, but is more in line with our alternative model of structured flexibility. According to a JETRO (1985) study, large firms play an important 'structuring' role in Japanese software industry. The JETRO study indicates that only 350 software companies are engaged in actual software development and manufacturing, the remaining 2500 or so perform simple data-entry and information-processing functions.(2) Moreover, just sixteen large diversified corporations—including electric industry giants Fujitsu, Hitachi, NEC, and Toshiba—account for three-quarters of all systems software production and introduce more than one half of applications packages. Recent research by Cusumano (1987a; 1987b; 1987c) documents the evolution of the highly routinized 'software factories' of Toshiba and Hitachi (also, see Fujino, 1987; Onoma, 1987). A large number of software establishments or so-called 'systems houses' are actually spin-offs from these software factories; many others have close subcontracting relationships with them. According to Nishioka and Takeuchi (1987), NEC has close links with eighty outside 'systems houses', and Toshiba has links with forty. Preliminary results from our study provide further evidence of a multitier linkage-structure that resembles that of Japanese electronics more broadly.

Summary

Our comparative exploration of the geographic dimensions of high-technology restructuring in the USA and Japan leads to a number of important conclusions. Although there are surface similarities between the new patterns of work organization and new linkage systems found both in the USA and in Japan, there are major differences in the way each of these very important elements is organized and structured.

The US model can be described as one of 'simple flexibility'. It is characterized by large numbers of small entrepreneurial firms and related institutions that are organized along the lines of a flexible industrial district. Despite the important advances of these districts, they remain plagued by limits and contradictions. This is evident in the high levels of employee turnover and burnout, frequent disruption of ongoing R&D, the premium placed on 'breakthrough' innovation, and

(2) Here, technological as well as organizational factors are at work. The Japanese software industry is focused mainly on large systems software (that is, mainframe software) in contrast to the personal computer orientation of the software industry in the USA. Difficulties in developing Japanese language programs for personal computers has kept the installed base of personal computers relatively low. As a result, the Japanese software industry is overwhelmingly oriented to large systems applications, much of these produced by large companies themselves.

a more general separation of innovation and production. High-technology districts like Silicon Valley and Route 128 remain enclaves of partial restructuring within the broader institutional framework of US Fordism.

Japan's approach is much more comprehensive, involving a much deeper and systemic process of restructuring. In Japan, large diversified companies are the focal point of high-technology restructuring. These companies are major players across a number of high-technology industries, they act to link innovation and production in those industries, and they anchor well-defined just-in-time production complexes. Japan's approach effects a reintegration between mental and manual labor which goes far beyond either US Fordism or districts of flexible production. It also creates a very stable institutional structure within which new rounds of technological innovation and economic growth can take place. To this end, Japan's response to high-technology restructuring can be characterized as one of 'structured flexibility'.

For all these reasons, we believe that it is time to consider a new category for high-technology restructuring in Japan that goes beyond the simple term 'post-Fordism'. It is in this spirit that we have advanced 'Fujitsuism' which we believe more adequately captures the nature of restructuring in Japan (see Kenney and Florida, 1989). 'Fujitsuism' is taken from the name of one of Japan's most important information-based companies, Fujitsu Ltd, which has recently replaced IBM-Japan as Japan's largest computer company. Its spin-off, Fanuc, is one of the world's largest manufacturers of industrial robots and one of the most automated manufacturing facilities in the world. (At one Fanuc factory, unmanned robots work at night, untended, producing parts of other robots in the dark.)

Japan is well on its way to developing a new form of industrial organization which is a qualitative advance over both Fordism and the flexible industrial districts of the USA and Europe. This includes a new way of organizing work, a new way of connecting innovation and production, a new way of establishing linkages among firms, and a new spatial fix. Although Japan already dominates a variety of traditional manufacturing industries, it is likely to play an increasingly important, perhaps hegemonic, role in the high-technology future of the world economy. It is for these reasons that we place Japan at the center of our comparative theory of restructuring. And we believe that ongoing theoretical work on restructuring must take Japan's dramatic technological and institutional achievements more fully into account.

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