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Organizational factors and technology-intensive industry: the US and Japan

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High technology industry in the US and Japan can be thought of as distinct organizational models. Here the authors examine the historical evolution, major characteristics, and benefits and costs of these different models. This leads to the conclusion that organizational factors exert a powerful influence on the ability of firms, industries and nations to adapt to new technology-intensive industries.

The US and Japan are engaged in an escalating competition in high technology industry, the results of which will have important implications for the 'next wave' of advanced capitalist development. Although the US retains its lead in breakthrough innovation, Japan has taken the lead in the mass production of a wide range of high-technology products. This is evident in high-technology electronics, where Japanese firms have overtaken a once sizeable US lead in the production of basic and advanced semiconductor products and are rapidly closing the gap in computers and telecommunications[1]. According to one recent ranking, Japanese corporations comprise six of the top ten global semiconductor producers and three of the top ten computer manufacturers, with NEC winning the 'triple crown' in high technology electronics ranking first in sales of semiconductors, fifth in computers and fifth in telecommunications, ahead of all US companies including IBM[2]. Japanese corporations are ahead in the invention, development and diffusion of advanced industrial process technology including semiconductor production equipment, flexible manufacturing systems and robotics[3]. In addition, Japanese chemical and pharmaceutical corporations have gained substantial ground on US biotechnology start-ups. Largely as a consequence, the US high-technology trade deficit with Japan has grown from $3.8 billion dollars in 1980 to $22.1 billion dollars in 1988[4]. Japan has also systematically narrowed a once overwhelming gap in technological capacity with the US. This is evident in trends in patent activity which show that between 1970 and 1989, Japanese corporations increased their ownership of US patents from under 5 to nearly 20%; in 1989 the top three recipients of US patents were Canon, Toshiba and Hitachi[5].

As this article will show, the US–Japan competition in high technology is not simply a competition over technology and market share, it is a competition between two distinct 'models' of high-technology organization. The victor in this competition will be well positioned to assume a position of

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international economic hegemony and eventually to provide the basic model of high-technology organization that will be followed (with variations) by other corporations and nations.

In the past few years, the US and Japanese models of high-technology organization have been the subject of a growing research literature. A large portion of this literature is devoted to the issue of the relative effectiveness of large versus small firms[6]. The emphasis on firm size is problematic because it excludes other intra- and inter-organizational factors (eg. the organization of production, organization of R & D, links between R & D and manufacturing, supplier systems, etc.) which have important effects on firm, industry and national economic performance. Size-based theories are confounded by the fact that in the realm of innovation small US firms typically outperform large US firms, but that both large and small US firms face extraordinary competition from large Japanese firms (which are considerably larger than US start-ups yet smaller than the largest US firms like IBM or GE).

A number of studies move away from firm size as an explanatory variable to other organizational characteristics. Cohen and Zysman indicate that the major problem US firms and industries suffer is their neglect of manufacturing[7]. Hayes, Wheelwright and Clark identify the highly bureaucratic organization of product development and R & D in large US firms as a source of competitive disadvantage[8]. Imai, Nonaka and Takeuchi suggest that the close integration of R & D, product development and manufacturing activities in Japanese firms is a critical factor in their success[9]. Aoki and Rosenberg contrast Japan's integrated approach to R & D and product development with the linear 'over-the-transom' approach of large US and European corporations[10]. Aoki and Koike indicate that team-based production in Japanese factories provides a powerful source of learning-by-doing and other production efficiencies in manufacturing[11]. However, such studies fail to provide a systemic account of the differences, determinant factors, or origins of the US and Japanese models of high-technology organization.

At a more general level, competing theories have been recently advanced to explain underlying aspects of the US and Japanese models. Ergas characterizes the US technology system as one of 'shifting' or emphasis on new technologies, the German system as one of 'deepening' or increasing specialization in mature industries and technologies, and the Japanese system as one which combines elements of both[12]. Sayer contrasts the Japanese 'just-in-time' production system with the older 'just-in-case' system of the US[13]. Morris-Suzuki suggests that Japan has developed a new set of institutional and organizational structures that allow it to more effectively harness and mobilize new information technologies than the US[14]. Sabel contends that both the US and Japan are converging toward a single model of 'flexible specialization' based upon networked communities of small firms[15]. Freeman and Perez explain the US and Japanese models as differential adaptations to the rise of a new 'techno-economic paradigm' based on microelectronics and other information technologies[16].

This article advances an integrated theoretical perspective for understanding the organizational features and developmental trajectory of the US and Japanese models of high-technology industrial organization. The central argument is as follows. The US rose to industrial leadership through successful application of Fordist principles of industrial mass production. This model and its rigidities later inhibited the development of new high-technology industries, giving rise to a parallel 'start-up' model of high-technology organization based on new modes of internal and external (inter-firm) organization. While this start-up model is especially well-suited to the development of radical new breakthrough technologies, it is beset by a series of problems including: high rates of turnover and defection, a proliferation of small firms and consequent pattern of 'hyper-entrepreneurship', a highly fragmented industrial structure, and a general disconnection between innovation and production. These factors impede ability of the US model to generate incremental product and process innovations. By contrast, the Japanese model emerged from a different model of mass production industrial organization in the first place which not only proved to be quite successful in heavy industry but provides a very effective organizational model for high-technology industry as well. This model is characterized by a high degree of functional integration (as opposed to functional specialization) in the organization of production, the organization of R & D, a high level of integration between the two, and highly structured relations between large firms and their supplier networks. The Japanese functionally integrated model is geared to incremental product and process improvements and other aspects of technological follow-through—the ability to turn innovations into mass produced products.

These findings in turn inform a broader conceptual insight. Differences between the US and Japanese models can be explained as a process of organizational adaptation to a new techno-economic paradigm based around microelectronic industries and information technology. While some recent formulations suggest that 'technology effects' are sufficient to overcome the constraints of social and organization[17], this article suggests that 'organizational effects' are important—exerting a powerful influence on the ability of firms, industries and nations to adapt to new technologies and industries.

The research presented here is based on both primary and secondary sources. Secondary sources included a systematic review of the trade literature and other industry sources on the US and Japanese semiconductor, computer, software, biotechnology and venture capital industries. Primary source research in the US included archival research in Silicon Valley, California and the Route 128 area, in-person interviews and site visits with representatives of more than two dozen high-technology companies, phone interviews with roughly 50 additional R & D scientists, engineers and entrepreneurs, and structured in-person interviews with site visits to roughly 75 US venture capital funds carried out by both authors between 1985–1989. Primary sources research in Japan included site visits and structured in-person interviews with more than 100 company officials in the electronics, software and biotechnology industries. To understand the differences between the US and Japanese models, we organized the research to focus on five interrelated organizational dimensions: (1) organization of production, (2) organization of innovation, (3) integration of innovation and production, (4) labor supply (eg. internal versus external labor market), and (5) inter-firm, inter-organizational linkages (eg. supplier-subcontractor relations). We present findings for the US model first and follow with the findings for Japan. A general summary, comparison and theoretical discussion is provided in the concluding section.

The US model

The US model of industrial and technological organization emerged from and was constrained by a previous model of Fordist mass production industrial organization. The Fordist model basically combined Taylorist principles of scientific management with the non-interrupted continuous flow of the assembly line[18]. The transition from small factories to giant industrial factories occurred via increasing specialization of jobs, the rise of detailed job classification systems, worker de-skilling, pyramidal management bureaucracy, and eventually the rise of the vertically integrated, multi-divisional corporation[19].

The organization of innovation also reflected Fordist principles[20]. The importance of R & D to manufacturing industry was proven with the success of Edison's Menlo Park laboratory which used technology to generate, improve and implement commercial products such as the electric light bulb. With Edison's Menlo Park R & D laboratory as a model, roughly 1600 companies established industrial R & D laboratories between 1890 and 1930[21]. As outlined by Schumpeter, this allowed large corporations to effectively internalize innovation, make it systematic and predictable, and capture the super-profits that flowed from it replacing the previous process of innovation via independent inventors, entrepreneurs and their financial backers[22]. During this formative period, corporate R & D facilities were small and relatively non-bureaucratic, focusing primarily on the development of commercial products. R & D labs were located at or close to the site of manufacturing allowing a constant interplay between production and innovation.

Over time however, this model of innovation was stymied by organizational rigidities which impeded its ability to function effectively. Functional specialization of R & D occurred across two basic dimensions: (1) R & D labs were organized along disciplinary specialties, and (2) the various elements of the innovation-production spectrum, basic research, applied research, product development, pilot production, and manufacturing, were separated from one another. This general pattern of functional specialization was exacerbated by a new 'spatial division of labor' in US industry, as large corporations moved their production activities to low wage regions of the US Sunbelt and Third World and later relocated R & D labs to new campus settings away from manufacturing plants[23]. Westinghouse for example moved various product lines from its central East Pittsburgh manufacturing and R & D center in the 1960s, and then moved its R & D lab to a suburban campus in the 1970s[24]. Initially, it was thought that separating R & D laboratories from manufacturing would provide the insulated environment needed to generate major technological achievements. But this separation simply increased the physical and social distance between the sites of innovation and production, causing each to develop along a distinct trajectory.

The separation of innovation from production under the Fordist model set the basic contours for the rise of the new start-up model of US high-technology industrial organization. In effect, the ability of large Fordist corporations to generate but not commercialize breakthrough innovations created the institutional space for this new model to emerge. This basic adaptive pattern can be clearly seen in two important high technology industries: semiconductors and computers. While corporate R & D labs (eg. Bell Labs) generated the great bulk of early semiconductor innovations (17 of 23 important semiconductor innovations prior to 1970), start-up firms became the primary vehicle for commercialization and later for innovation itself[25]. A major result was defections of researchers from large companies to start-ups. In 1951, for example, Gordon Teal of Bell Labs departed to join Texas Instruments; he was followed in 1954 by William Schockley who left to start his own firm which would later spawn Fairchild. A similar pattern occurred in the computer industry, although universities played a greater role as a source of early technological innovations and talent here. The development of early computer technology was mainly the result of joint ventures between university-corporate researchers, eg. the Harvard-IBM Mark I project, the ENIAC project at the University of Pennsylvania, the Princeton-RCA IAS, and Whirlwind project between MIT and RCA. As with semiconductors, initial commercialization took place through the vehicle of start-up companies, such as Eckert and Mauchly, a spin-off of the ENIAC program and Engineering Research Associates in the early 1950s[26]. Both firms were later purchased by Sperry Rand after they experienced financing difficulties. IBM became a major force roughly a decade later with the development of mass production and mass distribution systems for business computers. Although a number of established large firms such as AT & T, RCA, General Electric, Raytheon, Westinghouse attempted to enter this field, they were unable to mount successful efforts and abandoned their efforts.

The start-up model crystallized in 1957 with the formation of three important new companies: Fairchild Semiconductor in California's Silicon Valley, Digital Equipment Corporation in Boston, Massachusetts, and Control Data Corporation in Minneapolis, Minnesota[27]. These companies then became the focal points for technology complexes that would grow up surrounding them: the semiconductor based complex in Silicon Valley, the minicomputer complex of the Route 128 area, and the smaller but nonetheless significant computer-oriented complex in the Minneapolis area. These early events formed the basis for a general developmental model which would be replicated by countless later firms in the personal computer, supercomputer, computer workstation, computer peripheral, software and biotechnology industries. The model became firmly institutionalized with the rise of a formal venture capital industry and the emergence of a broader support structure of business service firms in the 1960s and 1970s[28].

At the micro or firm level, a key feature of the start-up model was its new mode of organizing internal R & D. R & D was organized in participative, interactive and team-based environments. Functional specialization was replaced by overlap and integration. Decision-making authority was moved down from the managerial hierarchy to R & D teams themselves[29]. In some companies like Fairchild, environments were modelled along the lines of university laboratories. At least one company, Hewlett-Packard, extended this model of interactive team based work organization to include shop-floor workers[30]. However, the inclusion of shop-floor workers in such participative environments was never generalized much beyond HP, as most companies continued to organize manufacturing along traditional Fordist or even pre-Fordist lines[31].

The start-up model was also distinguished by new forms of remuneration and personnel recruitment designed to secure highly motivated R & D scientists and engineers and to pump maximum work effort as well as maximum creativity and knowledge out of them. Start-up companies devised new forms of remuneration based upon equity or ownership shares which enabled R & D scientists and engineers to share in the 'super-profits' of innovation. Fairchild, for example, pioneered the use of equity ownership stakes for key personnel—a practice which later became common in start-up companies[32]. Formal and informal recruitment procedures were also used to select highly motivated workers[33]. As a consequence, the start-up model was able to attract extremely qualified personnel and extract 60, 70, 80, even 90 hour work weeks from them. This combination of a creative environment and long working hours was the crucial element behind the innovative performance of the start-up model. The effectiveness of the model is illustrrated by the fact that between 1970 and 1980, for example, the previous pattern of large firm innovation in the semiconductor industry was reversed, as 11 of 18 major innovations were made by small companies[34].

The growth and development of the new model was accelerated by exogenous forces as well, specifically the decline of basic manufacturing industry[35]. As established corporations reduced investment in R & D and product development, start-ups gained an increasing advantage in the development and commercialization of new technologies. In addition, a growing number of corporations and financial institutions began to invest in start-up companies either directly or by capitalizing venture capital funds. The rise of the venture capital limited partnership where venture capitalists were able to collect funds from large financial institutions and other institutional investors accelerated the flow of funds to high-technology activity. Between 1975 and 1989, the venture capital pool grew from roughly \$3.5 billion dollars to more than \$30 billion dollars, providing a huge new source of finance capital for high-technology industry[36]. This helped to establish a broad economic and financial environment to underpin the start-up model.

The rise of the new model was bolstered by the rise of inter-firm, inter-organizational networks or what we have termed 'social structures of innovation'[37]. Social structures of innovation are basically tight agglomerations of knowledge-intensive workers, technology-based enterprises, venture capital, and business support services which provide a well-articulated opportunity structure for new business formation and new product innovation. However, these inter-firm, inter-organizational structures are geared primarily to innovation but not production as a large share of actual manufacturing was ultimately shifted to the Third World. The concept of the social structure of innovation captures the innovative focus of these inter-organizational networks and truncated nature of the product development and production process.

The development of social structures of innovation in both Silicon Valley and the Route 128 area was an evolutionary, symbiotic process as high-technology enterprise and venture capital grew up together. In Silicon Valley, for example, Fairchild Semiconductor became a critical incubator for dozens of spin-off companies and a number of important venture capitalists such as Eugene Kleiner of Kleiner Perkins and Donald Valentine[38]. The success of Fairchild and concomitantly its venture capital backers also generated sizeable 'imitation effects' in the formation of other companies[39]. The Silicon Valley venture capital industry grew via a similar process of division and multiplication, expanding from a few informal groups in the 1960s to a well-integrated institutional network of more than 200 funds by the late 1980s[40]. The 1970s and 1980s saw this basic process of division and replication take place in other industries such as personal computer, computer software, and to a lesser extent in the biotechnology industry[41].

The Route 128 area around Boston underwent a similar development trajectory. But here the initial technological impetus was more closely linked to universities and their affiliated research laboratories. A recent study identified 636 entrepreneurial firms in Massachusetts whose founders came from MIT departments and labs[42]. Military-related research expenditures also provided a steady source of business opportunities for local companies, including university-based spin-offs. According to a leading Route 128 venture capitalist, a large number of his early investments were university-based spin-offs that had 'insured' business from pre-arranged defense contracts, thereby reducing investment risk[43]. Later however, Route 128 came to mirror the developmental path of Silicon Valley with a pattern of spin-offs from existing companies and industries. For example, DEC which was itself a university spin-off became a source of more than 30 spin-off companies including Data General, setting the stage for the area's emergence as a center for minicomputer start-ups, eg. Wang, Prime and Apollo[44]. Interestingly, Boston's venture capital industry predates its development as a center for innovation. American Research and Development (ARD) was established in 1946 by leading Boston industrialists, bankers and university heads who saw the need for a finance capital institution designed specifically to stimulate innovation and business development. ARD later became a prime source of other venture capital funds such as Palmer, Greylock, Charles River Associates and Morgan Holland which grew up alongside the area's high-technology base[45]. By the mid 1980s, the Boston-Route 128 area had developed a well-articulated but less extensive version of innovative social structure of Silicon Valley.

The nature and function of Silicon Valley and Route 128 are typically explained in terms of two related theories. The first conceptualizes their growth in terms of the 'markets and hierarchies' tradeoff associated with Williamson[46].According to this approach, Silicon Valley and Route 128 are characterized by a tradeoff in favor of vertically-disintegrated markets rather than vertically-integrated hierarchies. Here, disintegrated production units are knit together by new forms of economic linkage, inter-firm organization and territorial agglomeration that supplement the unregulated external transactions of pure markets. The second suggests that these areas are best understood as networks of small and medium-sized firms that are distinguished by high degrees of inter-firm interaction and cooperation, eg. through joint problem solving and innovation[47]. This approach basically extends the first by embedding economic relations in their deeper social contexts[48]. The basic premise of both approaches is that extra-economic cooperation and inter-firm linkage can overcome or at least compensate for the competitive forces of pure markets.

Both theories capture an important element of the small firm agglomerations that characterize the US start-up model. The following remarks from Robert Noyce, an original founder of Fairchild and Intel, indicate the historic choice made by high-technology industries in favor of vertical disintegration and agglomeration.

> We are going to less and less vertical integration. . . . All electronics firms do not feel that they must make their own semiconductor devices; nor do they feel they must grow single crystals, make their own masks, build their own furnaces or test equipment. . . . Our industry tends to use the same suppliers of equipment spreading the development cost of that equipment broadly. . . . Our industry tends to cluster geographically . . . to take advantage of the infrastructure of talent pools, support services, venture capital and suppliers[49].

However, both theories (especially the second) over-generalize the cooperative dimensions of these relations. Under the start-up model, cooperation is embedded within and mitigated by a highly competitive economic environment and incentive structure powered by the quest for private appropriation of innovatory super-profits. This 'hyper-competitive' aspect is evident in the hundreds of law suits charging competing companies with theft of trade secrets, intellectual property and/or employee raids. For example, Cypress Semiconductor, a fairly successful start-up currently faces 20 such suits. Larger high-technology companies like DEC and Intel now have staffs of 10 to 15 in-house attorneys exclusively engaged in intellectual property litigation[50]. The competitive aspect is similarly apparent in the constant breaking and re-forming of supplier relations and the increasingly general trend of US firms using foreign (eg. Japanese) component suppliers and outside contract manufacturers located in Asia and the US Sunbelt rather than local ones. According to a recent study, roughly two-thirds of principal components or inputs used in new product development by Silicon Valley firms come from suppliers located outside the region[51]. The demise of the US semiconductor production equipment industry was caused in large measure by the history of adversarial relations between equipment producers and US semiconductor firms which allowed Japanese producers to capture the US market[52].

Simply put, Silicon Valley and Route 128 are cooperative within the bounds of profitmaximization and economic competition. Cooperation is likely to be limited to and focused around activities where two or more firms perceive mutual profit opportunities, and is not the defining or determinant characteristic of these two innovative regions. Indeed, a more adequate theoretical explanation for the innovativeness of high tech firms and regions can be found in the strong economic imperatives provided the potential to realize super-profits from innovation and strong inter-firm economic competition.

The US model is characterized by distinct strengths and weaknesses. The basic strength of the model lies in its ability to generate radical new technological breakthroughs. According to a recent study, Silicon Valley took just 18 months to turn innovations into marketable products, considerably faster than the 24 plus months it took start-ups in other regions of the US, and much faster than the 3 or 4 year development cycles characteristic of large multinational corporations[53]. This breakthrough capacity stems in large measure from the ability to collect and mobilize huge aggregations of knowledge-intensive R & D scientists and engineers in small geographic regions. The combination of fluid external labor markets and readily available sources of external finance capital in turn result in a continuous stream of new business start-ups populated by various groupings of such personnel. The internal organization of high tech firms provides the micro-level organizational environment needed to generate the technological creativity and motivate the long working hours needed to develop and commercialize breakthrough technology.

The US model is also beset by a series of limits and weaknesses. First, the model is characterized by a process of chronic- or hyper-entrepreneurship evidenced in the continuing proliferation of small high-technology firms which lack the resources and the scale to be globally competitive. According to the US Small Business Administration more than 100,000 high-technology start-ups were launched between 1976 and 1986 (roughly 10,000 per year). Other data indicate that more than 1300 venture capital-backed companies were launched in 1988 alone[54]. This chronic entrepreneurship is in turn caused by extraordinarily high rates of employee turnover and defection or hyper-mobility. Labor mobility is exacerbated by the actions of so-called "vulture capitalists"—venture capitalists who actively raid existing companies for employees[55]. It has further been suggested that the recent increase in the venture capital pool has caused venture capitalists to fund a relatively large number of duplicative 'copy-cat' companies which duplicate each other's efforts, create increased market pressures and dilute the overall supply of human resources[56]. The combination of the hyper-mobile external labor markets and a hyper-entrepreneurial pattern of new business formation has shaped a process we refer to as the 'externalization of innovation,' whereby new companies become the vehicles for the development and implementation of new technologies. This developmental pattern is the reverse of the previous pattern of growing scale and internalization of innovation associated with both Schumpeter and product cycle theories of industrial development[57].

Second, the start-up model is characterized by a high degree of industrial fragmentation which makes it difficult for firms to generate 'hybrid' innovations via the combination of two or more discrete technologies, or larger 'systems' innovations such as high definition television which requires the development of a combination of unrelated technologies, eg. semiconductors, optical devices, cameras, receivers, antennae, satellites, transmission systems[58]. Indeed, the extreme organizational fragmentation and hyper-competition found in Silicon Valley and Route 128 contrast sharply with the idealized model of 'flexible specialization' developed by Piore and Sabel[59]. In an interview we conducted, an Italian high technologist in Silicon Valley characterized Silicon Valley as a dynamically innovative market economy driven by the potential to realize huge profits, drawing a sharp contrast to the Third Italy which he saw as an 'old world economy' where a legacy of family and community provided stability and an environment of long-term cooperation[60]. US high technology industrial organization is if anything characterized by too much flexibility and too much specialization. Lacking a broader context of stable social institutions as found in the Third Italy, the over-specialization of the US model is a source of fragmentation and hyper-competition—a sign of structural weakness rather than strength.

Third, the US model suffers from a systemic neglect from manufacturing and an extreme separation of the sites of innovation and production. This is evident in:

1. growing attempts to automate production to eliminate high-technology production workers,
2. the extreme low wages ($4.75 to $8.00 per hour), insecure employment conditions,
3. 'pre-Fordist' sweatshop conditions found in many US high-technology manufacturing plants,
4. the absence of unions in high-technology plants and the extreme anti-union position of most high-technology firms,
5. the increasing use of Third World branch plants and subcontractors to manufacture and assemble high-technology products[61].

In 1985, for example, US semiconductor firms employed 150,000 foreign factory workers and just 115,000 domestic production workers; recent estimates place the Asian share of subcontract manufacturing in excess of 60% of all subcontract manufacturing undertaken by US semiconductor firms[62]. The neglect of manufacturing recreates the separation of innovation from production found in Fordist industry, making it extremely difficult to turn new breakthrough innovations into a continuous stream of high-technology products. The end result is that although the US model continues to generate important new breakthroughs, it is particularly inept at technological follow-through.

The Japanese model

The Japanese model of high-technology organization evolved from very different organizational conditions than the US. Basically, its mass production industries have proved to be very adaptable to the new techno-economic paradigm of microelectronics and information technologies. This has provided the institutional 'space' for high-technology sectors to emerge within the parameters of the existing model of industrial organization. Early on, Japanese corporations began to experiment with alternatives to the Fordist model of industrial organization found in the US and Western Europe. These successful experiments led to the emergence of a distinct organizational model which we have elsewhere termed 'fujitsuism'[63].

The roots of the Japanese model can be traced to the immediate postwar period. This period was one of intense labor-management conflict and bitter political struggle as workers organized themselves into new unions, raised a series of radical demands for improved working conditions, greater job security, and more control over production. In some cases, workers even took over factories and implemented radical 'production control' strategies, running these plants without management[64]. It was these conflicts that transformed Japanese industrial relations and created the organizational context which has framed recent Japanese advances in the organization of manufacturing. Basically the settlements of these labor-management conflicts provided the ground rules for a new set of relations between Japanese business, labor and government, establishing a new and qualitatively different organizational framework for Japanese industrial relations. As in other industrial countries, neither capital nor labor was able to impose its will entirely on the other—a relatively stable set of accommodations or 'class accord' being the result. At the heart of this accord was a critical tradeoff. The accord gave Japanese shop-floor workers the right to be considered as part of the core employees of the firm and also provided an implicit guarantee of employment[65]. In return for this, workers lost their original demands for control over production organization and the right to specific jobs, giving management great leeway over the organization of work. This relationship in turn generated a major re-thinking of the role and function of manufacturing workers in the enterprise. On the one hand, tenure security made workers a fixed cost; but on the other, it enabled the firm to capture its investments in training. Eventually, management began to see workers as an asset that could contribute to improved quality, increased productivity, and shop floor product and process innovations[66]. Gradually, it became possible to devolve some managerial responsibilities such as production scheduling to the shop-floor. Over time, large firms began to erect formidable barriers to mobility (eg. by tacitly agreeing not to hire each other's workers) in order to protect their labor force investments[67]. Elimination of the problem of employee mobility enabled firms to internalize and reap the full rewards of heavy investments in human resources[68]. Secure tenure also made it possible for management to introduce new automated technology with little shopfloor opposition since workers had little reason to fear technological displacement. In addition, tenure security placed additional pressure upon management to develop new products and technologies that could absorb labor, creating significant internal pressure for innovation.

The end result was a powerful new model of production organization designed to harness the knowledge as well as physical labor output of shop-floor workers[69]. Japanese firms became very effective in marshalling workers' intelligence to eliminate idle downtime and waste—at filling in the pores of the working day by tapping the full and complete capabilities of their workers. The use of the self-managing team became a vehicle for devolving managerial functions, further socializing the production process, generating a source of internal self-imposed work discipline, and harnessing the collective problem solving of workers[70]. The words of the late Konosuke Matsushita, founder of the Japanese electronics company that bears his name, capture the essence of this synthesis.

> We are going to win and the industrial west is going to lose out; there's not much you can do about it because the reasons for your failure are within yourselves. Your firms are built on the Taylor model. Even worse so are your heads. With your bosses doing the thinking while the workers wield the screwdrivers. . . . For you the essence of good management is getting the ideas out of the heads of the bosses and into the hands of labor. We are beyond the Taylor model. Business we know is now so complex and difficult, the survival of firms so hazardous and fraught with danger, that continued existence depends upon the day-to-day mobilization of every ounce of intelligence[71].

In effect, the Japanese model has established a new way of tapping the knowledge and intellectual capabilities of its work-force, harnessing the productive capacities of both shop-floor workers and R & D scientists more totally than other systems.

The Japanese model was also distinguished by new integrated relationships between large corporations and their suppliers. This was partly due to firms' efforts to externalize costs of production, partly due to their desires to keep their unionized workforce small, and partly a result of extreme capital shortages. As a result, Japanese corporations chose to externalize supply transactions rather than internalize them as in US and Western European Fordism. This process of externalization was supplemented by the creation of dense and mutually supportive economic relations knitting suppliers and end-users. The end result was the emergence of the much heralded Japanese 'just-in-time' system of supplier relations[72]. Under this system, large corporations developed new forms of economic integration to govern their supplier networks and organize the growing external, inter-organizational division of labor. These new forms of integration included: co-location and agglomeration, tiered production networks, frequent communication and interaction in the form of shared management and engineering personnel, collective problem solving, and collaborative R & D. Gradually, this system came to be characterized by long-term, stable and mutually dependent relationships which Dore and others refer to as "obligational" and "relational" forms of subcontracting as opposed to the arm's-length, "spot contracting" of the US model[73]. Large firms play a key role in this system by organizing these relationships, functioning as 'hubs' for the system.

This model of industrial production ultimately proved quite adaptable to the demands of the new high technology paradigm, providing the organizational framework within which high-technology industries could be incubated within existing firms[74]. In sharp contrast to the US, large integrated corporations play a central role in Japanese high-technology. In fact, just a small group of diversified electronics corporations such as NEC, Fujitsu, Hitachi, Matsushita, Mitsubishi Electric, Sharp, Sanyo, Sony and Toshiba dominate Japanese microelectronics sectors from semiconductors to computers and telecommunications. A comparative study of innovation found that large Japanese companies accounted for all but 2 of 34 major innovations in Japan, while large US companies accounted for just half of all major innovations in the US[75].

Under this model, large corporations use high levels of horizontal integration to accomplish synergistic growth by constantly expanding into related fields. Basically, the same firms are active in the semiconductor, computer, telecommunication, electronic instrument, office automation, and industrial automation and consumer electronics industries. Together NEC, Hitachi, Fujitsu, Toshiba, Matsushita, and Mitsubishi Electric account for between half and two-thirds of all semiconductors, integrated circuits, computer, and computerized machine tool sales in Japan[76]. This system of horizontal integration and cross-fertilization provides significant advantages in the development of 'hybrid' and 'systems' technologies[77]. It likewise facilitates rapid diffusion of new technologies into traditional industrial, office and consumer products. Integration also allows Japanese corporations to amortize R & D costs over a variety of markets and product lines, allowing them to cross-subsidize R & D and to sustain low profits while gaining market share.

The Japanese model of high-technology organization is further characterized by a highly structured and functionally integrated external division of labor. As in the automobile industry, large electronics companies anchor well-articulated just-in-time complexes comprised of concentric tiers of smaller suppliers. According to a recent study, 90% of the parts used in Fuji-Xerox products, 70% of the parts used in NEC and Epson products, and 65% of the parts used in Canon products are actually made by outside suppliers and subcontractors. Other data indicate that large Japanese electronics companies like Hitachi, Fujitsu, NEC and Toshiba possess immediate galaxies of between 400 and 700 of subsidiaries and affiliate suppliers[78]. This system of high-technology subcontractor relations is similar to the pattern of obligational subcontracting found in the Japanese automobile industry and is much more stable than the constantly shifting, arm's length supplier relationships characteristic of the US model[79]. This highly structured 'quasi-disintegrated' system allows central hub companies to retain lean management structures and avoid extensive hierarchy to coordinate the production chain. It facilitates a continuous flow of information between suppliers and end-users, giving rise to unique technological synergies as suppliers and hub companies work together to generate and implement technological innovations[80].

This system also provides a unique vehicle for turning innovations into products through 'sponsored spin-offs'. Spin-off companies begin life within the corporate parent until they are large enough to leave. The parent provides financing, retains significant ownership, and ensures a permanent relationship with the new company. For example, when Nippon Steel recently formed its rapidly growing software functions into a spinoff business, the new company was guaranteed all of Nippon Steel's information processing business and any other business the parent could secure for the subsidiary[81]. Interestingly, many of Japan's leading electronics companies, eg. NEC, Toshiba and Fujitsu, are also spinning-off their software operations[82]. As time progresses, the spin-off is gradually weaned until it becomes a free-standing member of the parent's industrial network. Spin-offs can grow large enough to seek out new business on their own, loosening their ties to the original parent. For example, Nippon Denso, a Toyota spin-off, has grown into a leading manufacture of automotive lighting becoming a major supplier to other Japanese automobile companies. Consequently, Japanese corporations are able to move into new areas, while avoiding the high costs associated with the US model.

Perhaps most significantly, the Japanese model extends the interactive, team-based R & D environments of the US start-up model to include production as well as innovation. To do so, Japanese companies combine team-based modes of R & D organization (similar to that used in US start-ups) with the team-based organization of shop-floor production. In effect, functional integration is extended across the entire innovation-production spectrum[83]. Teams are used to stimulate creativity and generate collective solutions, changing composition as problems and projects change. R & D scientists are allowed to spend a small amount of time using company equipment to work on 'unofficial' projects. This is another way of stimulating creativity and individual initiative. If such projects prove successful they are turned into actual R & D efforts and eventually grow into sponsored spin-offs; if not they can be quietly scuttled by the individual scientist or group at no external cost. Through rotation, Japanese firms use their internal labor market to partially replicate the synergistic effects of new combinations achieved through the external labor market in Silicon Valley. Moreover, Japanese companies benefit from tenure security and barriers to labor mobility thereby avoiding the problems of disruption and leakage associated with high rates of turnover and defection.

Teams and team-based organization are used to achieve high levels of functional integration across the innovation-production spectrum. Under this process, a new team comprised of R & D specialists, along with product development experts, and engineers from manufacturing divisions and suppliers is formed at the initiation of a new product development project[84]. Although team members change as the project moves along, the same team will work on the project from initiation until early production runs are completed. As the project progresses, R & D scientists gradually depart and are replaced by representatives of product development and manufacturing divisions. Eventually, the entire team moves from the R & D lab to the manufacturing site. Throughout this process, a few senior R & D scientists remain with the project to the final production stage. They will often permanently relocate to manufacturing divisions where they will act as 'carriers' of those technologies. At NEC, for example, more than 80% of research personnel eventually relocate at applied labs or manufacturing plants[85].

This functionally integrated system of product development creates significant learning effects and technical synergies. Interaction between employees of different backgrounds, eg. marketing personnel, electrical engineers, and manufacturing engineers stimulates creativity and collective problem solving. Moreover, the involvement of hands-on manufacturing personnel at early stages ensures that scientists and engineers do not come up with ideas that are too difficult to implement, contributing to design for manufacturability. This process likewise helps to reduce proprietary interests and replace 'not-invented-here' syndrome with a powerful form of collaborative problem-solving and organizational learning. Functional integration of R & D and manufacturing creates a powerful interplay between innovation and production, reducing the time it takes to turn ideas into actual products.

Functional integration creates important advantages in diffusion as well as the development and commercialization of innovative products. Jaikumar indicates that the Japanese model is better suited to both the adoption and diffusion of flexible manufacturing systems (FMS) technology. In the US, FMS technology was hindered by its insertion into the existing Fordist model where it was used to deskill workers, increase management's power, and produce large batches of relatively standard products. In Japan, FMS was inserted into integrated relationships and combined with human intervention and worker re-skilling (eg. shop floor workers were typically allowed to do rudimentary programming), leading to higher rates of adoption and increased effectiveness[86].

In short, the Japanese model is especially well-suited to technological follow-through—turning innovations into a continuous stream of mass produced products. Its basic strengths include: incremental product innovation, manufacturing process innovation, technological cross-fertilization via hybrid and systems innovations, rapid product development and rapid technological diffusion. While the Japanese model lacks the breakthrough capability of the US model, it is much more advanced at the various dimensions of technological follow-through.

Conclusion

The US and Japan are characterized by very different models of high-technology industrial organization. In this article, we have shown the differences between the US and Japanese models and discussed how such differences effect the process of adaptation to new high-technology sectors and the related process of technological innovation. A key finding is that the organizational dimensions of US and Japanese high-technology go far beyond firm size as an explanatory variable. Our research indicates that the US and Japan differ along a series of salient organizational dimensions: the organization of R & D, organization of production, the integration of the two, the importance of internal versus external labor markets, and patterns of supplier relations. These organizational characteristics, not size, are the crucial determinants of differences in current performance and long-run competitiveness.

Across these dimensions, the two models share a basic similarity as well as fundamental differences. They are similar to the extent that both use teams to organize R & D and new product development. However, while the US model is dependent upon external labor markets to generate new combinations of scientists and engineers, the Japanese model facilitates this via internal intracorporate labor markets. The two models differ markedly in the relative importance and organization of manufacturing and the level of integration between innovation and production. The US model continues to organize manufacturing along Fordist or even pre-Fordist lines and suffers from an acute often global separation of innovation and production. The Japanese model extends the interactive and team-based organizational environments throughout the innovation-production spectrum, harnessing the complete capabilities of shop-floor workers as well as R & D scientists and engineers. If the Japanese model can be characterized as one of full-blown or systemic functional integration, then the US model is one of 'truncated' or partial integration (where interactive environments used in the R & D are not extended to the shop floor).

For these reasons, we are led to conclude that the Japanese model represents a powerful best-practice system of high-technology industrial organization. Over time, this is likely to imply a gradual shift in the center of gravity of economic and technological power toward Japan and increasing imitation and diffusion of the Japanese model by other firms and nations. Our own research on the rise of Japanese implant firms and firm complexes in North America confirms that such diffusion is already occurring[87]. Here, our findings suggest convergence toward the Japanese model and contradict the hypothesis advanced by Sabel of convergence toward the flexible specialization model of small networked producers. However, we must also note that our findings are suggestive of a co-existence between these two models (at least in the short-run), perhaps taking the form of a new global division of labor where the US model develops new breakthrough technology, while the Japanese model provides the technological follow-through.

The research presented here informs a broader conceptual conclusion. The findings provide evidence of strong 'organizational effects' in the process of adaptation and response to new techno-economic paradigms. In both the US and Japan, the response to high technology was conditioned and shaped by existing organizational arrangements that emerged first in manufacturing and which created parameters for future organizational adaption. Additionally, in both cases, patterns of organizational adaptation and response were strongly influenced by endogenous forces rather than exogenous shocks. In the US the existing Fordist structure motivated R & D scientists to actively construct a new parallel model, while in Japan postwar conflicts between labor and management pushed the system in a very different direction. In effect, our findings suggest that existing organizational forms and internal responses to them can block or alternately enhance the ability of a firm, industries or nations to move across similar underlying technological trajectories. We are thus led to conclude that organizational conditions play a strong role in adaptive responses to new technological paradigms. A continuing research agenda must be to sharpen our understanding of the dialectical interactions between technological change, internal intra-organizational structure and external inter-organizational relationships as they affect the performance of advanced industrial economies.

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