Globalization and Production

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I. Globalization and the Persistence of Place

Globalization

The word "Globalization" has suddenly become inescapable, but its meaning remains elusive. As the usage goes public (there were some 670 articles published in "prominent business and economics journals" last year that had "global" or "globalization" in their titles up from only 50 ten years earlier), the meanings become more private. There is certainly no workable, consistent definition. Even in the realm of finance where "globalization" seems clearest, the meaning of the term is far from evident. Financial markets run 'round the clock as massive waves of funds slosh across borders at electronic speeds. Most recently, even the interest spreads between the Yen, the DM and the dollar seem (this quarter) to be substantially narrowing, indicating to the globalists an increasing elimination of national barriers to a single global market. Yet the global wholesale banking market rests firmly on national foundations, its very character structured by government policy choices. The Bank for International Settlements has established a set of rules for insuring bank deposits for globalizing banks that places responsibility squarely and parochially on home country governments (1). Japanese national policy choices restrain the emergence of the Yen as an international reserve currency to maintain national control and shape the terms on which capital is exported from Japan and by whom, while central bank policy in some European countries pushes the use of the ECU as a reserve currency in part as a means of recapturing control of this seemingly international market and in part to capture national position in transactions in this incipient currency.

In the once grimy realm of production, the meaning of globalization is even less clear. The World Car came and went, moving from zero to sixty to zero in just a few years; its place quickly taken by the smaller hulk of The World Component. Now, seemingly it cedes place to a World Production System that strings together World Components through Global Telecommunication Networks as the world becomes an Industrial District. Globalization accelerates, but national markets remain critical. Despite the thousands of articles that have made similar efforts in the last several years, it might thus be useful for our discussion to put forward our own definition of globalization.

What, then, is Globalization?

The idea of globalization that undergirds this discussion may best be defined by distinguishing it from the code words of earlier eras, internationalization and multinationalization. International firms were those that sold abroad. They were to be distinguished from multinational corporations that produced abroad in a variety of locations (2). In the same way the British era of industrial pre-eminence was one of trade, imitation was forced by exports: the American era by contrast was one of direct foreign investment, imitation was forced by direct foreign investment (3). Thus both internationalization and multinationalization consisted of the same two main aspects, the first being the spread across borders of a single dominant style of production organization and the second being its imitation by foreign competitors, though the mechanisms of diffusion were different. In each case a single preeminent industrial power projected its industrial advantage abroad, and the others struggled to imitate and adapt.

The process of diffusion was effectively described by a simple product cycle model. The location of production shifted outward from the high-cost, innovative center (often an Industrial District) towards cheaper land and cheaper labor as the product matured enough to permit both its own standardization and the standardization of the production process. Away from the central Industrial District, maximal advantage could be taken of scale production combined with cheaper labor and the avoidance of congestion diseconomies so prevalent in intense industrial districts. As the product matured still further, new locations would be added off-shore for a combination of cheaper sourcing and access to new markets (4). This view, in various forms, dominated the Internationalization literature including both work deemed sympathetic to Multinational corporations and American power, and work critical of them, such as the Peripheralist school of development theorists (5). Those literatures differed substantially in their judgments, their tones and in what they selected as evidence, but they both built their arguments on the same core model of diffusion of a single mode of production from a single source. Internationalization generated intense competitive pressures for national producers; it generated major dislocations and reorganizations for governments. But, it did not generate much uncertainty for either. In post-war Europe and Japan the task was to catch up to the future, not to invent it.

Globalization, a cynic might then observe, is really a euphemism for Japanese industrial leadership substituting for that of the United States. In this view, a dominant new form of flexible volume production has been created by Toyota, Matsushita and friends. Japanese innovations in the organization of production have swept aside traditional mass production. A more complex version posits a new, dominant form that combines Japanese innovations in production organization with some older American managerial achievements in coordinating cross-nationally low-cost production factors, political obligations, modern production and marketing systems. Our cynic would note that, in addition to the emergence of a new form of volume production, a second distinctive feature of this new era of Japanese globalization. The market of the leader, Japan, remains remarkably impermeable, asymmetrically open, if you will, for both foreign products and direct foreign investment by companies from other regions. The Japanese market remains remarkably insulated, and the emergence of Asia as a rapidly expanding region that is strategically critical for all firms but dominated by Japan simply exacerbates this problem. Globalization would then point to outbound Japanese investment to leap over anticipated trade barriers just as American firms leapt barriers, in some of the same industries, generations earlier. This vision of "globalization" is simple and clear. It certainly contains elements of truth. But we would propose another vision that highlights different aspects of the current competition.

Globalization, by contrast to internationalization and multinationalization, should be characterized as an era of multiple innovative methods which originate in a variety of places in the world. Internationalization/multinationalization displayed a typical configuration of one basic innovator and a set of followers, thus fitting traditional diffusion models rather well. Globalization reveals multiple geographic sources of diverse innovations that are combined into several quite different approaches to production. There are competing production approaches and systems, evident in the flexible automation -- lean production -- model drawn from Japan and the flexible specialization model first depicted by those who focused on industrial districts in Italy and Germany. The technologies to implement these conceptions emerge -- likewise from different places. Robotics innovations, along somewhat different lines, emerge from Japan and Europe. Corporate telecommunications networking strategies to create market advantage have emerged from the United States. Indeed, as each place -- locale, nation, or region -- builds its response the variety and multiplicity and the importance of place is reinforced by globalization itself.

Globalization then is characterized by heightened uncertainty, by great market volatility. There are new and unexpected competitors. Intense new competitive pressures come from rival innovators in diverse places using varied strategies. Competition becomes multidimensional as well as multidirectional: price, quality, speed and differentiation, mark the product characteristics.

Because there is no clear leader, there is no clear target. For example, in some sectors or industry segments the reorganization of production brings even greater economies of scale, scope, and propinquity. One highly successful firm producing consumer durable operates on the assumption that the real scale economies for the firm have nearly tripled in the last decade. Some contend that what we witness is a simple confusion, until the dust clears and even the most obtuse realize that a dominant new production form has been created by Toyota and Matsushita and friends. Pushed to an extreme, this view suggests that, other than the new volume production, these are simply niche solutions, useful for niche players and niche regions or for traditional activities that will remain untouched by the changes. Whichever these activities may be, they are outside the mainstream of industrial development. They are no more -- and no less -- important to understanding fundamental change than were the niche organizations and players that were able to be sheltered from the previous stage of internationalization. They are likely, however, to be less important, because this time the niches will be far fewer and smaller (6).

By contrast, in other sectors we find clear indications of the competitive power of world-wide sourcing, diseconomies of organization scale, the competitive effectiveness of quick turnaround mini-fabs and mini-mills. Here the global world of giant firms and world products seems to disintegrate into an endless series of small companies and market niches. In addition, special industrial districts seem to have found a new resilience. These districts are composed of networks of mini-firms, spatially agglomerated and/or electronically connected networks that create "virtual agglomerations" or that make possible point-of-sale, semi-custom production. The uncertainty characteristic of globalization is not just confined to firms in a few particular industries, but extends across a broad swatch of sectors. It extends most importantly to the heart of national economic policy: what should a nation do (and not do) to improve its wealth and power? The contradictory experiences of different industries and different places compound the competitive uncertainties of producers and amplify the intellectual uncertainties of scholars and policy makers.

Our discussion will be based on a definition of globalization which describes rival innovators operating in multiple dimensions from at least three national (regional) bases and the result of which heightens competition and, critically, heightens uncertainty. It should be noted that the initial definition -- "no uncertainty, no complexity, it's Toyota et al." -- does not open a discussion, it shuts it off. It is conceivable, but not altogether probable, that we will conclude with this definition. If we do, however, it should come at the end, not the beginning. These competing visions of globalization are both rooted in a common observation: the end of mass production -- Fordist production -- as the ascendent and dominant mode of production organization. But by beginning with the notion of globalization as the manifestation of multiple and rival sources of new competition, and solutions to that competition, the terms of the debate about the evolution of production can be reset and made to encompass a broad range of pertinent industrial, economic and political phenomena.

The Discussion About Globalization

Production has been an important, often critical element in determining which firms win and lose in the new global competition, and by consequence how various communities and countries are affected. Indeed, the inability of American firms to maintain position in global markets has often turned essentially on their weakened competitive position in manufacturing narrowly and production broadly.

The discussion about the place of production in the process of globalization has become more diverse and complex than the conversations about the international and multinational economy. One body of literature focuses on innovative responses to the declining effectiveness of fordist mass production (Sabel and Piore are the best and best known exponents of this view). While exploring one alternative to traditional mass production, they fruitfully examined the limits to fordist production. In doing so, they pushed that question towards the center of a broad intellectual agenda. That debate has in fact had two parts. One has proposed a sharp drop in scale economies and focused on local industrial districts, specialized and flexible strategies and the relationships and institutions that support this approach. The notion has been that flexible specialization and local districts could displace, or at least diminish, the importance of large firms and hierarchy. The alternative emphasizes the continued importance of scale production, but highlights its significant reconception and reorganization. These competiting visions of the end of mass production are in fact complements, we shall propose.

Another major current concerned itself with the relative performance of national economies. We can call it "the competitiveness literature". It centered around notions of a declining U.S. position and a rapidly rising Japanese power. (It also generated particularly fruitful reexaminations of European positions.) Here the questions of relative rise and decline were posed in a new way; it was no longer the gradual and inevitable process of "catching up" which fit so well in the internationalization approach and its traditional diffusion model. Instead, a search began to identify new factors shaping competitive advantage and not simply explain factors that influenced the rate of internationalizing diffusion. The search for new factors quickly focused on innovations originating outside the dominant production paradigm, especially on innovations in Japan in both the organization of state-industry relations and the organization of production. (Chalmers Johnson's MITI and the Japanese Miracle [1982] was crucial in calling attention to innovations in state-industry organization; BRIE's Manufacturing Matters

[1987] and the MIT Commission Report [1989] are prominent examples of the competitiveness literature. Hayes and Wheelwright and Womack et al. mark important steps in studies of manufacturing practice that constitute another important current of this approach.) This competitiveness was, fundamentally, driven by the manifest success of giant Japanese producers and the relative weakness of their American and European counterparts. It differed in just about every way from the traditional internationalist literature: in its definition of the problem, in its approach to policy -- even in its methodology. It also differed from the new, flexible specialization approaches in that it emphasized different challenges and proposed different responses. At the same time, however, it still shared an analysis of the limits of Fordism and a critique of cheap labor strategies as a way to prolong the competitiveness of fordist organization.

A third approach is rooted more in the contemplation of new technologies than in an examination of production organization. Its origins go way back, but the promise of new and exotic materials (namely programmable automation, broadband links and the increasing "informational content" of product with production) is the driving force. Images extending from "lights-out production" through "virtual production" dominate this approach. It does not share a vocabulary with the two other approaches, although it uses most of the same words.

Finally, we must acknowledge a fourth approach, which is most distant from our concerns with production. This approach begins by denying, resolutely, the fundamental assumptions shared by the others: that of a revolution in the organization of production, a crisis, a transformation or a divide. It insists, instead, on continuity and the permanence of marginal change. Broadly speaking, the themes of this literature range from a secular shift towards a service-based economy that broadly parallels earlier shifts from agriculture to industry, to the paramount importance of unfettered markets as the premier device for equilibrating short-term imbalances. Policy is pointed towards broad factor quality and availability, towards macroeconomic balance and, of course, towards the removal of market rigidities. This approach is the dominant approach, certainly in the United States, both in terms of its total control of policy-making and its hegemonic lock on American economists. It is also strongly supported by Japanese sources that operate in the United States, though it receives a surprisingly weak echo in internal Japanese debates.

Places: Regions, Nations and Districts

The global economy is visible in trade, direct investment and finance, but it has not generated an end to the importance of place -- community/district, nation, or region.

The responses to the new competition are generated within particular places, rather than by world corporations that stand outside a home base. Firm strategies and tactics are formed within particular institutional arrangements and supply bases that at once constrain and direct their choices. It is an assumption of our work that differences in places shape something about the capacity for and character of production innovation as a response to global markets.

The word "globalization" usually prefaces some observations of how companies have gone, are going, or damn well better get global in order to respond to the new global challenge. The facts, however, stubbornly paint a more confusing picture that includes the enduring importance of place. We do not yet live in the age of the "global corporation" nor, in its logical concomitant, do we yet live in a world of politically undifferentiated economic spaces. Perhaps one day, perhaps soon, we will. But for the moment there are very few "global corporations", and there are relatively few economic spaces unconstrained by political considerations. Furthermore, current trends are unclear about which way we are moving. American MNCs are the most mature and the closest to global. Yet recent U.S. Commerce Department studies indicate that about three fourths of the total assets of American MNCs are still accounted for by the parent operations in the U.S., with similarly high proportions for sales and employment (7). For Japanese-based MNCs, despite recent massive outbound investment, we would estimate the proportions as being well in the ninety percents. This is a far cry from Global. Also, asymmetries abound in the crucial category of direct foreign investment. In Germany and most of Europe, foreign-based MNCs occupy a big place in the economy and are able to behave a lot like nationals; in Japan they can do neither. Furthermore, in the U.S. and the UK, there is a broadly open market for companies; in Japan there is not, nor is there in Sweden or Switzerland. These, and many other asymmetries challenge the notion of Global companies, and with it the most common image of globalization. For Japan is not a trivial exception to an otherwise general rule; in our geography it is almost one third of the globe. Again, how do we intertwine the enduring importance of places with the equally real facts of global competition? In our view, the new market conditions that are labeled globalization push toward a restructuring of markets at different levels: global regions, nations, and communities.

Our emphasis in this discussion paper is on regions and nations. This is in part because so much has been said by others about communities and districts. It is also because we tend to see a change in scale economies, sometimes toward lower scale, but often toward higher firm scale economies achieved in national and regional markets. Moreover, the corporate organizational changes of greatest importance to us seem to create vertical rather than horizontal networks; contracting is dominated from a center point. A crucial assumption that we share, however, is that "where" affects "how", that something about place shapes something about the capacity of firms for production innovation (as well as the character thereof) as a response to global markets.

Regions and Regional Supply Bases in a Global Economy

Three distinct, though interconnected, regional economies are rapidly developing in the industrialized world: a North American region comprising the United States and Canada, which represents about 25% of world GDP, a Western European region, also representing about 25% of global GDP, and a Japanese-led region including, for starters the four NICs weighing in at about 16% of world GDP but growing fastest (8). Each group, moreover, is heavily focused inward, despite the enormous discussion of the expansion of global trade. Foreign trade is quite a limited part of the GDP of each region, and trade within the regions is -- apparently since 1986 -- growing far more rapidly than inter-regional trade.

Consider Europe, which, as a relatively self-contained unit, already exists. For a generation, Western Europe as a whole represented roughly one quarter of global gross national product, and the European Community over twenty percent. There are certainly two competing images of Europe. One image is of Europe as a set of small and medium-sized countries that have opened themselves to the global economy and must adjust to it. The other image is of European nations, including those outside the Community but part of EFTA, moving over the last thirty years from interlinked national economies to a regional economy. Trade within the EEC has grown faster than the trade between the Community and the rest of the world since the establishment of the European Community in 1958. From 1967 to 1987, the ratio of EEC-EEC exports to EEC-non-EEC exports rose from 79 to 115. Moreover, intra-EEC trade has been a dominant proportion of each member nation's trade. Discounting intra-European trade, Europe's percentage of world exports and imports drops, exports from 44.6% to 13.8% and imports from 42.6% to 11%. Add to that the EFTA-EEC trade, and the picture is even clearer. Overall, then, intra-regional European trade is growing faster than trade between European and non-European countries. That trend is likely to continue with the creation of the Single Market and the adherence of the EFTA countries to it, whether they formally join or not. As in Asia, financial ties now reinforce regional trade ties. The European currencies are increasingly bound to each other through the formal mechanism of the EMS and the predominance of the DM. The mechanism pushes toward regional integrity by providing greater stability for each national currency. Progress is also being made toward formal coordination of fiscal and monetary policy, which could eventually culminate in a European Central Bank.

An economic and strategic challenge has driven a set of middle powers to consolidate their markets and their influence. The movement to create in Europe a single market, and perhaps more, is itself driven not only by the emergence of Asia but by the real decline of the United States as a source of technology and production know-how. For the last two generations, Europe's economic position has rested on a set of implicit bargains with the United States. Europe had access to American technology; even as it trailed in the development of advanced technologies, it excelled at applying them. Its position of privileged second might be grating, but it was tolerable and did not provoke joint action. Suddenly, crucial technologies often appear to be only available from Japan. In finance the dollar anchored the international financial system, which provided privileges to the United States, but stability and, at least until 1971, the right for others to devalue against the dollar to maintain trade equilibrium. Now Tokyo and Bonn as much as Washington shape financial evolution. In trade, the American market was open while the United States accepted and encouraged the creation of the Community. Recent American trade legislation now threatens to close the market, or at least raises the possibility, while the Japanese market is relatively impermeable. The implicit economic bargains were built inside of explicit security bargains. Set aside arguments about culture or history; America and Europe share a security problem, but Europe and Japan do not. Consequently, relative dependence on Japan in finance and technology and the asymmetrical market access in trade makes it unattractive to exchange America for Japan as hegemon. With the retreat of Soviet power from eastern Europe, the abrupt political reorganization of Europe has confronted the renewal and recasting of the EEC bargain.

Asia, by contrast, has become a Japan-centered trade and investment region. By almost any significant measure, Japan, rather than the U.S., is now the dominant economic player in Asia. Japan is the region's technology leader, its primary supplier of capital goods, its dominant exporter, its largest annual foreign direct investor and foreign aid supplier and, increasingly, a vital market for imports (though the U.S. remains the largest single import market for Asian manufactures). Moreover, Japan's dependency on exports is dropping (9), an element of the increasing Asian focus of trade in the region as a whole. Trade within Asia has grown faster than trade between Asia and other regions since 1985 (10). The major source of imports for each Asian economy is usually another Asian economy, usually Japan (11). Increased intra-Asian trade has permitted the NICS to reduce their dependence on the U.S. market. U.S.-bound exports have fallen from one half to one third of their total exports. Financial ties further reinforce intra-Asian trade trends. The result of trade and investment is a network of component and production companies that makes Asia such an attractive production location.

The Asian region appears to be very hierarchically structured, dominated by Japan. Japanese technology lies at the heart of an increasingly complementary relationship between Japan and its major Asian trading partner. In automaking and electronics, there appear to be two key elements to the regional strategy: one is to spread sub-systems' assembly throughout Asia while persuading local governments to treat sub-systems originating in other Asian countries as being of `domestic origin'; the second is to keep tight control over the underlying component, machinery and materials technologies, by regulating their availability to independent Asian producers and keeping advanced production at home. The two elements together would tend to deter too-rapid catch-up by independent producers to the competitive level of leading Japanese producers while simultaneously developing Asia as a production base for Japanese exports to the U.S. to avoid bilateral trade friction. Japanese firms seem to be pursuing that strategy with a vengeance. From 1984 to 1989, there was as much Japanese direct investment in Asia as in the previous 33 years, thus doubling the cumulative total. Japanese investment in the Asian NICs grew by about 50% per year and by about 100% per year in the ASEAN nations.

Advanced products and most of the underlying technologies are dominated by Japan, with labor-intensive and standard technology production in the periphery of the region, often under the control of Japanese industry. In a sense there is a competition of corporate and often national development strategies. The Koreans seek to break their technological dependence with national technology programs implemented by the large firms. Japanese technology programs seek to provide the basis for firms to compete not only with their American rivals but to maintain a technology edge in Asia.

The Regional Supply Base and Corporate Competition

The several regions, moreover, are not economically homogeneous; they are structured differently. This is certainly true in terms of the relations of the several countries in the region. Equally, and perhaps more importantly, each region has a distinct supply base of skills, component producers, subsystems capacities and final assemblers. That base creates advantage for, or constrains the firms rooted in that region. It appears that there are important differences in the character, sophistication and content of these regional supply bases and the linkages between the elements of the supply base; that is, they are tied together differently by markets and communities. An important research proposition for us is that these differences profoundly affect the capacity of firms that are rooted in particular region to create advantage. We find it intriguing that the most recent EEC industrial policy approaches, particularly those for electronics, are built on the notion of supply base. The significance of a regional supply base is becoming evident in high volume/high technology.

High-volume/High-technology Production in Asia

The concentration of new consumer durable manufacturing know-how in Japan and the rest of the Asian Region is fundamentally altering international competition in information technologies. It is certainly an example of flexible automation -- in which scale continues to matter powerfully -- creating product differentiation and speed to market. It also emphasizes the importance of regional supply bases in global competition. This argument implies that a firm producing consumer durable such as refrigerators or cars will have an easier time applying advanced electronics in Japan (Hitachi or Nissan) than in Europe (Fiat or Electrolux), because the base of electronics is broader and deeper in Asia. Acknowledging the distinct advantages of the German auto-electronics firm, Bosch, we still advance the proposition.

Our hypothesis is that high volume/high technology is emerging as a distinct technology trajectory in Asia. It is built on a foundation of flexible high-volume production, lean manufacturing, and will increasingly set the terms by which industrial, and even perhaps military hardware technologies evolve in the U.S. and Europe. A regional supply base has emerged with a broad range of sub-system, component, machinery and materials technologies which are increasingly being driven by high-volume commercial applications that boast leading-edge sophistication and extremely high quality at remarkably low costs.

The case is clearest in electronics, where a new industry segment is being defined in Asia, largely outside of U.S. and European control, and with only limited U.S. and European participation. Its distinguishing characteristic is the manufacturing of products containing sophisticated, industrially significant technologies, in volumes and at costs traditionally associated with consumer demand. Such products include the latest consumer items like camcorders, electronic still cameras, compact disc players, hand-held televisions and new micro-systems like portable faxes, copiers and printers, electronic datebooks, lap-top computers, optical disk mass-storage systems, smartcards and portable telephones. This "high-volume" electronics industry is beginning to drive the development, costs, quality and manufacture of technological inputs critical to computing, communications, military, and industrial electronics. At stake is a breathtaking range of essential technologies from semiconductors and storage devices to packaging, optics and interfaces.

Such products contain, for example, a wealth of silicon chip technology, ranging from memory and microprocessors to charge-coupled devices (CCDs). These products have been a principal factor behind the drive for Japanese semiconductor dominance. Over the past decade, emerging high-volume digital products have grown from 5% to over 45% of Japanese electronics production, accounting for virtually all of the growth in domestic Japanese consumption of ICs (12). With this segment continuing to expand at 22-24% per year, more than twice as fast as the approximate 10% per year average growth rate of the electronics industry as a whole, high-volume electronics will constitute an ever-larger part of the electronics industry of the next century. Its impact on the component technologies that all electronics systems share is just beginning to be felt.

Aside from silicon-integrated circuits, optoelectronic components like laser diodes and detectors, LCD shutters, scanners and filters, are also present in the new high-volume products. For example, the semiconductor lasers that, at different wavelengths, will become the heart of optical communications systems, are currently produced in volumes of millions per month, largely for compact disk applications. Displays and other computer-interface technologies provide yet another significant overlap between high-volume and other electronics markets. Miniature televisions from Japan are the leading-edge users of the flat-panel, active matrix, liquid crystal display technology that is vital to the future of the computer industry. Similarly, map navigation systems already appearing in domestic Japanese automobiles are the functional equivalent of military digital map generators.

Optical storage was refined for consumer compact and laser discs but is beginning to spread into industrial data applications, as are the latest miniature commercial power technologies like batteries for portable phones. High-volume requirements are also driving a wealth of imaginative packaging technologies that range from tape-automated bonding and chip-on-board to multi-chip modules. Producers of hand-held LCD televisions already use packaging technology as sophisticated as that being used in advanced U.S. defense systems. The new electronics products are driving similar innovations in precision mechanical and ferromagnetic components like motors, gears and switch assemblies and recording heads, transformers and magnets. Ball bearings used in video cameras, for example, are now of equal precision to those required for missile guidance systems.

Successful production for high-volume markets also requires mastery of several different kinds of highly responsive product development, materials and manufacturing skills. For example, Japanese consumer producers like Matsushita now supply the most advanced manufacturing equipment for IC board-insertion, a capability essential for most electronic systems production. Similarly, because elaborate repair and maintenance is not cost-effective in consumer markets, high-volume producers deliver product reliability levels that usually surpass military and industrial products at a far lesser cost. Indeed, the most advanced high-volume electronics suppliers do their market research by introducing products and fine-tuning product configurations and volumes to actual demand (13). They are masters of the new manufacturing, utilizing an extremely short and efficient development cycle and flexible, low-inventory manufacturing.

As high-volume electronics production begins to use the sophisticated technological inputs that industrial and military systems share, it begins to drive common technological development. By spreading the huge development costs across many more sales, high-volume markets can support the development of advanced technologies previously initiated only by public spending. Simultaneously, such markets demand much lower costs and deliver them through rapid attainment of economies of scale, learning and the other attributes of the new manufacturing. The associated product development and process skills permit the technology to be cycled much more rapidly. Cost-savings and rapid cycle times permit expanded R&D, broader experimentation, and the capturing of new opportunities for additional technological learning. The final result is a new technological development trajectory -- new generations of cheaper but sophisticated technologies emerging from high-volume commercial applications but applicable to military and industrial systems.

One impact of the new trajectory and its concentration in Asia is suggested by the following Table: the elimination of major parts of the domestic U.S. technology supply base.

Gaps in the U.S. Technology Supply Base

Precision-mechanical
- Motors - flat, high torque, sub-miniature
- Gears - sub-miniature, precision machining
- Switch assemblies - sub-miniature

Packaging
- surface mount, plastic

Media
- magnetic disk
- optical disk

Displays
- electroluminescent
- LCD, Color LCD, LCD shutter
- CRT - large, square, flat
- LED - arrays
- Projection systems

Optical
- Lens
- Scanners
- Laser Diodes

Ferromagnetic
- Video heads
- Audio heads
- Miniature transformer cores

Copier-printer
- Small engines for laser printers

Source: National Semiconductor

A second impact of the new trajectory and its emergence from the domestic Japanese base is the way it permits Japanese industry to shape a new production architecture for the broader Asian region. Specifically, Japanese technology lies at the heart of an increasingly complementary relationship between Japan and its major Asian trading partners. Japanese companies supply technology-intensive components, subsystems, parts, materials and capital equipment to their affiliates, sub-contractors and independent producers in other Asian countries for assembly into products. These final products are sold via export in third country markets (primarily in the U.S. and other Asian countries) (14). Conversely, non-affiliated, labor-intensive manufactures flow back into Japan from other Asian producers.

Elaborating this trend, in 1987 MITI noted the "growing tendency for Japanese industry, especially the electrical machinery industry, to view the Pacific Region as a single market from which to pursue a global corporate strategy" (15). In electronics there appear to be two key elements to the regional strategy. One is to spread subsystems assembly and low value-added systems production throughout Asia, while persuading local governments to treat subsystems originating in other Asian countries as being of 'domestic origin'. The second element is to keep tight control over the underlying component, machinery and materials technologies by regulating their availability to independent Asian producers and keeping advanced production at home.

Thus, by the end of 1990, Japanese producers had moved most of their low-end consumer electronics production off-shore into the NICs and Southeast Asia -- including most audio systems (cassette recorders, headphones, low-end tuners, etc.), under-20-inch televisions, calculators and low-end appliances like microwave ovens. Different Asian producers were concentrating on production of different systems and subsystems. Local Asian content had risen to over 60%, but key technological inputs -- e.g., magnetrons in microwave ovens, advanced semiconductor logic chips, precision mechanical components -- were exclusively sourced from Japan. Overall, the regional architecture appeared to ensure that leading-edge production know-how would remain localized in Japan, while selected production know-how would diffuse asymmetrically throughout the rest of Asia. This would tend to deter too-rapid catch-up by independent producers to the competitive level of leading Japanese producers while simultaneously developing Asia as a production base for Japanese exports to the U.S. and Europe to avoid bilateral trade debates.

Regional Structure in Europe and America

We do not have an industrial case with which to elaborate a broadbrush analysis of the European and American cases. The issue for us in each case is how the supply base and production arrangements are affected by the regional reshufflings. In Europe, the integration of Southern Europe, with lower-wage and lower-skilled labor, and Central Europe, with its confusing mix but relatively high-skilled and potentially middle-waged labor force, creates the possibility of a much more differentiated regional supply base. In North America, the changed trade policies of Brazil and Mexico, as well as of Canada, raises the same issues. The questions are not simply what will be produced where, important in its own right, or how that changed mix affects corporate strategies. In addition, the question is who owns which elements of that supply base and whether the nationality of the ownership affects the possibilities for product development and production of other firms in the region. Certainly the economic architecture and the supply base of each of these regions will change.

National Trajectories

The conventional working assumption is that things are done differently in each country. The notion is that, for whatever reasons, national differences mean that quite different activities -- factories and politics, say -- will be organized to give expression to nationally prevalent attitudes or to react to common institutional constraints (16). Yet, the demands of market competition in industry set standards of efficiency that often seem to require quite varied nations to imitate the best practices developed in other places. Technology or technological systems seem to impose their own rhythms. Whether it is through technology, particular machines, or organizational strategies for developing and using machines, the strongest industrial country seems always to export its own culture along with its products and production systems. National differences are then eroded. They survive only when sheltered from the market. In this vision, there are only leaders and followers, systems that permit competitive adaptations and those that do not or do so more slowly. There is not sustainable diversity and variety. The notion of globalization and the view of most at this conference, though, would contend that there are national differences, that real diversity can exist, and that it can animate global competition.

There are two questions. First, if there are national trajectories, on what do they rest? Second, when will national trajectories produce winners or losers, thereby pushing toward homogenization, and when will diversity be sustainable? For the moment, we consider only the first of these.

The Notion of National Trajectory

Once nations were seen to be on a common development course that they covered at different speeds. Policy could accelerate or retard that development, but not alter the course. Now it is argued that nations or sub-national communities within nations follow separate development trajectories. Those trajectories rest on differences in industrial structure, social organization and the role of government in the economy. Different trajectories imply not only that some countries will have faster growth because of higher savings rates, but rather that industries in one nation may make innovations or begin lines of development that are not readily transferable to others. The argument suggests that there can be decisive winners and losers in international trade; one nation can create advantages in related sets of industries that its rivals cannot match. Production costs and technology do not automatically converge, thereby inducing trade based on taste and marginal innovation, and on specialization within national sectors producing intra-industry trade. Rather, costs and technologies diverge, creating for producers rooted in one national environment a decisive advantage in a range of related industries.

The argument is most elaborately spelled out in the case of technology. The proposition is that technology's evolution follows trajectories that reflect the community and market context in which it develops. The technologies for production, the path of production innovation, would then follow a particular trajectory underpinned by market and social arrangements. Those trajectories are not simply dictated by technical knowledge. Rather, technology is a path-dependent process of learning in which opportunities for tomorrow grow out of research, development and production undertaken today. Studies of the process and history of technical change indicate that technology is not a set of blueprints given by scientific advances that occur independently of the production process, but often are a joint output of the production process itself. The pace and direction of technological innovation and diffusion are shaped by production and market position.

These arguments turn on a particular assessment of the nature of technological knowledge. In this view, technological knowledge is not simply information that can be bought or sold, but rather often a subtler set of insights that develop only in conjunction with both design and production. The process is step by step, an iterative interaction between opportunities and knowledge in specific settings. We must distinguish clearly between scientific and technological knowledge. Scientific knowledge establishes a set of basic theories, principles, and premises from which technology can be built. It is close to the notion of blueprint information that characterizes discussions of technology in the traditional economic literature. Scientific knowledge can often be precisely specified and easily communicated in a common language. Moreover, the institutions of scientific development are international, and the flow of information across national borders is extensive. By contrast, technological knowledge is often local in nature and advances incrementally. Such knowledge accumulated in local institutions in the form of learned know-how is intimately connected to locales in which it is generated and does not necessarily move between regions within countries, let alone between nations. It accumulates in firms in the form of skilled workers and proprietary technology and difficult-to-copy know-how. It accumulates in communities in such diverse forms as suppliers, repair services and networks of know-how. It accumulates in nations in the skills and experiences of the work force and in the institutions that train workers and diffuse technology. This kind of local or non-traded knowledge is crucial during the initial development phase of new products and process. Such accumulated knowledge, implicit in some cases and institutionally rooted in others, does not flow easily or quickly across national borders. This suggests that a particular national solution or advantage is not easily imitated.

There are several key notions in the concept of a trajectory. The first is that the *composition of production* matters; a dollar of grapefruit production is not the same as a dollar of computer production for the long-term national development; a micro chip is not, despite the belief of some, economically the same as a potato chip. In this case the future growth and technological development of a nation is molded by the current composition of its industries and activities. A nation's current competitive successes and failures in international trade will affect the areas in which technical skills will be accumulated, innovation undertaken and economies of scale reaped. And the growth and technological potential of different areas are not the same.

A second key notion is *linkage*. The ties between activities in an economy are not fully described simply by a model of market exchange, an assessment of who buys what from whom, or by a giant input output model. Activities are linked together in different ways. Consider the relation between services and manufacturing. Some service activities, such as advertising, are downstream from production and will go on no matter who produces a good or where it is produced. The production of these activities is not linked or is very weakly linked. Other services are more tightly bound to manufacturing. Some are very tightly linked indeed: if grain and animal production stopped in Nebraska and was replaced by imports, then those veterinarians and other service workers would be displaced. In a sense, very tightly linked activities are bound by geography. Other services activities are moderately linked to manufacturing; that is, they are not tightly bound by geography or are weakly bound by the market. Rather, they are tied together by community practice and industry organization. Banks and industrial firms are tied together in different ways in Germany, France and Britain. Similarly, manufacturing activities are linked together in distinct ways in different nations and often differently within countries. The patterns are, admittedly, complex, but national and regional differences are an important element. Part suppliers are tied to Toyota in different ways than they are to GM. Indeed, Keiretsu and financial relations create tighter technological links between firms in Japan than in the United States. The way technological learning and knowledge accumulates in a particular industry within a national community, and within a region within the national community, will turn on the character of these organizational and market linkages.

The third key notion, implicit in the discussion above, is *spillover*. Technological knowledge in one sector or activity can provide the basis for innovation in another; knowledge spills from its point of origin. When the spillover is great and the knowledge from a sector is tacit and passes through community institutions and not markets, then that sector can represent a piece of infrastructure to the economy as a whole. In some cases, the same technology might pass through communities, remain tacit and non-market, or through markets more explicitly. If one country maintains an industry that is structured so that technological knowledge remains captive and is not available readily on the market, then other countries that would benefit from the technological spillovers from that industry must develop their own domestic producers. Technological externalities will vary with industry and national organization. The issue is as much one of political and social organization as one of economic logic. The character of spillovers often sets the geography of spillovers. The mechanisms that confine spillovers to a particular geography may involve labor markets or restraints in goods markets that restrict diffusion.

The tighter the linkages, the greater the spillovers, the more the course of a few industries or technologies can shape an entire economy. Why might those courses of development be rooted in national settings? Technology is malleable; its particular form is set by social molds in which it emerges. However, one would argue that technology is entirely capable of simply being shaped to our will. Not all things are technically possible, but technology has no internal logic that inevitably dictates its evolution or use. When a technology is in its infancy and still fluid, the line of its technical evolution is inherently uncertain. This is not to say that all things are possible, but rather that more than one direction of development is possible. An emphasis can be put on making steel stronger or lighter. The pace and direction of development is a matter of decision. The direction a technology takes will depend partly on circumstance and individual choices. The directions of effort and evolution are set by the cluster of the technology bets. The outcome, the winners among competing possibilities, will emerge as the sunken investment becomes so great that the radical alternatives are too pricy. Broad market acceptance of a new technology, for whatever reason -- be it public relations or real performance -- excludes new possibilities. After positions freeze, a radically new technology will not be developed unless it is so attractive that producers and users are willing to walk away from their investments in earlier technologies. If the gains from new technical approaches look marginal, they will be ignored; if gains look potentially important but slow to develop or very risky, they may never be captured.

Since technological development is inherently uncertain, the technology then evolves from a distribution of bets. Those bets, and the innovations they generate, emerge from complex interaction among three factors:

1) market demands as expressed in prices;
2) needs that might be satisfied but are not yet expressed by buyers and sellers in the marketplace; and
3) new additions to the "technical pool."

Perhaps the best analogy is to covering the table at the roulette wheel. The multiple bets that technological development requires will not be placed evenly around the table. Instead, they will cluster in two areas, according to two principles. First, research and development bets will be historically rooted. They will reflect the past development of the firm and the national economy and tend to follow the direction of past work. The resources available for tackling the next round of technical problems will reflect what comes before. Technology has history. Second, the needs to which the technology is being applied will be different in each national community, and so the tasks that must be addressed will vary. These two principles around which technology bets cluster on the roulette table suggest the basis of a national technology trajectory.

Technology *becomes* a binding parameter; it does not begin as one. The bet "placer", be it a company or a nation, actively shapes technological development. The national context of technology development, by setting the cluster of bets, shapes technology. If there are competing national technologies, the winning routes block other options and are imposed by sustained investment on other communities. Because the winning and then dominant technological route reflects, at least in part, the historical roots and national needs of a specific community, it gives at least an initial advantage to the innovating country. The technology emerges from, and plays to, the national strength of the innovating country. The winning technology always imposes its own constraints, and once set, it can shape the patterns of trade. Learning curves, technological linkages and nationally-rooted technological developments all create the basis for firms in one nation to surge to advantage in world markets together, riding a common paradigm of technology emerging from their local experience.

For the notion of technology trajectory to really have meaning, the variables that separate and distinguish trajectories must be defined. Those variables cannot simply be macro-economic in an argument about trajectories. If differences are exclusively a function of levels of savings and investment, then development occurs along the same line at different speeds and following a universal logic. The micro-dynamics of technology evolution -- the local conditions that separate trajectories -- are then common to all cases and the argument about trajectories collapses.

On What Do National Trajectories Rest?

On what, then, does variation rest? We do not need a universal argument, just the logic that justifies the conclusion that the dynamics of technology development are different from one setting to another. Each of several approaches suggests that differences in the institutional, industrial or community structure and organization create distinct micro-economic dynamics. The logic of each market -- and thus rational market behavior -- is shaped by the context in which it lies.

One classic line of argument proposes that industrial organization (whether an industry is atomized, monopolized or oligopolized -- sometimes cartelized -- or is somewhere in between) sets the framework within which the individual firm makes choices. Industry organization and firm behavior, including strategies for the use and development of technology,.will change. Industry organization alone does not establish distinct technological trajectories.

A second and complementary approach would propose that the industrial institutional structure of the economy -- that is, the structure of the government and the character of institutions that regulate and arrange financial and labor markets, as well as the markets for goods and services -- also creates specific patterns of constraint and opportunity. Those patterns of constraint and opportunity produce regularities in the strategies of governments and firms. Let us contrast the French and Japanese cases. French interventionism has produced constant responses during the years, but the problems have varied. The difficulty now is that the classic solution is increasingly less applicable to a global and competitive economy. In the French model the government mobilized important resources -- financial, institutional, and human resources -- and directed them to specific tasks established in advance. The bases of this strategy are evident. The French bureaucratic system is centralized and could call on a financial system that was under the influence of the state. The industrial structure consisted of small firms historically protected from foreign threats and with competition often dampened at home. The French solution worked when the tasks at hand required mobilization of resources, when it was possible to define a limited number of technological results and when the competitive market could be suppressed, controlled or oriented by the state. The success was evident with Ariane, Airbus, the TGV, the Minitel system. The strategy did not work when the task was centrally for a company to rapidly adapt its products and processes to changing international market conditions. As a result, the French position in consumer durable has always been weak, its position in electronic components untenable. In sum, a particular pattern of policy in a specific industrial setting produced a particular pattern of technology development and trade. In a similar vein, Japanese interventionism produced a distinct pattern of policy and market response. The government acted as gatekeeper to break apart the multinational package of money, technology and management. Japanese policy produced intense internal competition in which pursuit of market share was the best way to pursue profits. As industrial followers in expanding markets aggressively borrowed technology abroad, Japanese firms that held market share and expanded production could more rapidly introduce new generations of technology. The market logic, in turn, induced corporate responses that resulted at once in a production revolution, in patterns of corporate search for external technology and rapid product introduction and in an interconnected web of production and distribution that so confounds foreigners. The same market logic induced excess capacity in Japan that spilled over into global markets in the form of dumping controversies. There was a multi-tiered process leading from politics to policy to market logic to corporate strategy and then production innovation. The result in Japan was success in consumer durable sectors such as automobiles and consumer electronics producing a distinct technology trajectory from the French. The same institutional/industrial structure approach has been used to examine U.S.-Japanese competition in a series of industries. The distinct strategies and technological trajectories produced a competitive interaction that favored the Japanese.

A third approach would emphasize the character of social conflict and community or regional social organization. Variation in industrial automation among Fiat, Volvo, and Volkswagen can be explained by difference in the character of the conflict between labor and management in each of these countries. Fiat approaches to automation which truly displace labor are certainly a response to the sabotage strikes and labor militancy a generation ago. A different instance would be the two paths of development within the German machine tool industry, each with a distinct industrial organization, industry institutions, market strategy and technological implications. Others distinguish between the trajectories of defense and civilian high-technology industries in the United States. Here, the defense trajectory is rooted in the nature of procurement with essentially a single buyer purchasing from a limited set of final contractors with products specified by performance with price and production cost being simply irrelevant. That market logic becomes entrenched in corporate strategy and organization with the result that the military market firms often do not have the organization skills or strategy to succeed in civilian markets. Indeed, a comparison of American and Japanese machine tool development traces a military and civilian line of technological evolution, each pushed by government policy.

In sum, the notion of technology trajectory emphasizes the particular and the local sources of development. The moving technological frontier and market trends refract individually across these multiple settings producing distinct trajectories.

How Do We Empirically Distinguish National Trajectories?

Depicting and distinguishing national trajectories is not an easy task. There are at least three complementary ways of conducting country analysis: one, to infer from case studies; second, to depict or construct market logic; and third, to focus on regions within national boundaries. Let us consider each.

In the first method, which involves inferring from specific industry cases, the choice of cases is of overwhelming importance. Machine tools and steel will, inevitably, produce quite different images. Comparing machine tools in one country with steel in another will produce a skewed country comparison. Analysts tend to generalize about countries from studies of assorted places or industries within that country. Often, they arrive at diverging conclusions even when they are looking at the same country. The Japan in the MIT automobile study, for example, and the Japan of David Friedman appear to be very different (17). In the MIT study, Japanese industry is characterized by large-scale operations with major assemblers at the center of tiers of smaller, interconnected, dependent, suppliers. For Friedman, on the other hand, the autonomy and independence of networks comparing smaller firms has the flavor of European industrial district descriptions. The difference is critical. Arguably, in Japan we never witnessed the break up of the vertically integrated firm but rather saw the creation of semi-market arrangements around dominant firms for volume production.

There are several criteria one might use to select sectors or systematize sector studies that exist to develop a country's economic structure. First, one might simply define which sectors constitute a dominant portion of a country's economy. This, however, simply presents a pattern, it does not provide insight into the dynamics of change. Second, one might examine exports, expansion or capital investment to discover the process of adjustment. Third, production equipment, intermediary capital goods, might suggest national patterns of production. The assumption is that national patterns can be inferred from careful selection of cases.

A second approach by which to conduct country analysis involves depicting the market logic generated by the institutional structure and political conflicts of a particular country. One variant, commonly used by BRIE, assumes that a particular set of institutional, policy and market arrangements generate an enduring pattern of constraints and opportunities for firms. Consequently, a predictable form of firm behavior emerges.

In the case of Japan, Tyson/Zysman have argued, as noted above, that particular political solutions created a unique set of institutional and policy arrangements at the first tier. At the second tier, this set of market institutional arrangements produced a particular logic in the market and firm behavior. Finally, at the third tier, the firm reflected a distinctive approach to production innovation. A parallel argument has been made by Zysman, and in a different way by Stephen Cohen, about France. The argument rests upon the way both business and state interactions structure domestic markets and the international economic policy structures domestic markets relate. The different patterns of trade in France and Japan can be attributed to these facts. Sabel and Piore provide a different line of argument, one that highlights labor politics, which is the connection between politics and market behavior (18). They reason that a specific set of national arrangements and conflicts characterizes a particular country. The open question is regarding which facets of national arrangements systematically produce particular market signals. In the case of France and Japan, the national logic may be assumed to dominate particular regional logics.

Similar arguments have been built linking labor politics or regional politics to particular market solutions adopted by firms. Note that nothing about these arguments distinguishes those cases in which the adaptations produce sustainable or unsustainable variety and those in which some solutions finally prove to be winners.

The third method of analysis focuses upon particular regions within a nation's boundaries. This notion points to a single market logic shaping the national marketplace. In this case, selecting sectors ceases to be a problem since only a few dominate a particular region. Hence, the notion is that regional political/institutional arrangements produce distinct outcome arrangements. Both the work of Herrigel on Germany and of Locke on Italy follows this logic.

Herrigel's argument rests on the notion that pre-industrial regional variation in agriculture shapes the types of firms that emerged in the machine tool industry. The work does not test whether those variations in the equipment industries in turn affect the production organization in final products. Locke's study, based on matched cases from three sectors in different regions, contends that variation in regional politics is more significant than sector in accounting for adjustment strategies.

Inherently, however, (not to be critical of their very interesting work) neither of the above studies can answer whether regional variation within a country looms larger than national variation. In federal systems, such as Germany and the United States, or systems with weak central governments permitting substantial local autonomy, regional variation may prove critical. Indeed, the question remains: Are there underlying common elements that characterize different regions within a nation and that differentiate them?

These approaches leave open the question of how to treat the problem of the transnational corporation? 1) Do they represent a separate pattern of production, that is an IBM or Toyota pattern? 2) Do they represent a transnational extension of a particular national pattern? That is, are they carriers of a particular production approach? 3) Or do they in fact adapt to the national context in which they are producing?

II. Sectoral Diversity and Differences in Corporate Practices

The pressures of globalization are felt unevenly across sectors and market segments. Innovations and competitive challenges that devastate one sector are considered to be of marginal significance to others. Witness the different reactions in Silicon Valley between the electronics and the bio-tech communities, or the contrast between automobile and petrochemical producers, to Japanese competition. The importance of production as a response to competition is similarly varied. It is essential in consumer durable and often irrelevant in pharmaceuticals.

If there is diversity, what is generalizable? A number of seemingly contradictory developments are simultaneously occurring. Consequently, it is not evident whether there is a new dominant mode, what it is, or whether there are multiple poles. For example, there is at once a tendency toward an increase and a decrease in scale economies, both of production and of the firm. In some cases, such as semiconductors, this is evident in a single sector. As a result, there are the evident questions: Is there commonality across diverse sectors, and, if so, what does it consist of?

<u>Industrial Sectors</u>

As we search for the pattern of production adaptations to globalization, it is evident that competitive adaptations will take on different forms within various sectors.

The critical elements of the response will vary. Production problems will be different in the steel and apparel industries and, indeed, will be different within each sector itself, if, for example, we compare high fashion and socks. There are two issues: first, which sectors should concern us?; and second, what aspects of their development should be our focus?

Which sectors should concern us? More specifically, can all sectors equally reveal axioms regarding the role of production in adapting to changes in global markets?; if one were to select a sample of sectors, which should one include?; should the sample be drawn randomly or the sectors selected using a criteria? One criteria would be a sector's *importance to the economy* (in terms of its contribution to GNP, labor force, etc.). A few very large industries, such as the automobile industry, may arguably define a national economy. Suppliers of components and parts, for instance, often depend on a few major assemblers, such as Ford or General Motors. This, of course, indicates that the size of this sector and, consequently, its significance for the economy become much greater. That is, Toyota's supply strategy conceptions or GM's telecommunication strategies, for example, influence a broad range of firms. A second criteria would be *diversity of process*. There are evident differences in the production processes of chemicals and autos. Third, and equally important, some sectors may be strategic and a significant source of *technological innovation*. This is the case with robotics or machine tools. These sectors may reveal distinct approaches to production, embodying both technology and innovative manufacturing concepts. The choice of sectors and of countries inevitably shapes and colors our picture of the transformation.

What should our focus be when we consider specific sectors? Perhaps the most debated issues are whether economies of scale are increasing or decreasing; we suggest that both are happening, and that administratively-managed vertical integration is softening into some form of internal contracting. We would start at a different, and perhaps more naive, point in the discussion. Production has changed, and with it changed the character of competition. The initial issue must be how production innovation and globalization have affected competitive dynamics in each sector. New competitors may use production innovations to create advantage. The second issue must be what the concepts and operational tactics in production and production innovation are and where they come from. The third issue is whether or not there has been substantial innovation in the competitive strategies of firms as a result of or using new production methods.

Let us list a series of questions we would want to address in each sector:

1. How did the initial production innovation originate within the sector?
2. Is there any agreement on what "best practice" consists of?
3. Has best practice involved a change in the efficient scale of operation or the relation of elements in the production process?
4. Assume that there are different solutions (lines of development) to achieve particular outcomes (conceptions of best practice). Are these lines created by competitive pressure and imitation or by a simultaneous response to similar problems?
5. What is the range of practice within the sector? Is the variation within nations as great as that between nations?
6. What are the mechanisms of diffusion? Most critically, are the mechanisms of diffusion strongest within nations, within regions, or within the global market?
7. Organizational and strategic changes are consistently at the core of production evolution with technology being used in a variety of ways. Nevertheless, to what extent has technology in the form of equipment designs, production equipment, know-how and the like begun to entrench particular lines of evolution?
8. How has the set of equipment suppliers affected or been affected by the evolution of this sector? Put differently, where is the decisive know-how embedded, in particular firms, in networks, or in suppliers?

Now let us set out a few snapshots to facilitate discussion.

Semiconductors: a Typical Mixed Model of Adaptation

For reasons of location (Silicon Valley being about one hour from here) as well as inherent interest, we have examined the semiconductor industry with particular care. The semiconductor case emphasizes that, in many industries, developments are moving quite happily in seemingly contradictory directions. Both capital-intensive, high-volume commodity production strategies and flexible strategies for niche markets can be seen in the semiconductor industry.

World leadership in commodity semiconductor manufacturing has passed out of U.S. hands. Measured by fabrication yields, defect densities, capital productivity, or almost any other index, both the best and the average performances of Japanese firms surpass their U.S. counterparts. The superiority of average Japanese performance strongly suggests the hypothesis that Japanese firms are systematically doing things differently. This inference is supported by much pointed anecdotal information. For example, one of the top American semiconductor producers has a production joint venture with a Japanese counterpart. The joint venture is the U.S. firm's most efficient production facility, but it is the Japanese firm's least efficient fab.

Incremental differences in a variety of variables may be tentatively advanced as explanation of Japanese superiority. The most significant variables include the purity of materials, superior clean rooms, superior equipment utilization, process control and work force skills. Unlike the automobile case, however, no systematic account yet exists which convincingly explains variations in semiconductor manufacturing performance. Nor is there a detailed account of whether Japanese producers are able to achieve similar performance in production operations they run outside of Japan.

Superior commodity semiconductor manufacturing performance is not confined to Japan, however. There is significant production innovation in Europe as well. One German firm, Intermetal, has in Germany a state-of-the-art, very high-volume, 'jelly-bean' (i.e., very low-average selling price) chip production capability which is fully competitive with similar East Asian fabrication facilities. The major difference is that the German firm is paying 10 or more times the wage rates paid in the comparable Asian facility. Once again there is no systematic study, detailed or otherwise, of how a European producer is able to accomplish that feat.

Equally critical at the moment: Japanese excellence is confined to high-very high-volume chip manufacturing. Slightly caricatured, the Japanese fine-tune their highly automated facilities, turn them on and let them run. By contrast, many U.S. firms with high percentages of lower volume proprietary, application-specific, or niche products -- particularly newer entrants like Cypress Semiconductor -- are leading flexible producers. They are capable of producing a broad variety of chips in quite small batches in facilities that are much smaller than the typical Japanese factory. Current Japanese facilities run with anywhere from 10,000 - 30,000 wafer starts per month compared to flexible U.S. firms with minifabs that run from a few hundred to perhaps 2000 wafer starts per month.

This situation may be changing, however. As CMOS process technology becomes the process technology of choice for an ever-increasing variety of chips, it appears that Japanese firms are installing fabs that have undifferentiated digital CMOS capability. Their intent appears to be to produce a variety of different chips, flexibly, all processed in CMOS. Only time will tell whether, by applying the flexibility aspects of the new manufacturing model, Japanese firms become superior flexible manufacturers.

In summary, there are two contradictory trends of occurring simultaneously in chip manufacturing. One is the trend toward ever-larger scale fabs, with projections approaching $1 billion per fab for the next generation facility. This is the trend being followed by the producers of high-volume commodity products, especially memory and micro-processors/peripherals. This trend appears to be a result of the fact that the existing overhead structure of commodity producers is able to support ever-larger fabs. Simultaneously, there is a second trend -- an effort to develop smaller, more flexible fabs for the non-commodity segments of the market. This would permit smaller firms to manufacture cost-effectively and flexibly without incurring the horrendously high investment costs of traditional production. In between these two trends is perhaps a newly emerging Japanese capability -- a fab that can manufacture in very high volume, but flexibly within the limits of a single process technology.

Finally, of equal relevance is the question of whether U.S. firms could adopt best Japanese chip manufacturing practices and make them work cost effectively in the U.S.. This larger issue is really a question of political and economic variables (e.g., tax policy) that lie outside of the shop floor and frame the business environment within which firms operate: Can U.S. firms operating in a different environment make the same technological and business practice choices as Japanese or European firms?

The Automobile Industry

The consumer durable sector highlights the differentiation in high-volume, high-tech markets. The automobile case, the most intensely studied industry in this sector, is characterized by the emergence of high-volume flexible production in Japan. It is agreed that there have been two production revolutions in the automobile industry and, more broadly, in consumer durable sectors. The first was created in the United States and diffused abroad through direct foreign investment. The second emerged in Japan and has had repercussions in the U.S. in the form of exports and direct foreign investment. The basic shift currently underway in the automobile industry is from mass to lean production, as described in the MIT automobile study. The main advantage of this shift in production organization is that lean production requires

> "less of everything compared with mass production -- half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also, it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever growing variety of products" (19).

The model presented in the MIT automobile study was based on one essential, basic shift, which the study's authors contend resulted from limited resources that impeded the introduction of mass production. Mass production required abundant capital investment for a large scale of inventories, assembly lines, etc. -- resources not available to Toyota, the empirical case for the Womack study. Yet they do not explain why this system emerged, or why it emerged in this particular country. Clearly, other places have been short of resources. Thus, this analysis does not fully explain the emergence of lean production. Moreover, scale has not disappeared from the industry even as scope has become a concern.

An alternate approach taken by Tyson and Zysman reveals yet another weakness in the MIT results. They argue that the logic of market competition in Japan, which was created by particular institutions and policy strategies as well as by a specific industrial organization, induced competition in production. Neither approach, however, can account for the circumstances in which the system can be imitated. On the other hand, Kenney and Florida's work suggests that the transfer is in fact proceeding, albeit under Japanese management (20). This kind of analysis aims to identify the critical element supporting innovation in the production conceptions and the organizations that support those innovative conceptions.

Whatever the source, what is the miracle? In looking for an answer to this question, it is useful to consider the argument of Robert Cole (21). It states that the widespread application of technology accounts for the Japanese auto industry's success and is thus the main transformation characterizing the industry; this success is not the result of any "state-of-the art" technology. The several transformations going on in the Japanese automobile industry (the prototype for this transition) are, hence, based not so much on technological innovations. Rather, they are based on skill formation, including problem-solving skills, better communication between labor and management, in-house training programs and often self-contained technical schools. Skill formation in the Japanese manufacturing process has been described as "integrated", as opposed to "separate", indicating the integration of the workers' initiatives into the organization process (22).

An alternative approach to explain Japan's "miracle" is taken in the Jaikumar study (23). It divides the evolution of process control into six stages, with Japanese innovations as steps four and five. In light of Jaikumar's framework, the Japanese auto experience might be seen as a controlled evolution made possible by skill development and induced by competition. In any case, the Japanese auto industry is one form of innovative volume production and flexible automation.

Production Equipment and Components

The relationship between users and suppliers is most precisely understood by examining the production equipment sector. This relationship not only affects an array of technological opportunities that equipment suppliers are able to explore. In addition, it affects the rate at which equipment innovations diffuse to different sets of potential users, both within national economies and without. For these reasons, we will not review machine tools as a specific sector but look at the issues it raises in terms of both its relationship to final users and to trade policy.

Machine Tools: The machine tool industry originated from firms' demand for specific machinery and has become a strategic sector. As Carlson puts it,

> "In order to have an engineering industry which is at the forefront in terms of its production technology, and by implication, internationally competitive, it is of primary strategic importance to have user firms on the technological frontier, i.e., firms which have the competence to formulate technical problems whose solution is generalizable to a larger set of problems and firms" (24).

Technological innovation in the production equipment industry resulting from demand pull can then be made available to other firms. It is at this point that production equipment becomes strategic. Companies that are not on the technological frontier rely upon access to innovations provided by their suppliers. Since these companies also depend more heavily upon domestic suppliers, leading-edge equipment manufacturers affect the technological development of the economy as a whole. Regarding the production equipment sector as such a strategic industry, the question arises whether it resembles an industrial artifact for an archaeologist. That is, can this "sector" be studied as a separate industry, or is it inevitably tied to particular production sectors? What is the underlying difference between such a cross-industrial cut into suppliers and users and an analysis of industrial sectors?

The machine tool industry in the United States retains a set of close organizational and technological ties to the U.S. aerospace sector, a direct consequence of the U.S. Air Force's early involvement in diffusing computer numerical control (CNC) technology to selected, large machine tool suppliers. Over time, these close collaborative ties have generated manufacturing innovations geared toward the particular needs of large aerospace and automotive firms. These innovations included the standardization of CNC programming around APT, a complicated programming language geared toward fashioning large, structurally-complex metal parts (integrally-stiffened wing sections, variable-thickness skins) for high-speed aircraft and missiles.

At the same time, American machine tool suppliers failed to develop a similar set of collaborative relationships with domestic consumer durable producers. Consequently, when breakthroughs in programming methods and computer design made it possible to develop low-cost, mass-produced CNC tools in the 1970s, most American CNC tool suppliers were free of manufacturing requirements imposed by consumer durable producers to detect any unmet demand for such equipment. In contrast, Japanese suppliers continued to cultivate their already close technical and financial ties to major domestic industrial users of machine tools. As a result, they introduced microprocessors into their CNC control systems rapidly. Thus, they were able to market smaller, lower-cost tools that could satisfy the latent needs of the American mass market more quickly.

Semiconductor Production Equipment: A key competitive issue in the semiconductor case involves the nature of the contracting relationship, i.e., the nature of the sector's actual links. In the U.S. semiconductor production equipment industry, there was no close collaboration between users and suppliers at any level. Early military procurement combined with easy access to venture capital in an effort to create an independent, entrepreneurial equipment sector in the United States. U.S. suppliers responded to the perceived needs of U.S. semiconductor producers for equipment that could process complex, design-intensive computer chips by breaking down the equipment in various processing steps. As chip designs became more complex, bottlenecks arose at specific points in the semiconductor production process; new equipment was introduced, on an ad hoc basis, to address the problem at hand. The financial independence of small equipment producers enabled, indeed required, their marketing the most technologically advanced equipment they had to all potential users. As long as competition was confined to American firms, the strength of this form of industrial organization -- the historically high rates of innovation diffusion that it brought about -- obscured its latent weaknesses. Among the most important weaknesses were a general inability among users and producers of semiconductor production equipment to coordinate investment cycles, share manufacturing know-how, or synchronize competitive strategy.

Japanese semiconductor producers, by contrast, had been encouraged to create long-term relationships with their domestic equipment suppliers (sometimes to the point of owning them outright). In the context of government-sponsored projects, Japanese computer chip producers purchased production equipment from American suppliers and then shared the technology with their domestic equipment affiliates. As a consequence of the Japanese chip producers' emphasis on processing large numbers of semiconductor memories for use in high-volume consumer electronics products, Japanese chip and equipment producers focused their attention on connecting the different parts of the production process and on speeding chips from one processing step to another. This special focus on overall manufacturing quality often enabled Japanese chip makers to achieve superior performance from inferior equipment. This ultimately empowered them to switch to domestic suppliers even in those cases where American suppliers remained more technically proficient.

Identifying the significance of innovations in the semiconductor industry necessitates looking not only at the kind of innovation that takes place but also at *where* it takes place. In consumer durable (high-volume, high-tech), the dynamics of production innovation were driven by trade policy. Conversely, U.S. semiconductor firms were driven initially by demand from military, space, and computer industry customers for high-performance chips. They emphasized product innovation over production competence as the major source of competitive advantage in the semiconductor industry. Firms that competed as technology followers with lower cost production strategies existed; however, they never systematically pursued manufacturing competence as a source of enduring industrial advantage. In either case, U.S. producers never succeeded in penetrating the market in Japan both because the Japanese market was formally closed to foreign firms and because few U.S. firms foresaw the market opportunities that would emerge there.

In contrast, because Japanese firms were insulated in their home market, Japanese entry into foreign markets was driven by its consumers' demand for the lowest cost chips produced in very high volume. Japanese firms thus emphasized manufacturing competence as the major source of competitive advantage. In order to eliminate defects and increase manufacturing yields, they systematically focused on the production process. Their efforts ranged from development of ultra-pure materials and the use of super-computers to model innovative clean-room designs to statistical process control and joint design of reliable manufacturing equipment with suppliers. Consequently, a decisive superiority in their ability to lower manufacturing costs and increase yields in commodity products has characterized Japanese manufacturing. This of course, has thoroughly altered competition in the industry.

Once Japanese firms secured their commodity manufacturing advantage, they engaged in blatant predatory behavior, dumping products in the world market and forcing most U.S. firms to exit the industry. As a result, few U.S. firms retained either the wherewithal or the market position necessary to respond to Japanese manufacturing innovation by learning how to be as effective producers. U.S. firms have made significant progress in performance, but Japanese firms have been moving targets.

At the same time (as mentioned earlier) many U.S. firms sought refuge from commodity competition in lower volume proprietary, application-specific, or niche products. This competitive advantage was (and remains) largely driven by design expertise and U.S. excellence in new product definition. Nonetheless, to sustain cost-effectiveness, U.S. innovators developed corresponding manufacturing strategies -- making due with significantly less capital investment, perhaps one-tenth of a typical commodity fab. For example, they developed techniques to permit flexible batch production of a variety of high-margin products.

Nonetheless, these U.S. production innovations have been insufficient to support an autonomous base of equipment and materials suppliers. As Japanese firms became the largest facilities investors, they preferred domestic Japanese suppliers in their purchases. The domestic supply infrastructure in Japan itself was fostered through government policy (and in particular, the entry of Nikon and Canon into photolithography directly resulted from the famous MITI-NTT VLSI project).

Driven by Japanese success in the chip market, the Japanese materials and equipment industry has surpassed its U.S. and European counterparts. It has become the world's largest and most technically advanced in the majority of significant market segments. This is significant for the future because Japanese suppliers generally appear less accessible to foreign firms than the suppliers they replace. It is routinely reported that Japanese chip firms have access to machinery and materials from domestic suppliers that are several generations ahead of what is being sold on the open market to foreign chip firms.

As markets proliferate and margins decline in the commodity area (courtesy of new Korean entry) a newly emerging Japanese capability becomes increasingly visible: a fab that can manufacture in very high volume but flexibly within the limits of a single process technology. This capability may well thrust the development of manufacturing machinery which is ill-suited to the low-volume proprietary chip strategies of U.S. producers. The regional concentration of chip production and suppliers thereto would then be reinforced to the disadvantage of producers outside the region.

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Process Sectors

The key competitive manufacturing issues in processing sectors differ from those in the other sectors examined here. The case of the steel industry accurately illustrates the major differences. A significant question for discussion is whether and how other process industries like chemicals differ from the steel case and from other manufacturing industries.

Steel: Process innovations have been at the very heart of competitive dynamics in the steel industry. In the 1960s and '70s, Japanese producers rose to the top-ranks of steel producers. This rise directly resulted from their more rapid and rationalized adoption of the two principle post-war European innovations in integrated steel-making, i.e. the basic oxygen furnace and continuous casting techniques. By investing in optimally laid-out, new 'greenfield' facilities in deep water port locations and in the scale of machinery required to make process innovations effective (e.g. BOF ovens permitted much larger pig-iron facilities upstream in the production process), Japanese firms put these innovations to productive use. In contrast, integrated U.S. producers were committed to open-hearth and traditional casting techniques (which they had perfected) and were confronted with noncompetitive production costs. During the 1960s and '70s, U.S. producers tried to modernize and gradually adopted the new process innovations. However, their facilities were neither optimally laid-out for the new innovations nor of sufficient scale to achieve the cost advantages of the Japanese. The integrated U.S. producers turned to domestic protection to defend their domestic market share.

One segment of the U.S. industry successfully engaged in competition with established U.S. producers, the Japanese and the newly emerging producers from developing countries, the so-called mini-mills. From a negligible position in the 1960s, the mini-mills today account for upwards of 25% of total U.S. steel-making capability. The mini-mills are responsible for refining the other major post-war process innovation in steel-making, the electric furnace. This process bypasses the pig-iron stage of steel production by melting scrap steel. It results in a much less capital-intensive production process but a very cost-effective one, particularly when combined with continuous casting. The major constraint on mini-mill growth has been the relatively more limited range of shapes that could be produced compared to integrated steel-making. However, improvement innovations by mini-mill pioneers like Nucorp have been expanding the range of shapes and begun to challenge integrated producers even in shapes that the majors dominate.

Meanwhile, faced with challenges from protectionism abroad and newly developing countries, Japan's major producers continued to innovate by successfully applying computer technology to automate the steel-production process and incremental organizational innovations. All of these techniques aimed at creating a flexible production capability. Today, a company like Kawasaki Steel uses a continuous flow production process to manufacture batches of steel customized for user needs along several dimensions that include thickness and tensile strength. Japanese producers have thereby remained major players on the international market. They have used their technological leadership to acquire significant holdings abroad, becoming the first true multinational steel producers. In the process, they have brought incremental process innovation to domestic U.S. producers like NKK-National, Kawasaki-Armco, etc.

What can a process industry like steel tell us about the production revolution? Aspects of the lean and flexible production model emanating from the consumer durable sectors do appear in the process industries. Firms attain steel-making flexibility through a combination of incremental organizational innovation and new technologies, e.g., the techniques that minimize down-time in changing the steel-making process to create product variety are not very different from autos. These new techniques include general purpose machinery that can be recalibrated off-line while redundant machinery operates on-line, innovations in materials and tool transport, and a work force highly skilled in rapid changeover.

Aside from similarities, there are, of course, significant differences from the consumer durable production model: steel markets are not characterized by the demand volatility of consumer markets nor by the short life-times of electronics products. The result is less emphasis on speeding up cycle times. Incremental process improvement remains more important than cutting development times as a basis of competition. Similarly, the real advantage in steel-making appears to lie with the kind of production systems integration. The issue here is how to put the various pieces of the steel-making process together into an efficient but flexible continuous flow. Decisive know-how continues to rest with the steel-maker rather than the suppliers of any particular pieces of machinery.

Chemicals: Would a focus on a different process industry such as chemicals convey a different story? The chemical industry, dominated by European and secondarily U.S. producers (with Japanese firms being factors in only limited sub-segments of the market, like electronic materials), boasts a scale-intensive, continuous-flow production process. The late 1970s shift from bulk commodity to specialty chemicals demonstrates that production innovation rests in two areas: 1) identifying and patenting new chemicals at the molecular level; and then 2) optimally breaking-down a feed-stock (normally petroleum) to produce the greatest number of products with a minimum of wasted by-products.

Production scale and cheap feed-stocks used to be the essential basis of competition with commodity chemicals. Today, flexibility as a means of reducing a given feed-stock to different products has become the new basis of competition with specialty chemicals. Flexibility appears to be achieved here less with clever, incremental organizational innovations and more with clever, molecular manipulations. As with steel, the essential know-how appears to rest with the producers rather than the machinery-maker. The current industry wild card is biotechnology; this poses yet another question: will fermentation scale-up create a wholly new production technology that challenges traditional chemistry?

Corporate Instruments of Adaptation

For firms attempting to adapt to global competition the question is which operational instruments to use. Those instrument range from notions of "just-in-time", robots and machine tools and telecommunications. More than a list of instruments, there is a list of debates about the strategies and tactics that have emerged. Some discussions emphasize the increasing importance of product variety and business speed. They begin either by noting that firms face drastically shorter product cycles, or that the ability to compete now rests on the ability to differentiate products and adapt them to varied markets. This often then opens the discussion about how to adjust commercial operations and marketing methods to exploit the new capacities for differentiated product. Other discussions emphasize the need to introduce organizational or technological flexibility within their mass production operations of American firms to differentiate products during production. At stake in the current re-organization and the equipment choices which embody them is the difficult transition from producing large volumes of standardized product to producing differentiated batches without losing the benefits of traditional mass production.

This issue of organizational innovation is crucial. Indeed the problem is conceptual as much as anything else. Firms certainly can draw upon a variety of new technological tools, from NC machine tools to CAD/CAM systems including telecom networks. But what do they do with them and how do they use them? The range of new manufacturing arrangements (e.g. the various implementation of "just-in-time"), new logistics know-how (e.g. autonomous production islands linked through new parts circulation schemes, such as Group Technology), and stock management methods (e.g. Materials Requirement Planning) together provide the firm with a substantially rejuvenated and enriched reservoir of methods to organize work and production. The relationships between headquarters and subsidiaries, and those with partners and sub-contractors are similarly re-organized. The basic principle behind the new forms of interaction is to retain the economic advantages of integration, while decentralizing to achieve lower fixed costs and to better specialize production without sacrificing flexibility. These contracting arrangements also provide leverage by large buyers over suppliers and allow the more effective management of risk and ambiguity (25). Thus, the combination of internal organization innovations with new kinds of external links, leads the firm towards new and varied social "network" forms (26), which are integral parts of its competitive drive and its adaptation to the environmental changes described above. In the end, the set of constraints just reviewed boils down to one essential challenge: Can firms create relative advantage and establish long-term competitiveness by developing the capacity to combine economies of scale and economies of scope, mass production and differentiated products in new organizations?

Instruments of Adaptation: Telecommunications and Production Innovation, The New Infrastructure

The adjustment of firms though does not take place in isolation. It occurs in contexts that shape and constrain choices. Some of those constraints are institutional and political, as emphasized in both national studies and analyses of industrial districts. Some of those constraints lie in the industrial structure and what we have labelled the supply base. Finally, others lie in the public infrastructure of roads and bridges, and now telecommunications. We highlight telecommunications here. We do so because the importance of telecommunications to production transformation is now becoming clear. Not only have telecommunications technologies become the indispensable backbone of new production arrangements, but, more importantly, information networks constitute active components of broader production systems. This means three things: First, the networks' configuration closely reflects the organization of the production systems they support. Second, production systems are only flexible in so far as the network behind them can be re-configured. Third, the ability to conceive of new organization modes rests on a clear understanding of the networks' possibilities. As a result, telecommunications network innovation, driven both by technological development and the politics of deregulation in each advanced country, has suddenly become entangled with the emergence of innovative production strategies. Let us look at two cases, autos and textiles, and then at the general questions.

The general issue is that network applications related to the manufacturing process generate major needs for intelligence and broadband. Consequently, manufacturing companies often find themselves at the forefront of the drive to deploy advanced networks. Individual steps in the manufacturing process rely increasingly on automation. Islands of automation have emerged around discrete sets of technologies and processes. Each island creates and processes an increasing amount of digital information, which describes product tools or processes. The current challenge is to link and integrate the various steps. Networks linking various CAD, CAM, or CAE systems, along with NC machines and robots are the obvious. The way these links will work, however, is not obvious.

At the most basic level, information has to be passed along from one step to the next. Manufacturing engineers must get and be able to use the data generated by design engineers which describe the part they are trying to make. The main issues are standards (so the data is reusable), the main application is file transfer. Also at the basic level, some resources must be shared, that is, certain complex CAD applications still run on mainframes, accessed via remote terminals.

The manufacturing networks built today will go beyond these basic applications. It is a move from networked computers to cooperative computing, to use HP's phrase. It is no longer simply a question of passing along a file but of establishing interactions among the various stages of the manufacturing process. That is, CAD systems must talk to CAE systems to take engineering constraints into account. Rather than sharing an application on a single mainframe, users now run their applications on their desktop workstation, but must share gigantic distributed databases. Further, access to those files must be swift; it has to feel as if they were local files, even when they are stored half way across the world and used simultaneously by many design or engineering teams in various locations.

Ultimately, as networks come to embody the manufacturing process, they also need to be extremely flexible so they can be reconfigured, as the process is modified. That very flexibility obviously requires network intelligence. It also requires extra bandwidth. Companies need to have bandwidth available that they can waste, by trying out new application ideas when they come up, without having to optimize them for network use.

GM vs. Toyota: Globalization in the automotive industry has meant the necessity to sell cars in the very diverse marketplace of the globe. Competitive success has come to rest on the auto makers' ability to adapt their cars and production methods to the diverse, rapidly-changing demands of the globe's customers.

The past situation, in which American auto makers had proved masters at the game of internationalization, is now reversed. Toyota succeeds better than GM in today's global markets. In GM's view, a substantial source of imbalance can be traced to the auto makers' respective "art-of-part" cycles: On the average, it takes GM twice as long as Toyota (5 years vs. 2.5 years) to move from a stylist's sketch for a new car concept, to actual new cars in dealers' showrooms. This obviously leaves Toyota in a better position to follow changes in its marketplaces.

Toyota's swiftness rests above all upon the production processes which underlie its lean factories. Carefully crafted sets of interactions -- within and between work teams, as well as between Toyota and its business partners -- constitute the foundation of the Toyota system. Some of these systems would seem obvious candidates for automation through information networks: indeed, why not replace the kanban paper slips with electronic mail or electronic data interchange (EDI), making the system faster and more reliable? Interestingly, however, Toyota has been extremely reluctant to introduce such technologies, lest they would disrupt the delicate balance of its current system.

GM's approach offers a striking contrast. GM traces its slowness not so much to the factory as to its cumbersome Vehicle Development Process (VDP); moreover, GM believes that sophisticated information technology is the key to overcoming its difficulties. A massive corporation-wide effort is currently underway to make "Fast-to-Market". Dubbed C4 (the four Cs stand for CAD, CAM, CIM & CAE), this project ultimately aims at deploying a standardized, broadband network through which all GM designers and engineers will be able to interact in real-time, through interlinked computerized design systems.

In their respective efforts to address globalization, GM and Toyota are following markedly distinct routes. In particular, while Toyota resists introducing information technology within its adaptable process, GM hopes investment in adaptable information technology can substitute for process changes, or even drive them.

Apparel: Benetton vs. Levi Strauss: Globalization in the apparel industry has meant significantly different things for different producers. For Benetton, whose products follow fickle fashions, the challenge was to detect and address rapid fashion changes in a wide variety of markets spread over the globe. By contrast, for Levi Strauss, whose main product -- the blue jean-- seems impervious to fashion changes, the challenge came from East Asian makers of cheap copies and was compounded by their commitment to keep all production in the U.S..

The two apparel makers have therefore allowed significantly different approaches in their respective globalizations. Benetton relies on an extensive network of subcontractors to deploy a flexible production organization. It draws considerable information about the shifting moods of the global marketplaces from its electronic ties to its retail stores, which quickly transmit back to the production facilities data on what is selling.

By contrast, Levi Strauss has focused its efforts on smoothing the materials flows within its own, vertically integrated production and distribution organization. Rather than deploying a proprietary communications systems with the retailers of its jeans, Levi Strauss has fostered the emergence of industry-wide standards for electronic data interchange and the growth of third party computer systems providers able to automate the retailers operations. Levi's purpose was to make its "filiere" -- rather than simply itself-- more efficient so that, as a whole, it would better be able to compete against foreign suppliers.

These two examples show how in one sector, apparel, globalization implies radically different choices for different companies. While flexible specialization was the best answer for Benetton in addressing global fashion shifts, Levi Strauss needed primarily to perfect old-fashion mass production processes.

The telecom case emphasizes the diversity of instruments in the reorganization of production and the multiple angles through which it can be examined. Moreover, it emphasizes the need for reformulating the policy debate across a wide range of sectors. The central issue that emerges is that the new network economics has to be about learning, about developing the balance between public and private networks to permit experimentation and diffusion, and about network flexibility. The old economics of marginal pricing is largely subsumed in a new debate. Policy must acknowledge that infrastructure affects both the resources available to firm and the terms on which those resources can be combined. Telecommunications and our supply base questions fall into this category of infrastructural questions. Those policies shape the "environment" of the firm and involve "externalities". Two sets of such policies can be distinguished. One set involves policies that develop production inputs. That is to say, they involve education and skills policies to raise the quality of labor as well as R & D policies. One debate across countries involves how far those policies affecting inputs, justified by externalities, should extend. It is widely agreed, for example, that government policies should finance public education to assure literacy, but should policies finance advanced education for engineers? More controversially, should programs to develop and diffuse sector-specific technologies or products be supported? The U.S. supports the agricultural extension service but quarrels about the place of Sematech. Another set of policies involves infrastructures such as roads, bridges, and telecommunications networks. Those infrastructures affect the terms on which the production inputs can be combined.

III. The Theoretical Debates: Accounting for the Pattern of Place and Practice

Present theoretical debates do not address this diversity. They begin from quite divergent lines. They generalize from sharply different places and sectors. Some begin with the logic of technology, and others with the character of social organization. They often have the appearance of being competing positions. In fact, the task is the more delicate one of delimiting the conditions under which each holds.

The present theoretical debates only partly help to answer questions about the responses to globalization. But they provide powerful starting points. Rather than review the literature, we group the work into categories to situate the conceptual and analytical contributions and to delineate the limits as a place to begin a discussion.

The Work Place and the New Technological Trajectory

The first analyses focused on technology and on the new potentialities embodied in the micro-electronics revolution. Following the works pioneered by the Science Policy Research Unit (SPRU) in the 1970s, a number of studies have progressively established that the micro-electronics revolution -- now labelled the "programmable automation" revolution -- gave rise to a new wave of automated machine tools, that ended with CIM technologies. Thus, the thesis was that new tools were available to face the uncertainty of the markets inasmuch as some "flexibility" in the process operations could be build into the new integrated complex of machines. Several case studies were done on this basis, illustrating both the potentialities and the limits of such modes of adaptation for dealing with the new challenges raised by new market characteristics in an age of globalization.

Consistent with this approach, but using his own tools and methodology, Jaikumar has provided new elements for the debate (27). Focusing on the work place, Jaikumar tells us an extraordinary story: Additional resources of technology and of organization have continuously shaped and reshaped control techniques to face the evolution of demand needs, while giving rise to improve products. The detailed story concerns the gun industry (the firm is Berretta), but the conceptual outputs (lessons) are many and of great importance for our concerns. From the Jaikumar study we especially note:

> - A new reading of the whole history of the labor process. Its originality is that the focus is on control techniques. From this particular reading (Jaikumar) Jay is able to distinguish six different phases of the history (the English system, the American system, the Taylor scientific, management, the Dynamic world, the NC era, and finally the Computer Integrated Manufacturing period) (28).
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> - For our own concern a very useful conclusion of the paper rests on the fact that the whole story can be read as the movement described by a large circle, which started with a mix of techniques combining human craft plus universal machines dedicated to high quality products, but in very limited series (in practice: dedicated products). The story passes through the standardization process (with its classical attributes: repetitivity, interchangeability...) to end with a new universality building onto the machines and the organization but capitalizing the benefits of mass production.

For us this story means that, at least in certain sectors, the challenge of quality and differentiation can be assumed, without losing anything of the benefits of the mass production techniques, by appropriate means introduced solely at the workshop and work place level. To what extent this conclusion is general and can be used for other sectors and competitive situations is a question to be answered. But a substantial contribution is made to our debate. This story of the Berretta arsenals tells us something very important about the potential direction of the ongoing technological trajectory since, starting from universality (i.e. variety and differentiation) but in very small lots, a way was found after the standardization episode to re assume the requirements of product differentiation while keeping the benefits of the mass production.

The Social Division of Labor and Industrial Districts: Lessons from the Italian Experience

The story about the Italian districts (see Capecchi, Bgansco, Brusco) is very different, and, in a fundamental way opposite from that story told so well by Jaikumar. Contrary to Jaikumar's study -- based on the technological trajectory hypothesis and focused on technology, machines and work places inside the firm -- the Italian school focuses on the social division of labor between firms, on questions of industrial structure and organization linking firms.

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Starting with case studies in sectors like apparel, ceramics and machine tools, the Italian scholars soon elaborated a theoretical vision of some adaptations to the challenge of differentiation. The focus is on places much more than on sectors (even if the characteristics of the sectors concerned matter). Their contribution consists essentially of demonstrating that, under certain conditions, external economies which grow out of agglomeration can exceed the advantages of scale in large, integrated firms. When the industry confronts markets characterized by segmentation and differentiation, the division of labor among mid-sized firms can constitute a principle of economic efficiency. Pursuing this approach, the Italian scholars were led to a reexamination of the Marshallian approach to industrial districts by showing how the numerous advantages associated with this productive organization (or form) can constitute an adaptive response to the challenge of differentiation. In this analytic approach, many empirical studies in diverse areas of the world (Germany, the U.S.) confirmed that variegated forms of firms "co-contracting" with one another could provide an effective response to the challenges of globalization inasmuch as these industrial districts are often strong exporters.

Nonetheless, the Italian scholars themselves have continued to insist on the specific conditions that define and limit the responsiveness of the industrial district. These include: 1)Technical limits: The product must be divisible in such a way that the division of labor among firms can work (petorochemicals do not exhibit this divisibility). 2)The product must be dedicated products with short life cycles. 3)Social conditions: a skill and entrepreneurial base in the local culture, access to financial and commercial markets, and a set of specialized roles such as those played by the *empanatore* in Italy. These elements explain why the Italian industrial districts are, for the most part, located in the Third Italy and by-passed the Second Italy.

Aware of these critiques and of these limits to the Italian form of the industrial district, a second generation of work by Scott, Storper and Walker posited an expanded notion of an industrial district to include aerospace giants and their suppliers located in southern California in what they termed Industrial Agglomerations. But the theoretical advantages of this expansive approach are not altogether clear as these kinds of agglomerations have always existed. The inclusion vitiates the critical distinction behind the revival of the notion of industrial districts, which was, after all, to emphasize and embody the distinction between scale and scope.

The Flexible Specialization Hypothesis: Joining Micro and Macro Issues in an Historical Perspective

The contribution of the flexible specialization approach (29) is at least two fold. First, it combines numerous case studies of various forms of industrial districts with an historical/social reinterpretation of industrial trajectories. This perspective permits a relativization of the form taken by capitalist development -- mass production -- and a demonstration that other configurations of the productive structure are quite as effective as mass production. The second contribution is based on an examination of the potential embodied in industrial districts. It formulates the hypothesis that different forms of flexible specialization develop as an effective response to the challenge of differentiation, which lay at the heart of large portions of current market competition. Perhaps most important, flexible specialization proves to be an enormously stimulating approach and it engenders new energies, interest and work.

Numerous scholars have, however, subjected the flexible specialization approach to much of the same criticism as those directed at the work of the Italian school of industrial districts. The effectiveness of the flexible specialization principle seems limited to a circumscribed set of sectors and competitive configurations defined by dedicated products for segmented markets. Furthermore, substantial evidence has been accumulated to show that, in many domains, the quest for economies of scale -- pursued through the same means of "giantism" -- is still a critical issue. This is true for classic sectors such as autos, televisions, etc., and also for new and emerging products such as memory chips and most consumer electronics. In all these cases, giant firms have demonstrated that they are able to introduce new organizational concepts and new electronics-based productive tools and systems to conserve the classic advantages of scale economies, while, at the same time, introducing flexibility and differentiation sufficient to meet (and even to promote) shifts in consumer demand. In fact, flexible high-volume production is an inescapable, triumphal reality.

Dynamic Flexibility, Flexible Automation and the New Micro-Foundation of Volume Production

Other analysts -- often those concerned with Japan and sectors influenced by Japanese competition -- have emphasized the emergence of a distinct approach to volume production. This work often builds on the intuitions formulated by B. Klein [1986] (who first introduced the "dynamic flexibility" hypothesis) and often benefits from the numerous stimulating works based on the flexible specialization hypothesis. But it goes in a very different direction (30).

The main contributions of these approaches could be summarized as follows. Differentiation and flexibility are indeed key challenges to the firm. However, viewed from the vantage of the firm, the concrete choices and the possible responses are very different in each sector. Moreover, viewed at the level of the national economy, the choices and the responses are likewise quite varied. In more theoretical terms, the end of the mass production paradigm does not mean the end of the hegemony of large firms and the search for high-volume techniques of production. In fact, besides the models of small, flexible co-contracting firms as illustrated by the industrial districts studies, new models of large firms based on the high-volume production and dynamic flexibility principle of efficiency are also emerging. The masters of this art are triumphing -- witness Matsushita and Sony. According to some authors, the ensemble of the Toyota model of production, recently baptized "Lean Production" by the MIT group, is presented as the new hegemonic mode of production, the triumphal successor of Fordism. It is entirely constructed on the hypothesis of high-volume flexible production (31).

Flexible high-volume production certainly has a distinct form of subcontracting. The contract networks that depict this system are, however, vertical and dominated by a few large firms rather than by the horizontal co-contracting characteristic of industrial districts. There are many innovations in contractual forms emerging in both horizontal and vertical networks. These networks produce what has been labeled "relational rents", that is, special gains captured from group-specific economic returns (32).

To summarize, the thesis sustained by the approach can be presented in the following way. At the micro-level, we are experiencing a set of new micro-foundations that are a combination of new organizational concepts, electronic machines tools and new protocols in subcontracting arrangements. These arrangements are consistent with both small-lot dedicated products and mass markets, and, moreover, are able to revitalize the principle of producing in high-volume, long-series products, even in case of unstable and differentiated demands (33). At the macro-level, the "virtuous circles" of the old fordist growth model appear to be lost; many different "post-fordist" ways of adapting to the new challenges posed by globalization are ongoing. The German and Japanese models for this type of adaptation are particularly successful.

Linkage and Its Multiple Meanings

The basic approaches outlined in this section, which range from industrial districts to flexible specialization, from virtual integration through virtual-districts on telecom networks, commonly reside on a well-established set of concepts called, in the regional planning literature, linkage. The basic approaches often differ in how those linkages are institutionally organized -- in horizontal or vertical networks, local districts, national markets or global regions -- and how the gains are captured, particularly in the importance of scale and large firms. Nevertheless, it is important to point out the emphasis on linkage common to these studies.

As every first year regional planning student learns, industries have a pronounced tendency to cluster spatially. The 1980s data shows that the concentration of automotives in the mid-west is not especially pronounced. Most manufacturing industries are even more agglomerated (after adjustments for special circumstance industries such as water, or mineral related locations). For most industries, location is best understood over time. The locational origins are most often "arbitrary", the results of accidents of history rather than broad questions of factor endowments and prices. But then an identifiable dynamic sets in as growth generates positive externalities, as scale generates specialized supplier markets and networks, which in turn favors further concentration of new enterprises, skilled labor, speciality suppliers, special services, etc. The process cumulates and the regional economists map takes form. The generating principle is less pecuniary externalities than technological externalities, as Alfred Marshall put it in his classical treatise.

A linkage approach has always been part of BRIE's work, due in no small part to our origins which extend, to an important extent, into regional planning. Much of the substantive research on industrial districts, network organizations, flexible specialization, corporate unpacking, virtual integration, technology diffusion, and, of course, supply base, can legitimately be understood as efforts to define kinds of linkages, their extent and their modes of functioning.

An older development literature distinguished between forward and backward linkages. Their content, however, remained generally empty. Input-Output analysis similarly says nothing about the nature of linkages that relate buyers to sellers, and therefore has a limited role in our deliberations.

The way in which know-how diffuses in differently-configured industrial settings is central to our concerns. Here, national differences in industrial structure, labor markets, cultures, etc. play a major differentiating role, conceptually dividing, districts like Silicon Valley from Japanese Keiretsu from German industrial districts. We would like to embed our analyses of different national and sectoral experiences in a concrete examination of the pattern of linkages in which those national experiences operate in order to compare them.

To conclude, this short survey of the available tools and approaches, one can easily see that if there are some strong points of agreement among the scientific communities about what are the challenges, much has to be done to integrate the different contributions on a more complete, and hopefully unified, representation. To our understanding, at least two crucial issues must be investigated in more detail. The first one consists in identifying the various way of facing the novelties precisely: to what extent and in what sense "sectors" matter? Our intuition is that there is a lot to learn from a cross-sectorial comparison. Some general and theoretical arguments can be drawn from carefully identifying the different ways of adapting to the new context. This requires taking into account what is specific to the internal economy of each sector (technical constraints, forms of competition...). The other relevant dimension to be explored, seems to be the "national" issue. Even if globalization is running, and if regionalization is a part of this rapidly advancing process, in many senses the world economy is not yet "global", and nations still do matter. National regulations, heritages evaluated in terms of industrial structures, educational systems, R&D apparatus and policies, international specialization, still remain quite different from one country to another and strongly affect each national trajectory to face the new challenges.

IV. BRIE's Approach

BRIE finds itself torn between the enormous sophistication of the theoretical debate and the persistent diversity and contradictory character of many of the empirical snapshots and theoretical arguments. We hope therefore to reassert the capacity to examine these changes fresh by proposing a "naive" research design. The trick is how to build on what we know without prejudging what we see. Therefore BRIE is organizing a structured, cross-national comparison of production innovation in industrial firms. Within each of the countries under study, we will assemble a group of companies whose representatives will meet regularly. We will prepare and lead group discussions of production innovation issues. Complemented with additional research and interviews, these discussions will provide the evidence for our study. This research methodology is an effort to duplicate the form, and the success, of the BRIE Telecommunications User Group (TUG) project.

Based on this simple design, the Telecommunications User Group project produced substantive empirical knowledge and insight into production innovation issues. While there were many studies of competition in telecommunications and anecdotal case histories of how telecommunications services had given the advantage to individual firms, nobody had systematically studied the role of information networks in the current transformation. Our initial research question for the telecommunications user group was intentionally naive and simple: How do firms use telecommunications to create advantage in their own sectors?

The initial user group included a dozen firms and met monthly. Each firm in turn presented its own case, which was prepared with the assistance of a BRIE researcher, as the basis for a group discussion. We then created similar "user groups" in six other countries, which also met regularly. This strategy permitted us to examine both how business strategy and regulatory environments shaped the use of telecommunications as a competitive instrument. It provided insight into public policy decisions, business strategy choices and the limits of traditional regulation economics in a new telecom era. Finally, and critical to the success of our research effort, this process proved useful enough to the companies to motivate their sustained participation over the two-year life of the project.

The Production Innovation Project will follow a similar structure. It will focus on how firms in different countries use production innovation to respond to market competition. In contrast to the Telecom User Group, which began with a virtual blank slate, this project will build on the numerous studies on international competition and the growing set of theoretical and empirical production innovation studies. With simple initial research questions, we hope to generate fundamental discussion and analysis of how production innovation alters the terms of competition and serves to create advantage. Put differently, the group meetings will serve to explore three major questions:

1. How and for whom is production innovation creating advantage in each industry?
2. What is the decisive element of competition in each sector, and what is the place of production in relation to that decisive element?
3. How are firms venturing to create production advantage?

Such questions resist statistical investigations or formal surveys. As was our experience with the Telecom Project, the real answers only emerge slowly, through sustained and repeated discussions among knowledgeable industry insiders. Further, for these people to accept revealing detailed and often sensitive information, they have to be convinced that they will themselves benefit from the ensuing debate and analysis. The methodology we propose, based on regular meetings of select company participants, is the best way we know to create the context for such interaction.

Extrapolating from the stories of a few firms to sectoral or national dynamics, however, does create research challenges. Which firms should be selected? How should the findings in each sector be situated? Also, how do the findings develop into a national story? These questions require careful attention from each national academic coordinator.

In this project, the coordinator of each user group has three basic tasks. The first is to design a format (protocol) for giving presentations to the group. Second, the coordinator must put case findings into a national and industrial context. In other words, the coordinator must analyze the materials on national approaches to production innovation and industrial competition, considering the issues raised in Section I. Finally, the group of coordinators, drawing on the distinctive expertise of the group's members, must review industry analyses and national design presentations.

Permanent research groups in France, Spain, Germany, Italy, the United States, and Japan will be established for this research endeavor. Research coordinators in Europe and Japan will be supported by the BRIE core group. These coordinators will both organize the planning and discussion meetings to structure comparison and evaluate the industry and country material (34).

Notes

1. See Basel Concordat.
2. Raymond Vernon Sovereignty at Bay
3. Robert Gilpin, U.S. Power and The Multinational Corporation, Basic Books
4. See Hoover and Vernon for New York Regional Planning Association, 1959.
5. See Andre Gunther Frank, The Development of Underdevelopment and E. Wallerstein, The World System.
6. See James Womack et al., The Machine that Changed the World, New York, Maxwell, MacMillan International, 1990, pp. 3-73.
7. Mataloni, Survey of Current Business, June 1990.
8. see CEPii.
9. Japan's export dependency has dropped from a high point of 13.5% of GNP to 9.5% last year, thereby reverting to its historical form of domestic demand-led growth. Despite this, Japan's trade with Asia in 1989 surpassed her trade with the United States, more than doubling since 1982 to over $126 billion.
10. By 1988 Intra-pacific basin trade has risen to almost 66% of the regions total from about 54% only eight years earlier.
11. In the late 1980s, for example, Japan supplied on average about one quarter of the NIC's imports (vs. the US' 16-17%). Indeed, Japan supplied well over 50% of Korea's and Taiwan's total imports of technology products in the late 1980s, more than double the US share of Japan's imports of technology products, rising form 14% to 19% between 1985 and 1989.
12. See Dataquest Incorporated and Quick, Finan and Associates, The Drive for Dominance: Strategic Options for Japan's Semiconductor Industry, (Dataquest, 1988), pp. 4-7, citing Electronics Industry Association of Japan (EIAJ) data.
13. This characterization comes from a lecture by IBM's Director of Technology, James McGroddy, at Cornell University's Graduate School of Engineering, Distinguished Lecturer Series, May 1, 1989.
14. See Yung Chul Park and Won Am Park, discussion and data.
15. MITI, 1987 White Paper on International Trade and Investment, (Tokyo: MITI, 1987), as cited in Japan Economic Institute, "Economic Regionalism".
16. Michel Crozier, The Bureaucratic Phenomena and Reinhard Bendix, Work and Authority in Industry.
17. Womak et al., The Machine that Changed the World and David Friedman, The Misunderstood Miracle: Industrial Development and Political Change in Japan (Ithaca, New York: Cornell University Press, 1988).
18. Michael Piore and Charles Sabel, The Second Industrial Divide (New York: Basic Books, 1984).
19. Womack et al., The Machine That Changed The World, p. 1.
20. Richard Florida and Martin Kenney, "Organizational Transplants: The Transfer of Japanese Industrial Organization to the US," November 1990, forthcoming in the American Sociological Review.
21. Robert E. Cole, "Issues in Skill Formation and Training in Japanese Manufacturing Approaches to Automation", research paper, University of California at Berkeley, Berkeley, Calif., 1990.
22. Kazuo Koike, Understanding Industrial Relations in Modern Japan (London: Macmillan Press, 1988) pp. 158-61.
23. Ramchandran Jaikumar, "From Filing and Fitting to Flexible Manufacturing: A Study in the Evolution of Process Control." Working Paper, Harvard Business School, February 1988.
24. Bo Carlson and Stefan Jacobson, "What Makes The Automation Industry Strategic?" forthcoming in Economics of Innovation and New Technology, Vol. 1, No. 4 (1991), pp. 5-6.
25. Semlinger, Klaus.
26 Semlinger, ibid. Elaborations on this theme of the network firm can be found in Thorelli, "Networks: Between Markets and Hierarchies", Strategic Management Journal, Vol. 7, 37-51 (1986), and Cristiano Antonelli ed., New Information Technology and Industrial Change: The Italian Case, Kluwer Academic Publishers, 1988.
27. Jaikumar, Op cit. p 17

28. For details concerning each phase, and the dynamic underlying the whole process of transformation and one phase to another, see Jaikumar's 1988 paper, especially the résume presented (pp. 8-10).
29. Approach pioneered by Michael Piore and Charles Sabel, The Second Industrial Divide.
30. Among many others, this set of studies includes the works done by BRIE on apparel, machine tools, and semi conductors (OECD Telecommunications study, ditto number 10), and the studies done by the French regulation approach theorists (see Boyer and Coriat [1986], Coriat, L' atelier et le Robot [1990], and Coriat, "The Revitalization of Mass Production in the Computer Age", BRIE working paper no. 53, Berkeley, 1991.
31. On the solutions provided by Ohno for high-volume flexible production, see B. Coriat Penser a l'Envers: Travail et Organisation dans l'Entreprise Japonaise, Christian Bourgois, ed., Paris 1991.
32. The term is used here to parallel the formalization given by Aoki [1989] who first introduced the category of "relational rent" to describe the benefits arising from the "group-specific economies" embodied in the social network of co-contracting firms in the case of the Japanese economy. Among the various studies done on the "contractual" and/or "relational" innovations, we refer specially to the fantastic analysis given by Asanuma in both automobile and electric machines: Japanese Manufacturer-Supplier Relationships in International Perspective: The Automobile Case, Kyoto, 1988. For a stylized presentation of the main findings of the Asanuma contribution, see Coriat, 1991.
33. For a tentative delimitation of the relative domain of efficiency of the flexible specialization principle and of the dynamic flexibility principle, see B. Coriat 1990a; for resume of the argument, see B. Coriat 1990b.
34. In addition, there is a series of other Berkeley studies about production, manufacturing and industrial competition that is not conducted within the BRIE group itself. These studies include the place of skills in production innovation (Brown, Reich, and Stern) and new product development strategies (Bacon and Mowery).

A number of academic studies have argued that a critical factor in accelerating product development cycles is in the early stage of the development process, during which critical parameters of product design and marketing strategy are established. UC Berkeley faculty Glenn Bacon (Electrical Engineering), Sara Beckman (Haas School of Business) and David Mowery (Haas School of Business) are working with Edith Wilson of Hewlett-Packard Corporation and Professor Philip Barkan of Stanford University's Industrial Engineering department in a study of "product definition" in six US corporations: IBM; Hewlett-Packard; Motorola; General Electric; General Motors; and Xerox Corporation.

Each of these six firms has nominated two projects for intensive study, one of which the firm's management has deemed to be a failure and one of which it has deemed to be success. This failure refers to either project termination or inability to meet original projections following a project's release. Each project is located in the electronics industry (either a component or a systems product), occurred during the past 3-5 years and consumed "significant" internal financial and human resources. Survey questionnaires and interviews are being employed to obtain information from project managers about the project itself, its organizational and management structure, the operation of the product definition process (how was it done, if at all?) and the extent and management of change in the product definition during the development cycle. A second, shorter questionnaire and less elaborate interviews will provide information from project team members on the project's alignment with business unit strategic goals, the methods used to solicit information on user preferences, the competitive positioning of the product in the market and other issues.

The project should yield new information on a heretofore neglected phase of the product development process which will be of interest to both managerial and academic audiences. A modified version of the questionnaire administered to project team members will be developed for use as a diagnostic tool, enabling mangers to assess the their product definition quality and organization at the development project's inception. Finally, we hope to develop materials for use in courses in the management of technology. This first phase of the product definition project will extend roughly through mid-summer of 1991. Future work will compare product definition practices in US manufacturing firms with those of Japanese and European electronics firms.