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BRIE not online 4/07

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BRIE Working Paper

Creating Advantage: How Government Policies Shape High Technology Trade

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Berkeley Roundtable on the International Economy
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Creating Advantage: How Government Policies Shape High Technology Trade

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Originally prepared for the 50th Anniversary of the
Export-Import Bank, October 1984

CREATING ADVANTAGE: HOW GOVERNMENT POLICIES SHAPE HIGH TECHNOLOGY TRADE

by Michael Borrus, Laura Tyson, and John Zysman

Government, this paper argues, can influence trade patterns. Policy can create competitive advantage in specific sectors. International market outcomes, winners and losers in competition, can be set by conscious government choices. Economists often argue that the resources displaced from particular sectors by international competition will be redeployed elsewhere. Therefore, apart from the redeployment costs, which may have to be borne disproportionately by the affected sectors, they contend that national welfare may not be diminished even if foreign governments do promote advantages for their firms. We argue more strongly that policy can shape not just the position of single industries, but the patterns of comparative advantage, affecting not just the position of individual firms or sectors but the national welfare.

The analysis focuses on the effects of policy on the dynamics of competition in high technology industry. We intend to facilitate a dialogue between business practitioners concerned with the experience of their particular industries and economists speaking through their theoretical models. Consequently, we first set out the analytic framework that structures the economist's policy view of trade and then present our position within that framework. In the second part of the paper, we develop our view by looking at the dynamics of market competition and the effects of government policy in two particular high technology industries -- semiconductors and telecommunications.

PART I

TRADE IN HIGH TECHNOLOGY: THE STANDARD MODELS OF ECONOMIC ANALYSIS

The strength and the performance of the United States economy depends critically on its high technology industries. For the purpose of this discussion, high technology industries are those which have an above average level of scientific and engineering skills and capabilities, or an above average level of R&D relative to sales, and those which have a rapid rate of technological change. High technology industries, as thus defined, provide a significant contribution to overall national output growth, productivity increases, and trade. During the past decade high technology industries as a group had a rate of growth of real output more than twice that of total U.S. industrial output, and nine out of the ten fastest growing U.S. industries were high technology industries. In addition, a large and growing share of U.S. merchandise exports came from high technology sectors. Indeed, the U.S. is unique among industrial countries in the relative importance that high technology goods represent in its exports. According to recent Department of Commerce figures, between 1967 and 1980, high technology goods accounted for between 40% and 44% of total U.S. manufacturing exports, compared to between

25% and 30% for West German, French, and Japanese manufacturing exports.[1]

High technology industries are also important, in the minds of many observers, because they are developing new inputs and technology which may fundamantally change production methods throughout the economy, with major consequences for how we live our lives, both inside and outside productive organizations. Such observers tend to characterize high technology industries as strategic linkage or infrastructural industries which will shape the productive and trade profile of the entire economy. References to the second industrial revolution and the factory of the future emanate from this perspective. Even if one takes a skeptical view of such grand visions, it seems clear that the new technologies have already had and will continue to have profound effects on methods of production and productivity in a variety of sectors which themselves are not high technolgy in the sense defined above. Efforts in the United States to alter textile and, more remarkably, apparel manufacture are instances of this broader process. There is substantial evidence that the organization of manufacturing and its links to corporate strategy are being dramatically altered.[2]

Growing concern about the competitiveness of U.S. industry in world markets stems in large part from the observation that the U.S. share in high technology exports is declining in a number of sectors. Between 1962 and 1980, the U.S. share of total industrial country high technology exports declined, while the share of each of our major industrial competitors increased. A recent Department of Commerce study found that among ten technology-intensive industries examined, only two --representing some 15% of U.S. high technology exports-- showed an increase in exports relative to similar industrial country exports between 1965 and 1980.[3] These numbers disguise the extent to which trade in other sectors, such as textiles and apparel, is affected by the pace of diffusion of advanced technologies. Consequently, the trade loss from a declining position in high technology may be understated.

One must acknowledge that, to some extent, the erosion of the U.S. market share in high technology is the natural result of rapid economic development abroad, especially in Japan, since World War II. In addition, because world markets for high technology goods have been growing, the entrance of new competitors has not automatically necessitated actual declines in either the volume or the value of sales by U.S. producers. Finally, by itself the entrance of new competitors may have a beneficial effects on both U.S. and other consumers of high technology goods, by driving down the price and improving the quality and choice of the goods available.

The presumption in much of the U.S. policy debate, particularly among economists, is that declining market share and other manifestations of U.S. competitive difficulties in world markets for high technology goods are the result of natural market forces, do not harm the national welfare, and require no policy responses. Indeed, many of those who recognize that the targeting of high technology industries by foreign governments may reduce U.S. shares in these markets, argue that the U.S. directly benefits from such policies which push down the prices of high technology goods for American consumers. Such policies, in this view, may increase our national welfare at the expense of the welfare of our competitors. If foreign governments wish to subsidize American consumers by targeting high technology industries, so much the better for us and the worse for them. Such views emphasize our role as consumers who benefit from lower prices; they assume that in our role as producers --by which we earn the income to be consumers-- we can adjust to the changes imposed by trade without a reduction in our national welfare.

We do not accept these views. To explain why, we need to address the explicit and implicit assumptions on which they are based. As it turns out, these assumptions diverge from the realities of market structure and performance in high technology industries in a number of critical ways. While there is no automatic presumption that activist policies are appropriate, the lack of realism of these assumptions means that the traditional unequivocal policy recommendations in favor of free trade must be questioned.

Let us state this conclusion more forcefully; it is precisely in those high technology industries on which future U.S. domestic and foreign economic performance rests, that the standard models of economic analysis fail. Consequently, the standard presumption of these models in favor of free market outcomes is not a reliable guide to policy. The first part of the paper examines both traditional and new theories of trade and international organization to demonstrate how government actions can affect market outcomes and trade patterns in high technology industries in enduring ways. We mean something quite specific by enduring advantage. In some cases the effects of subsidy are only temporary. A government may provide trade protection or direct financial subsidies which sustain their companies. Unless the subsidy continues indefinitely the subsidized companies cannot compete. If the subsidy is removed the market will revert to what it was before the intervention or would have been without it. In such cases, the advantange created by intervention is <u>arbitrary.</u>[4] However, in other cases the effects of subsidy are permanent. Protection may provide firms the time to develop research, production, and distribution capacities at home. Subsidy may allow them to entrench themselves in foreign markets by building client loyalty, service, and distribution networks. The basis of advantage is not the subsidy, but rather the capacities created by the subsidies. When the subsidy is removed the market does not revert to its original form, like an elastic band. It has been permanently reshaped.

The traditional view of economic theory and the role of policy in high technology industry: Can government policy affect the competitive positions of individual firms or countries in world markets in enduring ways? To the businessmen engaged in international competition with foreign companies benefiting from a variety of promotional policies, the obvious answer to this question is yes. On at least one level, an affirmative answer is also obvious to economists who study the pattern of trade among countries from the perspective of traditional comparative advantage theory. According to this theory, which implicitly underlies much of the debate about the appropriate trade policy for the U.S. government, countries export goods in which they have a comparative advantage and import goods in which they have a comparative disadvantage. A comparative advantage means of course that countries export goods which they produce most efficiently and at lowest cost and import those goods they produce least efficiently and at highest cost. A nation of course can have an absolute advantage in international competition in all sectors, but it will still --by definition-- have a comparative advantage only in some sectors. Traditional theory suggests that comparative advantage depends on the relative factor proportions required in the production of different types of goods.[5] That is, a nation will tend to specialize in those sectors that require the factors of production --labor, capital, raw materials --

which it has in relative abundance. Seen through this optic, given the growing relative abundance of engineering and scientific skills and R&D effort in the U.S., it is not surprising that U.S. exports tend to be concentrated in high technology goods. Nor is it surprising that as these factors have become relatively more abundant in other industrial countries, their exports of high technology goods have also increased in importance.

From the perspective of comparative advantage theory, it is evident that government policy can affect national trading patterns by influencing the relative availability of factors of production over time. In most sectors of production on which the exports of the U.S. and other industrial countries depend, comparative advantage rests on the relative availabilty and hence the relative costs of capital, skilled labor, and/or R&D resources. The availabilities of all these can change over time, in part as a consequence of government policy to promote investment in physical and human capital and to promote R&D expenditure. Seen in this light, the growing comparative advantage of Japan in many capital-intensive and high technology goods and the declining share of U.S producers in world markets for these goods is the result of market forces the dynamics of which have been accelerated and shaped by the variety of policy differences that have produced a high investment rate in Japan and a low rate in the U.S.

The influence of government policy on the dynamics of comparative advantage over time becomes even more pronounced if one allows for the possibility of differing production technologies across countries. As extraordinary as it may seem to the participant in or observer of industrial competition, the standard factor proportions explanation of trade patterns --the textbook explanation-- assumes that all countries have access to the same production technology. In reality of course, production techniques differ across firms, across time, and across countries. Both new product and process technologies are usually embodied in fixed capital. Embodied technological progress --a term often employed by economists-- implies that policies to promote investment will change comparative advantage over time both by changing relative factor endowments and by changing technological conditions. In other words, comparative advantage is not static but changes over time, and government policy can help create comparative advantage, especially in those industries in which the exports of the advanced industrial countries are concentrated. (For those participants less familiar with economic argument who may find a more detailed discussion of this notion of created comparative advantage useful, we have attached a longer discussion in Appendix A.)

In the last few years there has been a growing recognition of the fact that traditional comparative advantage theory does not provide an adequate explanation of trade patterns and hence cannot serve as an adequate guide to trade policy formation. In particular, a large and growing share of world trade in manufactures is trade among advanced industrial countries with similar factor proportions. Furthermore, a large and growing share of this trade is intrasectoral involving two-way exchanges of similar goods produced with similar factor proportions. Indeed, a recent study revealed that in major countries very few industries classified at a medium (three digit) level of detail, had less than 30% of their international trade as intra-industry trade in most industries, i.e. international trade involved significant volume of both exports and imports.

The classical textbook trade story is different. It tells of the British trading woolens to the Portugese for wine. It doesn't even sketch the plot of the major trade story of our day, a story which is typified by Americans and Germans exchanging one type of machine tool for another. Traditional comparative advantage theory is capable of explaining intrasectoral trade flows only when it can be demonstrated that there are different factor proportions involved in the production of goods that fall within the same industrial classification. Put differently, classical theory can explain trade between Germany and France in autos or America and Japan in steel, but only if the products are made differently. The differences in the way the goods are produced must, moreover, hinge on differences in the mix of factors of production. Clearly, this is possible. If we compare Japanese and U.S. techniques in steel production or automated and labor-intensive techniques in U.S. textile production, we find that production techniques and factor proportions can and do differ within an industrial sector. These differences are likely to grow over time, as the industrial countries use their skill and R&D resources to automate heretofore labor-intensive production. For example, the organization of industrial production, and the mix of machines and labor will continue to evolve and diverge among the advanced countries as programmable automation is introduced on the factory floor.

Moreover, it should be clearly understood that variation in the factor proportions used in the production of similar goods in different national economies does not depend only on or often even primarily on national differences in the cost or availabiity of these factors. The Japanese introduced new and highly capital intensive steel production technologies when they were a capital poor country in the 1950's and 1960's for example. Different American and Japanese approaches to the manufacture of consumer electronic products in the 1960's saw the Japanese move to automation and the Americans move to cheap labor assembly. The differences depended not only on, or often even primarily on, differences in relative labor and capital costs, but also on different manufacturing philosophies that involved different uses of labor and capital.

Finally, there is no developed theoretical argument or empirical data to support the view that intrasectoral trade flows among the advanced industrial countries depend on differences in factor proportions. It appears that in the industrial sectors that characterize such trade, especially the high technology sectors of special concern in this paper, similarities in factor inputs outweigh differences. This rules out traditional comparative advantage explanations of intrasectoral trade among the industrial countries.

Rethinking trade theory: Because the simplifying assumptions of comparative advantage trade theory are so distant from the realities of international markets, its relevance to any explanation of trade patterns in manufacturing goods is suspect. Most manufacturing industries, especially the capital-intensive and high technology ones in which the comparative advantage of the industrial countries lie, are characterized by some kind of increasing returns to scale, are imperfectly competitive to some degree, and involve substantial amounts of risk and uncertainty. Under these conditions, the traditional conclusions that free market outcomes are really desirable, that there are mutual gains to free trade for all trading partners, and that there is no potential for welfare improving government policy must be re-examined.

Recently, a group of economists, a group well represented at this conference, has developed new models that try to address some of the shortcomings of comparative advantage theory noted here. The models have two main objectives: first, to explain trade flows, such as intrasectoral trade flows among similar countries, that cannot be explained by this theory; and second, to examine the effects of government policy on trade and welfare outcomes.[6] A characteristic of these new models is that their results rest on very special assumptions. This is to be expected because once one leaves the world of constant returns to scale and perfect competition there are possibilities for a wide range of alternate economic behavior and for multiple market outcomes. No longer can one assume that firms compete by price alone; no longer can one rule out the interdependence of actions taken by different firms and goverments competing in the same world markets; and no longer can one rule out the possibility that some market outcomes are preferable to others in terms of national wellbeing.

Despite differences in the underlying assumptions of the new models, there is a basic similarity in their conclusions that under imperfectly competitive conditions there is potential for government policy to affect the competitive positions of individual firms and countries in world markets in enduring ways. In many cases, the conclusions of the models simply confirm intuition about the possible effects of government policy under such conditions. For example, it is not surprising to find that under conditions of increasing returns to scale, of either the production or learning curve variety, government policy to protect domestic markets and promote exports can reduce per unit costs, allowing both firms in the protected/promoted industry and all firms that purchase inputs from such firms to become more competitive in world markets. This kind of intuition has motivated Japan's postwar strategy of insulating its domestic firms from foreign competition until such time as they have developed the domestic output base required to realize production and learning curve economies. Thus, for example, in successive decades the Japanese successfully used this strategy -- for steel in the 1960s, semiconductors in the 1970s, and fiber-optics in the late-1970s, early 1980s.

In steel, state intervention closed the domestic market to preserve it for Japanese firms, staged investment through a series of rationalization plans in the closed market to avoid overcapacity, and helped to manage excess capacity when it did occur. In 1960, Japan produced just over 20 million net tons of steel, by 1970 over 100 million net tons a year was being produced, and Japan had used its scale advantages in its closed market to become the world's most efficient producer of steel, exporting about 40% of its domestic production annually. In semiconductors, Japan again used a closed domestic market both to buy its firms time to respond to U.S. innovations that would have otherwise overrun the domestic Japanese market, and to provide a mass production base off of which Japanese firms could enter world markets with product at competitive prices. Japan was not a factor in world semiconductor markets in 1970, but by 1980 it had leveraged production in its domestic market into a leading world market share in certain semconductor memory devices -- precisely those devices that were most amenable to cost reductions through high-volume production in a closed domestic market. Finally, Japan pursued a similar strategy in fiber-optics, particularly for the production of light-guide cable. By refusing to permit Corning Glass to sell such cable in Japan in the early 1970s, when Corning had a massive advantage as the world's first volume producer and would have easily captured the Japanese market, Japan bought its domestic light-guide producers time to develop an alterative production process and reach commercial-scale production. Today, Japanese producers own their domestic light-guide market, and have begun to penetrate the U.S. and world markets successfully.

As these examples suggest, it is important to emphasize that while such a policy of protection may be temporary, its effects on the competitive capabilities of the protected firms can be enduring, since the economies of scale --for example-- persist even after the protection is removed.

Another intuitive example from the new models concerns the role of government policy in shaping competitive outcomes in industries in which R&D and technological change are important. As is well known, the returns to innovation and diffusion are extremely uncertain and very risky for the individual firm. Government policy measures that help underwrite this risk in a variety of ways, including protectionist measures that raise the expected return on R&D by providing the protected firm with a more reliable market, will increase the amount of R&D that is undertaken. Once again, a temporary subsidy or protectionist measure can have an enduring effect since even after the protection or subsidy is removed, the technological advantage gained from the R&D effort can leave the firm in a permanently improved competitive position.

Again, Japan's semiconductor industry provides an ideal example. Working behind the walls of the protected market described above, MITI and NTT together organized with Japan's major producers a set of R&D projects aimed at developing world scale competitive abilities in semiconductor design, development and production. The most successful of these projects was the much-heralded VLSI project, from 1976 to 1980. By joining together in this government-organized and subsidized cooperative research aimed at developing and diffusing the knowhow to produce advanced semiconductor devices, Japanese firms were able to develop world class competitiveness in far less time and at far less cost that they would have achieved operating independently. NEC, for example, estimated that it was able to develop certain memory devices through its participation in the VLSI project about 5 times faster and at one-fifth the cost than it would have taken working independently.

This position is explicitly argued by many Japanese analysts, whose interpretation of the dynamics of the development of the semiconductor industry is similar to ours.[7] In fairness they draw different conclusions about current market dynamics and different policy implications. As these examples demonstrate, the new models of international trade present a variety of circumstances under which government policies can have an enduring effect on trade flows and competition in world markets. What is more ambiguous is whether national welfare will be improved by such policies. To answer this question requires additional assumptions about such things as the actual form of the policies used, their costs of administration and the costs they impose on different producing and consuming groups within a country, and the responses of both national and foreign firms and of foreign governments to the policies undertaken. In an endnote we describe one effort to do this.

The traditional theory of comparative advantage, by contrast, indicates that policymakers should be sanguine about foreign market intervention. Taken collectively the new models suggest, despite this ambiguity, that domestic policymakers cannot assume that the efforts of foreign governments to protect and promote their firms in international competition will not harm the domestic welfare. Given the characteristics of the industries in which firms from the industrial countries compete on world markets, there is no presumption that free markets and free trade produce the most desirable outcome from a national point of view or that foreign government efforts to protect and promote their firms work to our advantage by subsidizing our consumption.

These conclusions apply with special force in the high technology industries which tend to be imperfectly competitive, exhibiting a variety of externalities and market failures. The nature of the R&D process underlies these market difficulties. There are usually a wide variety of ways in which existing products or processes can be improved, and several different paths toward achieving any of these improvements. Ex ante it is not certain which of the objectives is the most worth pursuing and which of the approaches will prove most successful. More fundamentally, the uncertainty arises not only because there is randomness in which of several possible outcomes may occur, but because it is impossible to identify all possible outcomes in advance -- real uncertainty or real surprises exist, not just disagreements among informed individuals about the probability of known possible outcomes.

Second, external economies are usually involved in R&D because the returns to the R&D process can be appropriated only to a limited extent by those who engage in it. When new products or processes are developed, it is extremely difficult to sell or transmit them without allowing some information of their nature into the public domain. Consequently, the costs of enforcing property rights to R&D results are quite high, and the ability of others to share in the returns to such results without paying a price to the innovating agents is quite large. These inherent difficulties in appropriating the output of R&D create externalities which are presumed to make the private return to R&D significantly smaller than the social return, and existing empirical studies have confirmed this result.[8]

Third, there are increasing returns to R&D of both the traditional and the learning curve varieties. R&D expenses are fixed costs, generating economies of scale in the production of goods in which the results of R&D are embodied. In addition, R&D-intensive goods tend to be precisely those for which learning curve economies are most important, because only with production experience can the full potential of the underlying product or process technology be realized. In the presence of increasing returns, there are high barriers to entry in R&D-intensive industries, resulting in oligopolistic market structures.

All of these reasons for market difficulties in R&D-intensive industries are well established in the economics literature and support the conclusion that market outcomes in international competition are not automtically socially optimal. This complicates life because it means that, there are no automatic policy answers. Moreover, recent studies in the economics of innovation suggest that these difficulties are becoming even more important in modern technological circumustances.[9] Both market and technological risk are increasing. Lead times for new product development are becoming longer for both technological and regulatory reasons. At the same time, the very fact of rapid technological change raises the risk that a given invention will have a short life before the entrance of new competitors will bid down its returns. Ironically, innovations in communications, information processing, and transportation that link together world markets in high-technology products have probably shortened product life cycles, thereby making it even more difficult for those engaged in R&D to appropriate the returns to their activity. Moreover, given the degree of technological sophistication and specialization involved in product and process innovation. R&D costs are increasing and tend to be greatest at the earliest stage of development, when uncertainties are also the greatest.

The literature on the economics of innovation also suggests several other reasons --besides those of risk, appropriability of returns, and increasing returns-- for market imperfections in high technology industries. Scholars of the R&D process emphasize the systemic nature of many important innovations. In contrast to a stand-alone or autonomous innovation which can be introduced without modifying other components or products, a systemic innovation may not only permit but may require significant modifications in other components or products. Examples of systemic innovations include front wheel drive which necessitated modification of basic auto design, jet engines which necessitated new stress resistance airframes, and in telecommunications, digital switches which are forcing the redesign of entire communications networks, and fiber optic transmission which requires the redesign of transmission systems to incorporate fundamentally new optoelectronic transmission components like laser diodes and light-guide repeaters. Examples of autonomous innovations include the transistor which could be incorporated into existing radio design and power steering which did not require the redesign of the automobile.[10]

The term "systemic" connotes strong interdependencies in the R&D process. When an innovation is systemic, the speed of innovation and diffusion will depend on the degree of coordination among interdependent actors, any of whom will face significant risk acting alone. This has led some scholars in the industrial organization literature to conclude that systemic innovations require the kind of coordinated information flows and coordinated investment plans that are not produced by hands-length, price-mediated relationships among firms but by stronger forms of organizational linkage, such as vertical integration.[11] From a national perspective, this suggests that government policies to promote the flow of technological and R&D information among interdependent firms or to promote the coordination of investment activities in a variety of related products can speed the innovation process while policies that hinder integrative efforts among firms can harm it. We note that many Japanese development programs are aimed at joint development of critical generic technologies. They are thus intended to speed the innovation process.

The innovation literature also draws attention to another kind of interdependence in the R&D process -- the interdependence or "connectedness" between a technological change and prior developments in the same technology and complementary or facilitory advances in related technologies. In the words of Nelson (1984), "many technologies advance over time in what might be called an evolutionary manner, with today's round of R&D activities aimed to improve upon today's prevaling technologies in cetain particular directions or to create variants better designed for certain particular purposes."[13] As a consequence of this kind of technological interdependence, firms have to be plugged into a whole range of past and contemporary technologies that are related to their individual R&D efforts.

For example, knowledge of auto manufacturing or airplane manufacturing has promoted innovation in machine tools, and advances in machine tools have allowed innovation in a range of other industries. The technological interplay, the plodding adjustments and improvements, are as critical if not more so than dazzling breakthroughs. Economic historians have well documented this in tracing industrial development. Rosenberg, another well-known scholar in the economics of innovation, has described the interdependencies in the process this way:

> The ways in which technological changes coming from one industry constitute sources of technological progress and productivity growth in other industries defy easy summary or categorization. In some cases the relationships have evolved over a considerable period of time, so that relatively stable relationships have emerged between an industry and its supplier of capital goods...
>
> Often, however, an innovation from outside will not merely reduce the price of the product in the receiving industry but will make possible wholly new or drastically improved products or processes...
>
> The transmission of technological change from one sector of the economy to another through the sale of intermediate output has important implications for our understanding of the processes of productivity in an economy. Specifically, a small number of industries may be responsible for generating a vastly disproportionate amount of the total technological change in the economy.

Given the complex interdependencies in the R&D process, a particular product, such as a new machine tool or a new oil refining method, does not embody the entirety of a new technology. The know-how, the understanding of how the technology was developed and how it can be used or modified, extends beyond the product into the network that developed the technology and helps apply it. This know-how is untraded information embodied in people. Access to innovative products is not always sufficient to diffuse the innovation throughout the economy or to make sure that all of the possible applications of a new technology are realized. The more standard the machine, the more conventional its uses, the less vital are the informal extras. The more advanced and innovative, the more critical the extras become. These vital "soft" extras form a pool of scientific, engineering, and technical know-how. The pool is organized differently in each country. When vital technical knowledge is sold as a product by specialized service firms or equipment companies, then that know-how becomes easy to access. For example, the pattern of innovation in the American electronics industry has created a variety of market networks and specialized service suppliers. Consequently, access to American technology in this industry is relatively easy.

Interdependencies or externalities in the innovation process of the types identified here provide new perspectives on how government policies can influence the competitive positions of individual firms or nations in high technology industries in enduring ways. In the presence of such interdependencies, a temporary policy aimed at a specific industry can produce long-term effects in a variety of related industries. One need only think of a temporary protectionist policy toward the semiconductor industry and possible long-term effects on computers and telecommunications as the argument in the next section makes clear. Furthermore, under such conditions, market indicators of profitability can be singularly poor guides to resource allocation, if for example, production and R&D experience in one industry provides the knowledge base for successful innovation in related ones.

For example, Japanese dominance of consumer electronics markets enabled those Japanese firms to development strong expertise in a semiconductor process known as CMOS (Complementary Metal Oxide on Silicon) which delivers the kind of low-power, low heat-dissipation ideal for consumer electronic products. By contrast, the U.S. semiconductor firms had no comparable expertise with CMOS since they had little demand for it because U.S. consumer electronics firms had lost their world leadership to Japanese firms. It has turned out, however, that exactly those characteristics of CMOS ideal for consumer products make it an increasingly critical process for the development of the very-dense semiconductors increasingly used in computer and telecommunications applications. Thus, Japanese firms are in a potentially advantageous position versus the U.S. with CMOS, and hence in computer and communications systems markets, all because of the respective experiences in consumer electronics.

Finally, when interdependencies are strong, special types of government policies that coordinate the behavior of related firms or industries can be very important in shaping market outcomes. Of particular significance are policies to coordinate investment projects in a number of related industries; policies, such as the setting of standards, to prevent unnecessary duplications of product or process prototypes; and the relaxaton of anti-trust policies to promote rather than impede the flow of knowledge among firms and industries. Clearly, governments, such as the Japanese one, with a tradition of policy tools that encourage coordination among firms, may be better equipped to deal with the special types of interdependencies in high technology industries than governments, such as the American one, with a policy tradition of reliance on price coordination by markets and anti-trust.

Perhaps the fundamental question that arises from the literature on the economics of innovation is whether a country's gain or loss in competitive position in a paricular high technology industry can result in a cumulative gain or loss across a whole spectrum of "connected" or related industries. Theoretical models are inadequate to this task and cannot predict such developments. This does not mean, however, that we should overlook the question, relying instead on traditional modes of analysis that focus on developments in one industry without sufficient regard to their spillover effects elsewhere. There are smatterings of evidence that this is a real problem. Given the interdependencies among various technological developments, traditional industrial distinctions such as those between semiconductors, computers, and telecommunications, may be misleading as a guide to analyzing markets and evaluating policy options.

There can be little doubt that sectoral interconnections are critical to the continued innovation process on which comparative advantage in high technology industries and steady productivity growth depend. At best, some of these interconnections are such that they can be maintained by standard price or buyer-seller relations in international markets. When such interconnections are at issue, there are no obvious national boundaries to the innovation process. In other words, firms in one nation can purchase high technology products from foreign suppliers without losing the know-how required to use them or, even more important, the know-how required to innovate in related products or processes. The economics of innovation, however, suggest that there are other kinds of interconnections in the innovation process that require tighter links and more complicated and complete information flows between firms than standard merchant relatonships provide. When such interconnections are present for a particular technology, the know-how to use it, and the know-how to innovate in related areas may be slow to diffuse across national, let alone community or enterprise boundaries. Under such circumstances, the !bility of a firm or a nation to be competitive in one high technology area may rest on its ability to be competitive in a whole chain of closely related areas.

Unfortunately, our current knowledge allows us to say very little _a priori_ about which industries, products or processes may turn out to be critical to a nation's comparative advantage in a particular set of high technology industries. We know that each national economy is interconnected, but we do not know which interconnections can be maintained by market relationships across national boundaries and which require tighter national linkages. This puts us in a puzzling and unsatisfying spot. How can we evaluate the national consequences of a domestic or foreign policy aimed at a particular industry without understanding the nature and extent of that industry's interconnections with the rest of the economy?

At this point in time we feel that the best way to approach this question is to examine the process of technological change in a particular industry and its actual and potential interconnections with the rest of the economy on an empirical case by case basis. In this paper, we apply this approach to an analysis of developments in the semiconductor and telecommunications industry.

Government Policy and Corporate Strategy in High Technology Trade

In the cases which follow we consider two questions. The first, and the focus of our discussion, is "Has government policy affected the outcomes of market competition?" The second, which we pursue less fully, is "Does the character of technological development of these industries generate important spillovers?" The related matter is whether these spillovers concentrate in a single national community or are generally available in international markets.

Creating Advantage in Microelectronics, The Story.* Because micro-electronic products are crucial intermediate inputs to all final electronics system, competition in the semiconductor industry is at the center of competition in any and all industries which incorporate electronics into their products and production processes. Indeed, trade in integrated circuits and electronics in general is typical of competition in industrial goods between the advanced countries. Market success in the products which the advanced countries exchange between themselves depends on the management of

* This section depends heavily on the work of Michael Borrus. It is drawn from two sources, and in part paraphrases or quotes them: U.S. Japanese Competition in the Semiconductor Industry, Michael Borrus, James Millstein, and John Zysman (Institute of International Studies, University of California, Berkeley, 1982); and Responses to the Japanese Challenge in High Technology, Michael Borrus with James Millstein and John Zysman, (Berkeley Roundtable on the International Economy [BRIE], 1983). Sections of these publications appear here without footnoted references.

complex processes of product development and manufacturing rather than simply on national differences in factor costs such as wages or raw materials. The corporate capabilities that afford a national advantage in high technology can be promoted by government policies for industry and trade.

To explore government's role in shaping competition in this sector we begin with an interpretation of current competition. Then we shall turn to an analysis of the development of the industry that set up this competition. Finally we shall turn to the analytic economic issues posed in the first part of this paper.

The Current Market Battle: Interpretations of U.S.-Japanese industrial competition in semiconductors have not kept pace with rapid and complicated developments in the market. Business analysts have discounted or underplayed crucial factors in international competition and the industry's development, dismissing important parts of a very complex story. Recent analyses of the industry tend to fall into two broad categories. One emphasizes manufacturing investment and looks for signs characteristic of a "maturing" industry. The second emhasizes rapid innovation, particularly the development of Very Large Scale Integration (VLSI) and the cultivation of new markets for custom and semicustom integrated circuits. The two perspectives agree on one point: the technical and market dominance of the U.S. semiconductor industry is threatened for the first time by Japanese producers. A closer look at these opposing perspectives will be necessary before we suggest how they can be integrated.

One current interpretation of events in the semiconductor industry focuses on Japanese domination of the latest generation of Random Access semiconductor Memory (RAMs), the 64k dynamic RAM. The successful Japanese high-volume manufacturing strategy-- based on high quality, rapid market entry with relatively simple design, low costs leading to low prices, and relative lack of concern for short-term profits --demonstrates certain important chracteristics in the evolution of semiconductor competition. A growing portion of the industry's capital is being spent on the increasingly costly equipment needed to establish a competitive production system for commodity devices like RAMs. Indeed, capital costs appear to be rising faster than revenues and profits. Manufacturing expertise, lowest-cost production postions, and strong competence in marketing appear to be essential to competitive success. These factors are indicative of an indstry entering a "mature" phase of its life cycle, in which capital investment and production strategies are relatively more important than the innovation strategies that have characterized the industry's "growth" phase.

This "maturing" of the semiconductor market environment plays directly to the strengths of the Japanese industry's production strategy. The structure of Japanese finance, particularly the easy availability of cheaper capital and the government's targeted industrial policies, permits and encourages heavy investment in production capacity. The focus on manufacturing leads to production refinement and the incorporation of high levels of automation. The net result is thought to be a substantial Japanese advantage over U.S. firms in the more rapid accrual of learning economies, which in turn means higher production yields, lower production costs, more aggressive pricing policies, and consequently lower returns to U.S. firms. The American firms would become increasingly less competitive over time as production costs rise with succeeding generations of products. Japanese success in RAMs, according to this view, is significant because it directly impedes the growth of the critical merchant segment of the U.S. industry. As both the largest product market and the simplest of successive generations of increasngly complex semiconductor devices, RAMs have historically returned both the <u>margins</u> and the <u>production know-how</u> necessary for U.S. merchant firms to grow, reinvest, and competitively produce more complex devices. Japanese dominance in RAMs --now at the 64k and soon at the 256k levels-- disrupts the acquisition by U.S. firms of margins and know-how; hence, in tandem with the industry's maturation (of which it is a part), Japanese RAM dominance means the end of an independent merchant segment of the semiconductor industry in the United States.

However, this first interpretation ignores two critical parts of the overall industry story, which are highlighted in another view of current semiconductor events. In this second interpretation, innovation and growth rather than maturity continue to characterize the industry in two ways. First, the emergence of VLSI capabilities permits the development of new and expanding markets for increasingly complex commodity products like non-volatile memory, microprocessors and peripherals, and telecommunications signal processing chips. Here, the U.S. industry's relative advantage in design expertise and software gives U.S. firms a substantial lead over their Japanese competitors -- who are nevertheless intent on duplicating their success in RAMs in these newer commodity markets. Second, the technological capabilities of VLSI permit the realization of electronic systems designed in customized (or semi-customized) semiconductor chips. Hence, broad new market opportunities are also emerging for custom and semi-custom circuits that serve proprietary needs of systems producers. Here, a number of new merchant U.S. start-up firms and the captive semiconductor divisions of vertically integrated U.S. systems companies are rapidly pursuing new custom opportunities. Still, as systems companies themselves, the Japanese semiconductor producers are moving rapidly into custom and semi-custom arenas on the back of purchased U.S. technology. A competitive battle therefore looms in this area as well.

Both of these broad interpretations are accurate as far as they go. But the apparent paradox of simultaneous maturity and innovation begs for a synthetic interpretation. In our view, the semiconductor industry is at a turning point in its development, a point at which its structure and competitive success in the industry will both be determined by a struggle <u>over changes in the economics and hence the strategies of production in the industry.</u> There are two basic arguments to be made concerning those changes.

The first argument juxtaposes the current RAM/maturity interpretation of the industry's development with the emergence of the new commodity product markets described above. It suggests that the conventional wisdom about the importance of RAMs to continued product and process development needs to be reconsidered. A number of issues are important here. First, the massive and costly Japanese investment in 64k dRAM production capacity and the consequent Japanese-led price erosion on the device has made it unlikely that the Japanese industry will recover its enormous capital investment. This will almost certainly be the case if Japanese firms move too quickly, as some observers suggest they will, to introduce volume production of the next generation 256k dRAM. The willingness of the Japanese industry to sustain losses in this regard suggests a strategic determination to eliminate U.S. competition in semiconductor memory, and --according to the conventional wisdom about the centrality of RAMs-- eventually in other devices as well. Despite the costliness of the RAM game, a few .S. companies with large capital resources, such as Texas Instruments, Motorola, and United Technology's Mostek, have shown that a segment of the U.S. industry can be quite competitive in RAMs. Other U.S. merchants, however, have opted for limited or no participation in RAMs, and have turned instead to concentrate on the newer commodity opportunites in non-volatile memory, microprocessors, and the like. Hence the second issue is raised: <u>Is it possible to generate both</u>

enough profits and enough production experience elsewhere than in RAMs, so that a viable commodity strategy can be preserved for the merchant segment of the U.S. industry?

The growing size of the new commodity markets suggests that significant profit margins can be generated outside of RAMs. At first glance production experience still seems to depend on RAMs, yet there are ways in which it may not, which we pose here as questions. First, does experience in producing fewer, more complex, and design-intensive, semiconductor devices generate equivalent production know-how to RAMs -- or just as important, the know-how to produce more complex devices? Second, can a flexible production strategy be possible for commodity circuits, in which the production of smaller volumes of a wider range of devices is both cost-effective and competitive with the traditional strategy of applying high-volume RAM production know-how to other devices? Third, if RAM production experience is still necessary, what level of participation in RAM markets is needed to gain the know-how to compete successfully in other products? For example, would an in-house RAM development program with limited participation in the market suffice? The answers to these questions are not yet known, but they will determine the future viability of the commodity strategy of merchant U.S. producers. In a moment we will examine the implications of this first argument for U.S.-Japanese competition.

The second argument concerning changes in production strategies focuses on the emergence of custom and semi-custom design capabilities associated with VLSI, and the consequent growth of new market opportunities for custom and semi-custom circuits to serve the proprietary needs of electronic systems producers. An important part of custom development is occurring in-house, in the captive semiconductor divisions of the largest systems companies. However, many new merchant U.S. firms and most of the established ones are simultaneously pursuing custom or semi-custom opportunities. They suggest the possible emergence of a new merchant segment of the U.S. industry as an engineering-service cum foundry-production business with a new approach to semiconductor production. The new strategy requires unbundling the economics of traditional production by sharing the costs of custom circuit development and production with systems companies: design technology is transferred to systems companies, who design proprietary circuits and absorb the costs of development, and then ship completed designs (or masks) back to the merchants for production on foundry lines. In such flexible merchant production strategies, the ability to handle different custom designs on the same production line, combined with a production-cost assist from the systems producers, may allow successful amortization of capital costs. The custom-design technology and strategy have been developed in the United States, where its commercial potential appears to be developing faster than in Japan.

Although Japanese producers, using imported U.S. technology, are developing custom and semi-custom capabilities in-house and for their domestic market, they face a difficult competitive obstacle on other world markets because of the nature of the emerging custom business. In particular, very close cooperation is required between a systems manufacturer and the semiconductor supplier in the development of custom circuits. At the end of the process, the semiconductor supplier will have an intimate knowledge of the propietary circuits that give the systems product its performance characteristic. This strongly suggests that U.S. and European systems companies should be unwilling to give such proprietary information to Japanese competitors, and that they ought to avoid designing custom circuits with the semiconductor divisions of the same Japanese electronics firms that will compete with them in final systems markets.

Taken together, the two broad arguments on new commodity and custom strategies developed above suggest two scenarios for the evolution of U.S.-Japanese competition in semiconductors. In one scenario, Japanese firms leverage their strength in RAMs, production expertise, and in-house custom and systems know-how into a dominant position in markets for both new commodities and new custom production. In the other scenario, the Japanese industry is strategically squeezed from both sides: U.S. merchant firms succeed in developing both new commodity opportunities and new custom production, leaving the Japanese with a very costly dominance in RAMs. Of course, parts of both scenarios could occur simultaneously. In our view, however, there is nothing in the technology or in the parameters of current market competition that inevitably determines which scenario the actual outcome will more closely resemble, or what the synthesis will look like. Rather, government policy actions taken in the United States and Japan may well determine whether competition shifts to favor the Japanese or to preserve the U.S. merchants and the U.S. industry's dominant position.

In sum, international competition in semiconductors is in a period of rapid change, in which features that are typical of a maturing industry paradoxically cohabit the market environment with continuing rapid innovation. Signs of maturity include extremely high capital costs for production, strategic emphases on marketing, and a Japanese-led focus on the engineering of manufacturing systems that deliver competitively lower production costs. These features push in the direction of maturity because they emphasize the relative importance to market success of capital investment, manufacturing, and marketing rather than product innovation. Simultaneously, however, the pace of innovation associated with the development of the technological capabilities of Very Large Scale Integration (VLSI) has accelerated. New markets for new commodity semiconductors are opening up, and dramatically new commercial possibilities for the design and implementaton of custom and semi-custom circuits are concurrently being developed. Hence along with signs of maturity, semiconductor technology is changing and new competitive strategies are emerging, so that instability continues to reign in semiconductor competition. It is against the background of the paradoxical market environment that the evolution of U.S.-Japanese competition in semiconductors must be evaluated. Without that evaluation, a focus on current events in the industry might simply assume that current competitive outcomes will rest on the respective competitive strengths of each industry in the market. As we argue below, however, those characteristic Japanese strengths in the market are in great measure a product of past Japanese industrial policy.

<u>The Current Competition in Historical Perspective:</u> The present competition is a new round in an ongoing struggle. For over twenty-five years after its inception in the late 1940s, the U.S. semiconductor industry enjoyed a position of unchallenged technological preeminence and international market dominance. U.S.-based firms retained international leadership through several stages of technological innovation, market growth, and the consequent restructuring of their industry. In the mid-1970s, however, that leadership was challenged for the first time by large multi-divisional Japanese electonics firms. The share of the world market for integrated circuits held by U.S. firms declined between 1974 and 1978, while the Japanese share grew, mostly at the expense of U.S. producers. Then, in the late 1970s, those Japanese producers captured a significant percentage of the domestic U.S. market for large-scale integrated circuit memories (LSI-MOS).*

Since then, the major Japanese electronics companies have risen from

* See appended glossary of technical terms.

relative obscurity to become strong and enduring competitors in international markets for both semiconductor devices and the electronic systems products that incorporate them. From 1980-1982, when the domestic economies in the United States and Europe suffered through recession, the Japanese industry has achieved significant gains in global semiconductor market share. During that period, profitability dropped dramatically for many merchant U.S. semiconductor firms, with outright losses for some. Capacity expansion and R&D plans were cut back at most U.S. firms. The drop in U.S. industry spending, however, was relatively smaller than in the 1974-75 recession, when failure to sustain capital investment permitted Japanese inroads into the U.S. market in the late 1970s, as demand outstripped U.S. capacity. Nonetheless, Japanese semiconductor capital spending continued to grow rapidly between 1980 and 1983 as the domestic Japanese economy experienced a slowdown in growth but not a comparable recession. Table 1 compares the respective spending of the two industries.

[NOTE: TABLES TO BE DDED IN FINAL DRAFT!!]

As Table 1 suggests, Japanese companies accelerated their capital spending relative to U.S. firms. Such heavy Japanese spending in the context of a domestic economy half the size of the U.S. economy has two implications. It suggests, first, that the Japanese economy was moving very rapidly toward the widespread incorporation of electronics. As a new proving ground for the application of microelectronics across industrial and service sectors, the domestic Japanese market will increasingly become strategically vital to the development of new products for competition on world markets. To the extent that the domestic Japanese economy remains insulated from foreign competitors in electronics --a matter we shall address later-- Japanese companies will gain vital advantages when they export to world markets the products they have developed at home. A second impliction of heavy capital spending in the semiconductor area is that a substantial part of installed capacity is destined for export --currently over 50%-- especially to the United States and Europe. Hence, the approaching U.S.-Japanese parity of installed capacity demonstrates intensified competition between the U.S. and Japanese industries in international semiconductor markets. Moreover, the rise in Japanese semiconductor R&D spending suggests that Japanese electronics firms began early to make a concerted effort to innovate -- that is, to challenge the leadership in component innovaton that has been the U.S. merchant industry's hallmark and its main competitive strength. Although the 1980-1982 recession in the U.S. and Europe disadvantaged U.S. firms and was partly responsible for the rapid gains the Japanese have recently made at the expense of the U.S. industry, the Japanese challenge in microelectronics has not faded with economic recovery.

Indeed, by 1982, Japanese semiconductor producers came to dominate global production of the latest generation of dynamic Random Access Memory (dRAMs), the 64K dRAM. The loss of leadership in this area placed severe competitive pressure on the U.S. industry for the two closely related reasons we noted earlier. First, commodity memory devices like RAMs have historically generated the <u>margins</u> necessary to allow U.S. merchant firms to reinvest and attract additional capital for R&D and growth. Second, and equally important, successive generations of RAMs have been the simplest of increasingly complex integrated circuits; experience gained in their production has heretofore provided U.S. merchant firms with the <u>manufacturing know-how</u> to move through successive iterations to the competitive production of more complex devices. Growing Japanese success in RAMs therefore posed a double dilemma for U.S. firms. The margins of the U.S. companies, and hence the capacity to continue to innovate, were squeezed at the same time that their abilities to acquire critical production know-how were threatened.

The Japanese strategy is an attempt to force international competition in semiconductors to rest on the more mature industry features of capital investment, production, and marketing --the Japanese strengths-- rather than on U.S. strengths in product innovation. The strategy emphasizes rapid market entry with relatively less complex, high quality standard components at low cost. The first international impact of Japanese expertise in producing semiconductors was revealed by the controversy in the late 1970s over the higher quality of Japanese 16K dRAM devices, the prior generation of RAMs. U.S. firms have since met that initial challenge and there is now no significant difference in quality between U.S. and Japanese producers. Japanese success in 64K dRAMs, however, illustrates a second phase in the Japanese challenge based on expertise in manufacturing. As we shall argue later, Japanese producers chose a relatively straightforward migration in RAM design from 16K to 64K and beat most U.S. producers to the market. They entered into production rapidly by refining the production equipment and adapting the manufacturing systems that had delivered the 16K dRAM, while U.S. producers emphasized new production equipment. Simultaneously, Japanese producers also incorporated more systematic automation of the production process. The net result was a substantial advantage in higher yields, a more rapid accrual of learning economies, and lower overall production costs. Given ther willingness and ability to forego short-term profits or even sustain losses in order to capture market share, it is not surprising that Japanese firms captured close to 70 percent of the world 64K dRAM market in both 1981 and 1982. In the manner descibed earlier, Japanese success, in tandem with the domestic U.S. recession, has placed severe pressure on the ability of U.S. firms to generate reinvestment and to acquire production know-how.

The critical point for this paper is that Japanese semiconductor producers have continued to pursue a competitive strategy that rests on the innovative engineering refinement and management of manufacturing systems for the production of RAMs and related semiconductor devices. This situation bluntly represents a shift in the terms of competition in established internatIonal semiconductor markets.

That shift in the terms ofcompetition could not have happened without government support. Japanese success in RAMs rests on heavy capital expenditures for RAM production capacity which are comparably beyond the resources of many smaller U.S. firms, and on the engineering of manufacturing systems that deliver lower-cost production than many U.S. firms have achieved. In turn, these characteristic features of growing Japanese success in semiconductors depend on strategic and systematic exploitation of the domestic Japanese industry structure and related industrial policies. Our earlier study, U.S.-Japanese Competition in the Semiconductor Industry, argued in detail how a nation's domestic policies and market structure could produce advantage for domestic firms in international competition. That study focused on the ways in which different domestic industrial structures and policies of the United States and Japan shaped the development of their respective national semiconductor industries, and encouraged systematically different capacities and strategies to compete in international markets. As we wrote, in Japan's "relatively stable and predictable domestic market environment ... large integrated firms have prospered in international markets chiefly with producton strategies that focus competition on cost and quality of commodity products rather than with entrepreneurial strategies [characeristic of U.S. firms] that focus competition on the diffusion and advance of new technologies and the rapid adjustment to shifting markets."

The Evolution of the Competition: Let us step back then and compare the evolution of the Japanese and American industries to contrast the role of government in each case. In America in the earliest period, from the invention of transistors through the commercial introduction of the integrated circuit, the U.S. military played the role of "creative first user." Military R&D programs, emphasizing miniaturization, high performance, and reliability, set the direction for early product design, and military and space agency procurement provided an initial market for the integrated circuit. The existence of strong government demand contributed to the entry of new firms and accelerated the pace of diffusion of the integrated circuit into nonmilitary markets. Also, particularly critical in this phase for the industry's longer-term development, was the role of Bell Labs. Bell Labs innovated much of the basic research and process technologies which led to the development of the integrated circuit. Government anti-trust policy (the 1956 Consent Degree) assured that Bell Labs' knowhow diffused cheaply to small new firms, which took the technology to the market.

The second stage of the industry's devlopment rested upon its synergistic relationship to the computer. Advanced integrated circuit design moved from the implementation of basic logic circuiuts to the implementation of entire computer subsystems on a single chip of silicon. In turn, the growth of the mainframe and minicomputer markets both was fueled by and contributed to the rapid expansion of domestic digital integrated circuit production.

The third stage of the industry rested upon the shift to MOS technology, the emergence of large-scale integrated circuit designs, and the appearance of the microprocessor. This stage saw a wave of new merchant entries and a broadening of the final systems markets that the integrated circuit producer served. Large-scale integration brought with it new markets in semiconductor memories, in consumer products, in telecommunications, and most importantly in a wide variety of applications markets for the microprocessor and microcomputer. In turn, the strategies of firms changed as the markets for the more complex LSI ICs became more segmented, and as the microprocessor, the third generation of computation equipment, offered new market development opportunities and challenges.

As the industry has moved through large-scale integration, the nature of the products it produces has changed and therefore so has its status as a "components" industry. Increasingly, the major merchant firms in the industry appear to be consolidating their strengths in integrated circuit technology and emerging as a new generation of diversified electronics "systems" manufacturers. In turn, the smaller merchant firms are increasingly establishing themselves within niches of the rapidly segmenting markets for integrated circuit components. Also, "captive" production --either through acquisition or in-house start-ups-- appears to have steadily increased as a variety of final electronic systems producers have recognized the strategic nature of the integrated circuit to their future product development and market growth.

Although the industry's evolution has certainly been shaped by changes and by growth in the final product markets for semiconductor devices, it is important to recognize that these market opportunities were a direct result of successive innovations in semiconductor technology. In the early years, semiconductors were simply replacements for vacuum tubes; they performed the same functions more effectively but they did not fundamentally change the products into which they were incorporated. In the second stage of the industry's development, advances in semiconductor technology made possible the substitution of electronic circuits for many types of electrical mechanical functions. In the third phase of the industry's development, the advent of the microprocesor opened up new market opportunities beyond those substitution uses for which semiconductor technologies had proven cost-effective and performance enhancing. In essence, the microprocessor and the growing range of complex large-scale integrated circuits opened the development phase of the industry.

The character of the current U.S. semiconductor industry remains diverse and dynamic. The existence of a set of merchant firms whose primary business is the design, manufacture, and open-market sale of advanced integrated circuit devices has over time been complemented by the emergence of a rapidly increasing number of systems firms engaged in custom IC fabrication and design. Together, with the addition of the two giants of the domestic electronics industry --IBM and ATT-- the structure of the domestic sector exhibits a technological breadth and dynamism unique in the world community. As we have argued elsewhere, the existence of the merchant segment of the industry has been the critical stimulus to commercial market diffusion of integrated circuits: by making the most advanced integrated circuits available at low cost on the open market, merchants have lowered technological and capital barriers to entry in existing electronic systems markets and led the development of new markets for the application of microelectronics technology. This competitive dynamism has spurred technological advance and until recently has sustained the international competitiveness of th American electronics industry as a whole.

Japan, by contrast, was a follower industry, the late-comer. As a consequence its evolution was different. Critical to our story is the role of government in assisting and promoting catchup. We have explored in detail our interpretation of the Japanese system, the strengths of the business community and of the effects of Japanese policy. We do not reproduce here our full disussion of the evolution of the Japanese industry. Rather we emphasize the elements of policy that proved critical.

We have characterized the Japanese economic system as one of "Controlled Competition" in which the intensity of competition between firms in key industrial sectors is directed and limited both by state actions and by the formal and informal collaborative efforts of industrial and financial enterprises.[13] The precise rules guiding the system evolve over time with the structure of the economy, the financial and market strength of the companies, and the political position and purposes of the bureaucracy.

> There is every evidence of intense competition between firms but that competition seems to be directed and limited both by state actions and by the collaborative efforts of the firms and banks themselves. Though the state bureaucrats do not dictate to an administered market, they do consciously contribute to the development of particular sectors and they help in a detailed way to establish conditions of investment and risk which promote their long-term development and international competitiveness. An agency such as MITI (Ministry of International Trade and Industry) is not so much a strict director as a player with its own purposes and its own means of interfering in the market to reach them. Government industrial strategy assumes that the market pressures of competition can serve as an instrument of policy. It is not simply that the government makes use of competitive forces that arise naturally in the market, but rather that it often induces the very competition it directs. It induces competition by creating the market for products and the conditions for high returns, thus seemingly assuring a profit and attracting the entry of many competitors. The competition is real, but the government and the private sector also possess mechanisms to avoid "disruptive" or "excessive" competition. Such limits on competition include product specialization agreed on within a set of competing firms and the often-cited cartels to regulate capacity expansion in booms and cut-back arrangements in downturns. The fact that these arrangemnts to manage the market often break down should not be taken as evidence that they do not operate or do not matter. In semiconductors today, as in steel a generation ago, these collaborative arrangements appear central to Japanese interational success. In this setting, in which business collabrates as well as competes, the government appears as a marketplace actor, prodding here and promoting there.
>
> The government, acting through the semi-insulated state bureaucracy, has continuously formed its own view of the future of Japanese industry (and of the proper structure of specific industries) and then pursued that vision. It became a market player, using its capacities to advocate and to promote industrial development. The limits on its capacities should not deceive us about the extent of its influence, nor should the significance of

> the Japanese pursuit of actively created comparative advantage be underestimated. MITI policy involved a rejection of the limits of the neoclassical equilibrium economics and a recognition of how government generates national advantage.

The government's promotion objectives were pursued through two sets of policies: (1) Those controlling the links between the Japanese market and international markets: and 2) those manipulating the domestic firms to stimulate expansion. Let us look at both sets of policies as they bear on our case story.

T.J. Pempel once characterized the Japanese state as "an official doorman determining what, and under what conditions, capital, technology, and manufactured products enter and leave Japan. The discretion to decide what to let in (and at the extreme what to let out) of Japan, permits the doorman to break up the packages of technology, capital and control which multinational corporations represent. Until the liberalization of Japanese mrkets, which we have tended to call the loosening of its developmental objectives, the Ministry of Finance operated selective controls over inward foreign investment. MITI controlled technology imports in order to force foreigners to sell raw technology in the form of patents, licences, and expertise.

Limits on foreign entry and forced transfer of technology helped accelerate the early development of microelectronics in Japan. The story of Texas Instruments entry to Japan, in which it traded licenses which could have blocked Japanese development for a share of the market, is really exemplary. As we have written before:

> Thus, during the 1960s and the early 1970s the Japanese government, principally through MITI, sought to build a competitive semiconductor industry by limiting foreign competition in the domestic market and acquiring foreign technology and know-how. Foreign investment laws created after World War II required the Japanese government to review for approval all applications for direct foreign investment in Japan. The government consistently rejected all applications for wholly owned subsidiaries and for joint ventures in which foreign firms would hold majority ownership. It also rejected foreign purchases of equity in Japanese

semiconductor firms. Simultaneously, the government limited foreign import penetration of the home market through high tariffs and restrictive quotas and approval-registration requirements on advanced IC devices in particular. For example, until 1974, ICs that contained more than 200 circuit elements simply could not be imported without special permission. Penetration was also managed by exclusionary customs procedures and "Buy Japanese" procurement and "jawboning" policies.

The price to U.S. firms for limited access to the Japanese market was their licensing of advanced technology and know-how. This, too, was regulated closely by the Japnese government, whose approval was required on all patent and technical-assistance licensing agreements. Since MITI controlled access to the Japanese market and its approval was required for the implementation of licensing deals, it was in a powerful monopsonist's position of being able to dictate the terms of exchange. Its general policy was simple and effective. It required foreign firms to license all Japanese firms requesting access to a particular technology. It limited royalty payments by Japanese firms to a single rate on each deal, thereby preempting the competitive bidding-up of royalty rates among Japanese firms. In line with the characteristic emphasis on export strategy, MITI often linked the import of particular technologies to the acquiring firm's ability to develop export products using that technology. MITI also conditioned approval of certain deals on the willingness of the involved Japanese firms to diffuse their own technical developments, through sublicense agreements, to other Japanese firms. The total result of these policies was a controlled diffusion of advanced technology throughout the Japanese semiconductor industry. Tilton gives a convincing measure of the extent of Japanese firm dependence on the acqisition of U.S. technology: by the end of the 1960s, Japanese IC producers were paying at least 10 percent of their semconductor sales revenues as royalties to U.S. firms --2 percent to Western Electric, 4.5 percent to Fairchild, and 3.5 percent to Texas Instruments.

Royalty income may have been substantial for a number of U.S. firms, but market access was ephemeral indeed. The one successful entry into the Japanese market by a U.S. firm came when Texas Instruments reached an agreement with Sony on a joint venture in 1968. Texas Instruments petitioned the Japanese government for a wholly owned subsidiary in the early 1960s, and was offered a minority-share joint venture which it rejected. Its chief bargaining chip during these negotiations was its continuing refusal to license its critical IC patents to Japanese firms without gaining a substantial production subsidiary in Japan in return. NEC and the other firms sublicensed to it were in fact producing ICs based on technology developed by TI and Fairchild through an NEC-Fairchild licensing agreement. However, because the TI-Fairchild patent accord explicitly excluded Japan, those Japanese firms were not protected, as Fairchild licensees in Europe were, against patent-infringement suits brought by TI. The Japanese government stalled approval of TI's patent application in Japan, and this enabled NEC and the other firms to play domestic technology catch-up, thereby forcing TI to negotiate for quicker access. The Japanese government then held up Japanese exports of IC-based systems to the United States because TI threatened infringement action. A compromise was finally reached in which TI got a 50 percent share of a joint venture with Sony, and agreed further to limit its future share of the Japanese semiconductor market to no more than 10 percent. TI bought Sony's share of the joint venture in 1972, and though 1980 remained the only U.S. merchant firm with a wholly owned manufacturing subsidiary in Japan.

We concluded then that "the strategy of technological diffusion and limited market access, implied in the TI story ...enabled Japanese firms roughly to mimic technological developments in the United States." Thus in the early phase, the market space to permit firms to grow in the face of foreign advantage was generated by government.

The importance of such a closed market is substantial advantage. It permits the possibility of gearing up to reach world-scale production at home and then very aggressively pursuing foriegn markets. Foreigners are unable to exploit a technological advantage and turn it into a enduring market presence. Our data suggested that at least in the early 1980's the markets were still substantially closed. We wrote then:

> A closed market and government promotion aimed at import substitution will produce a very predictable trade pattern in electronics: the most advanced goods will be imported until domestic producers can make them, and when they can, domestic production will be abruptly substituted for imports. Our premise is that the local producer, at the beginning of domestic production, would not be expected to be fully competitive in price-quality terms with the foreign producer. (Otherwise, policies of protection would not have been required.) A pattern of aggressive import substitution blurs easily into actual market closure, but we judge implausible and inconsistent with the economics of the industry an argument that Japanese producers upon entering production consistently have an immediate and dominant competitive advantage over American firms that are selling advanced products in Japan.
>
> In open competition within Japan, American producers should retain at least a portion of the market or specific products that a technological monopoly initially won for them. Local producers may initially win sales because of specific market advantages, or they may use captive capacity to achieve the volumes that allow them to match the foreign competitor's costs. In an open market, American firms, would lose market share slowly when Japanese production began, whereas in a closed market the American market share would drop off abruptly. A Japanese breakthrough might provide an immediate product or production advantage in a specific product.

> However, the overall pattern of trade in a range of semiconductor products in an open market should see American producers losing market share slowly to Japanese producers but retaining a permanent market position based on their initial advantage. American integrated circuit manufacturers retain the international lead in the broad range of products. It is therefore hard to make a case that failure to penetrate Japanese markets results simply from competitive weakness. Given the history of discrimination --as well as the evidence in Chapters 2 and 3 that closed markets and difficulty of access have been critical parts of Japanese development strategies and have deeply influenced corporate tactics-- the burden rests on the Japanese to demonstrate that their markets are in fact open.

Since the early 1980's access to Japanese markets has eased. Continuing negotiations of the High Technology Working Group has resulted in a staged reduction of tariffs. Pressures have been brought to accelerate domestic purchases of American products. Even if all government pressures were eliminated, features of the Japanese market would still make entry difficult. As Borrus has written:

> Controlled access is the term that best captures what we believe occurs in semiconductor and related systems markets in Japan. This is not, strictly speaking, the issue of whether Japanese markets are formally open or closed: rather, as we emphasized in our earlier study, we believe that Japanese semiconductor firms can concertedly control the composition and extent of U.S. semiconductors sold in Japan, because the largest Japanese producers are also the largest consumers of semiconductros and are directly tied to other major consumers through the *keiretsu* structure. One set of aggregate figures suggests that the ten largest Japanese semiconductor-electronics firms account for almost all of Japanese semiconductor production and about 60 percent of domestic semiconductor consumption, but on the average, only about 20 percent of production is captively consumed by each producing firm. Another set of aggregate figures suggests that 80 to 90 percent of semiconductor output is consumed within the *keiretsu* of the major semiconductor producers.

Two possible arguments have been offered to account for these aggregate figures. First the figures illustrate trade among the major Japanese firms and their *keiretsu* based on a pattern of component and systems specialization. The evidence for this is that the joint research and development programs encouraged exising product specialization. In the case of machine tools MITI pressures for product specialization were formal, and thus the proposition here is consistent with government practice. Breaking out of that specialization is costly and time consuming and may involve entering new final product markets. There are formal ways of testing our proposition. We have never been able to obtain evidence in a form that would permit a test, though it is our judgment after much research that appropriate data exist. Such specialization, though, may be breaking down. It rests not so much on formal agreements as on the logic of making what you do best and need the most, and buying the rest. All the firms are clearly trying to broaden their product base. Many now hesitate, moreover, to buy from direct competitors.

This argument about component specialization and consequent collaborative Japanese inter-firm trade has been criticized because it allegedly "fails to answer why one Japanese firm would sacrifice profits by purchasing from another rather than from cheaper foreign supply."[14] When the Japanese industry was technologically backward and facing technologically advanced foreign competitors, collaborative inter-firm trade would be a perfectly rational response: profits would be sacrificed simply to prevent the low-cost foreign competitors from overrunning the Japanese domestic market. An alternate argument is that the d!ta show extremely high intra- keiretsu consumption (and thus a captive market at the level of the keiretsu . The public evidence on intra- keiretsu purchasing patterns consists mostly of pronouncements about purchasing patterns and is mixed.

Whatever the precise eplanation -- and the reality is probably a mix of our two arguments -- the collaborative arrangements that control access to the Japanese market would appear to derive logically from past government-industry efforts to rationalize production in the domestic Japanese market when that market was small and Japanese firms were vulnerable to foreign competition. On the one hand, the arrangements would endure to the extent that each firm continued to enjoy benefits consonant with its own strategic conception of which products it wants to produce itself (given its long-run aims in systems markets). On the other hand, since domestic Japanese policies and practices have controlled new entry and regulated the pace of inter-firm diffusion of new technology through cooperative R&D like the VLSI project, the ability to sustain such collaborative behavior against outsiders would also endure.

The collaborative promotional policies referred to above and considered here are the R and D programs, not the broader industry development programs.* We agree with Professor Kenichi Imai (cited earlier) that the programs such as the VLSI project in the mid 1970s were aimed at developing generic technologies, not product-specific technologies. As such the government reduced the cost of the riskiest and least predictable phase of the R and D process. The government also encouraged the diffusion of the generic technologies amongst the several firms. It only influenced product choices by the company groupings and tehnological directions of the projects it chose. Because these projects came at the beginning of a technology cycle, they did not cost huge sums. The much larger sums for actual product engineering and manufacture came through company coffers, though often subsidized by the governement, and through premium-price procurement by government agencies like NTT. These research investments, however, proved critical. They permitted Japanese firms to develop the production refinements (of the collaboratively-acquired generic technologies) that have vaulted Japanese firms into a world-class competitive position (as described in the previous section).

* Again, for our broad review of the Japanese system, and these programs, we refer the reader to our paper prepared for the United States-Japan Trade Advisory Commission.

Government Policy and the Current Competition: Which strategy --product or production innovation-- or what mix may prevail? Let us return to the story of the current competition. The U.S. industry is now entering a fourth stage of development, which is loosely associated with the move to even greater levels of complexity in integrated circuits that is characteristic of VLSI. In part, this fourth phase represents an intensification of some of the major trends of the industry's previous phase. The production of more systems-like components, forward integration into systems markets by merchant fims, the increasing penetration of markets such as factory and office automation (in which electronic intelligence has had, up to now, only limited or no application), and the rising presence of captive production are all now ingrained features of the industry's evolution which find their roots in the era of LSI. To these should be added a number of new structural trends which are beginning to take shape and which will dramatically influence the nature of competition in the latest phase of development. The most important of these can be roughly chracterized according to our innovation and maturity theme. Pushing toward innovation are four factors: (1) the emergence of potentially large markets for non-standard application-specific (custom and semi-custom) integrated circuits made possile by the design capabilities of VLSI; (2) the latest wave of new merchant firms; (3) the identification of new standard system-like commodity components, along with the emergence as commodity products of certain formerly low-volume market niches; and (4) closer strategic cooperation in some areas between merchant producers and final systems manufacturers. Pushing toward maturity are two other factors (5) the enduring presence of Japanese competition, with the manufacturing-based strategy described earlier; and (6) high and rising capital costs of R&D and production. Because implementation of the capabilities of VLSI dominates the industry's technological agenda, and indeed underwrites the emergence of the trends described above, industry observers have dubbed this fourth developmental phase the era of VLSI. That characterzation captures the direction of technological advance, but it is silent about what the advance implies for the terms of competition in the industry. Instead, viewed from the perspective of competition in the industry, we prefer to call the new developmental phase the era of <u>strategic diversfication.</u> A diversified range of old and new strategic approaches to market success in t(e industry will highlight semiconductor competition during the 1980's. These approaches should be viewed as responses both to the potentials of VLSI and to the Japanese presence.

These developments require some explanation. As an industry matures, product design prameters become standardized and the focus of competition shifts toward incremental manufacturing refinement and marketing. Technological innovation which upsets established design parameters, refocuses the search for competitive advantage on new products and processes. VLSI, as we shall explain, has the effect of upsetting established semiconductor design parameters. It represents continuing technological innovation that cuts directly against arguments that the semiconductor industry is "maturing." Indeed, the firms that succeed in implementing VLSI will set the terms of future competition in semiconductors.VLSI rests on technological advances in semiconductor fabrication that permit dense packaging of extremely complex circuits, with a transistor count starting at roughly 100,000 per chip. VLSI is both a process innovation, and a product innovation that permits the ability to implement more complex and radically new systems architectures in silicon. The limit on the widespread diffusion of these complex large circuits is the great difficulty of design: the extremely high cost of VLSI design generally precludes the widespread use of application specific circuits. One solution to this dilemma is design automation -- the use of computer aided design (CAD) systems to simplify and reduce the cost of designing VLSI circuits.

The continuing development of automated design for custom and semi-custom circuits is indeed drastically reducing the design costs associated with VLSI. In turn, broad new merchant markets are emerging for application-specific circuits, especially among the vast majority of systems manufacturers that have no captive semiconductor production. In past phases of the industry's evolution, new merchant firms have been the development vehicles by which major technological advances have been diffused into commercial use. In this regard, application-specific VLSI is no exception. The entrenched positions of the captive and established merchant producers -- the strategic focus of the former on keeping custom circuits proprietary, and of the latter on standard commodity components -- have militated against their developing and bringing the new technology to market as fast as its potential applications warrant. As a consequence, many new merchant firms have entered the semiconductor business with the avowed aim of developing markets for application-specific circuits.

In sum, if the new strategic alternatives to the traditional commodity semiconductor strategy pan out, a growing segment of the U.S. industry will become, in effect, an engineering service business tied to silicon-foundry production strategies. The new entrants have fragmented the traditional commodity strategy of the merchant producers in order to pursue new potential markets in custom design. Indeed, the transfer of design technology is a new strategy for creating market demand by educating the user to the potential of VLSI custom design. In that sense, the new merchants have taken a strategic page from the book of earlier generation merchant producers like Intel, who introduced microprocessor development and support systems to radically expand their markets by educating users to the virtues of the microprocessor. If users can be quickly educated to custom design, then the markets for applications-specific circuits will expand rapidly because the potential competitive advantages of the new approaches are numerous. Indeed, the growth of application-specific markets, and the market presence of the new merchant entrants seeking to push along the use of custom circuits, has created new dynamic instability in existing component markets. Virtually every major established merchant firm has committed resources to respond to the new opportunities and competitive challenges associated with custom circuits.

The relative lack of Japanese participation in the U.S. custom arena is due in part to the market's small size relative to standard component markets. However, in great part, the nature of the custom business also cuts against Japanese participation. In particular, very close cooperation is required between a systems manufacturer and the semiconductor supplier in the development of custom circuits. At the end of the development process, the semiconductor supplier will have intimate knowledge of the proprietary circuits that give the systems product its performance characteristics. Very few U.S. systems companies appear willing to divulge such proprietary information to potential Japanese competitors before they are ready to take their products to market. Thus U.S. systems companies appear likely to avoid designing custom circuits with the semiconductor divisions of the same Japanese electronics firms who will compete with them in final systems markets. Here, the vertically integrated, multidivisional structure of Japanese electronics companies, which has been a great strength in commodity component markets, actually impedes their ability to compete for design wins in foreign custom markets. Thus as both new and old U.S. firms push semiconductor development in the custom area, a growing part of the semiconductor business may be receding from the Japanese aim. However, because systems products can be disassembled and their proprietary custom circuits dissected, Japanese companies can acquire proprietary design information relatively soon after the products appear on the market. Thus although U.S. systems companies might not want to design custom circuits with Japanese producer, they might be very willing to have the Japanese second-source the production of these circuits. Here, the Japanese strength in manufacturing could provide them with important custom sales opportunities in markets outside of Japan.

The current low profile of Japanese firms in the custom area also reflects their desire to keep proprietary the custom circuit skills that give their own systems products a performance edge in international competition. In this, they simply resemble some of the larger U.S. systems houses like IBM. Nevertheless, there is comparatively little public indication of very advanced Japanese work in application-specific circuits (except, of course, gate arrays -- where their need to respond to IBM's systems innovations forced them to develop gate-array capabilities). The work that is occurring relies very heavily on design technology, methodologies, and software imported from the United States. The most innovative Japanese custom work seems to involve Japan's public telecommunications monopoly, NTT. In 1982, NTT set up a majority-owned subsidiary to develop and manufacture custom VLSI circuits for small- and medium-sized Japanese companies, to transfer custom design technology to them, and to produce for NTT itself. The subsidiary, Japan Electronic Technology, uses NTT's proprietary VLSI CAD systems, and is owned 60 percent by NTT, 30 percent by a consortium of Japanese banks, and 5 percent by the Japanese Telecommunications Association, which includes the major Japanese electronics companies. That NTT has moved in this way to diffuse custom design technology to smaller Japanese systems companies suggests a recognition that the oligopoly structure of the Japanese electronics industry, advantageously used to catch-up to merchant U.S. companies in commodity semiconductor markets, may not be the best structure for promoting the competitive development of new opportunities in either semiconductor or systems markets. We shall elaborate on this general point in the next section, which concerns Japanese competition.

While the advent of custom capabilities associated with VLSI is an important competitive development that plays to American strengths, standard commodity components will continue to dominate semiconductor production for the foreseeable future. This is so because VLSI permits the commodity production of increasingly dense and versatile memories, microprocessors, and peripheral circuits that will open new markets in areas like factory and office automation, and also because complex systems products will continue to use standard components in tandem with custom-designed circuits. Standard devices accounted for approximately 88 percent of the total market for semiconductors in 1982, a percentage that we believe is unlikely to undergo drastic deterioration before the late 1980s. Indeed, commodity component markets are conti.uing to grow at rapid rates. Even such memory subsegmnts as complex nonvolatile memories (EE PROMS) are becoming high volume. And, any one commodity segment can be broken into subsegments and within each subsegment broken down further according to device density, access time, and other characteristics. Many of these segments and subsegments have now taken on a commodity character and are capable of generatng sufficient returns to sustain merchant firm growth. There are limits though, which hinge on the ability to gain production experience.*

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* In theory, there are a number of ways in which acquiring production experience need not depend on a full-scale commitment to commercial production of RAMs. How they would work out in practice is not yet known, so we shall state them in the form of questions. First, does experience in producing fewer, design-intensive, more complex semiconductor devices generate equivalent production know-how to RAMs? Or does it generate different though equally important production experience -- that is, know-how to produce more complex devices competitively with those who take the traditional route of first producing RAMs in volume? Second, is it possible to succeed with a flexible production strategy for commodity circuits -- perhaps similar to the production strategies that may emerge for silicon foundries -- so that the production of smaller volumes of a wider range of devices becomes both cost-effective and competitive with the traditional strategy of applying high-volume RAM production know-how to other devices? Third, if RAM production experience is still essential, what level of participation in world RAM markets is necessary to gain the know-how needed to compete successfully in other products? Would an in-house program that produces RAMs as a vehicle to perfect process development for the production of more complex devices, and which involves only limited competitive participation in commercial RAM markets, suffice to generate the necessary production know-how?

If the Americans have pushed the innovation of custom devices and the expansion of subsegments into commodity products -- thereby pursuing the strengths evident in the first development phases of the industry -- the Japanese have pursued their partly policy-induced advantage in commodity component manufacturing.

As explained earlier, the Japanese producers leveraged their entry to the U.S. market by engineering a system of commodity component manufacturing that allowed rapid entry with relatively simple components of high quality and low cost. By entering in this way, Japanese firms changed the terms of market competition by imposing new basic manufacturing parameters that favored Japanese strengths. By putting a premium on manufacturing in the context of rapidly escalating capital costs, Japanese firms speeded the maturation of the industry and further enhanced their own competitive position. Indeed, as shown earler, the formidable character of Japanese competition in semiconductors has been amply demonstrated since 1980.

We recall that as a result of coordinated research in the Japanese VLSI project (1976-1980), Japanese firms led their U.S. merchant competitors in more quickly introducing the 64K dRAM and moving it into volume production. This represented the first commodity IC device for which Japanese firms <u>led</u> U.S. merchants in new product and market development. Because the 64K dRAM requires high capital investment, generates very high volume demand among a few large purchasers, is relatively less complex than other dense circuits, does not require much servicing or support, and involves production know-how and capacity that is fairly easily transferred to the manufacture of similar commodity devices (such as static-RAMs), it meshed perfectly with characteristic Japanese strengths and manufacturing strategies. Nevertheless, Japanese success at developing the product market and <u>sustaining</u> a leadership position in this device, represents an important departure from the established Japanese strategy of being succesful market followers.

As demand for the device grew, the market gap created by delays in production by U.S. firms was filled by the aggressive and rapid Japanese production strategy. While the second-tier U.S. firms (behind Motorola and TI) concentrated on product innovations and new process development, their Japanese counterparts spent heavily to bring down production costs by automating their 64K dRAM production. They continued to invest in highly automated capacity expansion for 64K dRAMs during the 1981-1982 U.S. recession, while U.S. firms delayed or cut back their expansion plans (Recall Table 1). The ability to spend heavily during rough economic times, and the move to automation, illustrate again the characteristic domestic-based strengths of the Japanese industry. The ability to spend was based on the stable access to cheap capital (which was undoubtedly much cheaper for Japanese firms, given the grossly high interest rates that obtained in the United States from 1980 to 1982) afforded by the Japanese financial structure. The point to be made about automation is more complex. First, automation implies high front-end manufacturing costs, which bring with them two kinds of associated vulnerabilities. One is vulnerability to product innovation, where automated production that is optimized for a particular product or design is made obsolete by a new product or design that becomes an industry standard. Japanese 64k dRAM producers were helped in this area because no single 64K design became an industry stadard as Mostek's 16K design had been in the previous generation. Moreover, the Japanese financial structure and government policies generally decrease this kind of vulnerabilty by permitting cheap reinvestment combined with rapid tax write-offs and less concern about the impact of obsolescence and reinvestment on current earnings. The related vulnerability is to fluctuations in demand because the higher fixed costs of automated production place a premium on the use of full capacity. If demand drops but capacity is fully used, oversupply could eliminate profits on the device in question. However, given the arguments earlier about an essentilly closed market, Japanese companies face a sufficiently high level of stabile demand to avoid this second vulnrabiliy.

The question remains whether the Japanese government still plays the same roles in this round of competition that it played earlier. Importantly the government still plays a critical role in funding the generic research in device and production technologies, both through projects funded by MITI and by NTT. The details of these newest projects have not yet been translated into market products, so we do not review them here. Our conclusion, though, is consistent with that of several national panels charged with evaluating these issues. The programs appear significant and successful. It is less clear to us whether the Japanese market still is formally closed by government pressure or by internal corporate relations, or whether and to what degree the continous political pressure from the United States has loosened access to the Japanese market. Access to markets and R&D remain terribly difficult. The answer is not crucial to this argument that government policy has mattered at least until now.

Let us then summarize our position. The Japanese semiconductor firms have consolidated in their manufacturing-based strategy the international advantages afforded them by domestic Japanese industrial structures (themselves part policy-inducd) and policies. That consolidation has permitted them to dominate RAM production and compete in other product areas. In tandem with rising capital costs, the Japanese strategy has pushed the terms of international competition in semiconductors toward heavy capital investment and manufacturing -- signs of a "maturing" industry which play to Japanese strengths. U.S. firms have responded by diversifying their competitive strategies and flexibly positioning themselves to take advantage of new market opportunities. Rather than abandoning their strengths in innovation in the face of signs of "maturity," U.S. firms have chosen to push the pace of innovation. Some large U.S. firms have chosen to compete head-on with the Japanese in RAM markets; other merchant firms have ceded RAMs to concentrate on the development of newer commodity component markets where the U.S. leads. Simultaneously, new and old U.S. merchants, and U.S. captive producers have begun to take custom and semi-custom technology to market, creating new competitive opportunities. As these strategic maneuvers indicate, the diverse structure and flexible responses of the U.S. semiconductor industry enable U.S. firms to keep on the move as they respond to Japanese competition. In our view, policy actions taken by the U.S. and Japanese governments structure the competition and will ultimately determine whether international competition in semiconductors shifts to favor the Japanese or continues to preserve the dominant position of U.S. merchants and the U.S. industry. As argued, current and past Japanese government policies tend to slant the terms of international competition toward Japanese strengths. One could envision appropriate U.S. policy actions that could make a decisive difference. For example, the point of U.S. policies might be to ensure that the newly emerging strategies of the U.S.industry, and particularly of its merchant producers have a fair chance to succeed in the market.

The Semiconductor case, the Issues: What, then, can we conclude about our initial questions from this story? Our first question was how has government affected the evolution of the industry? In the early years in the United States, the military procurement and development policies assured a launch market for the firms innovating the new technologies. The long run development, though, was assured by the role of Bell laboratories, which acted as a technology pump assuring a constant flow of new technology and ideas into the industry. It meant the small firms could concentrate on product development, since much of the basic research was being done elsewhere. Government policy which structured the role of Bell labs and the financial possibilities of the industry was therefore essential. In our view joint industry research programs such as MCC or SRC are useful, but not sufficient substitutes for either government sponsorship of generic research projects or the prior role of Bell laboratories before divestiture.

In the Japanese case, government policy was an absolutely indispensable element in assuring the competitive development of that nation's industry. Without active government policy in the 1970's the industry could not have climbed to international prominence. That policy consisted of two parts; market closure and financing of generic research projects. In the current period it is difficult to judge the precise extent and significance of government promoted market closure, but government sponsorship of generic research at critical technology junctures remains essential. How widely such technology projects will be diffused is an issue. There appear to be limits on their internatonal diffusion. In sum, government actions altered the resources available to firms and thus changed the character and ambition of their strategies. Shifting the set of possibilities available to firms, expanding their resources and lifting constraints, does not guarantee market success. The Japanese firms acted effectively to capture the possibiities opened by the choices of government, in particular with their mastery of complex manufacturing. Japanese government policy depended on the strengths of the firms and exploited the market, but the policy was essential to the market outcomes.

The second question, of course, is whether those outcomes matter. Will the technologies of microelectronics diffuse differently if the origin of innovation is different? The density and the significance of the innovative interconnections in this industry are easy to underestimate. Four issues emerge from our story. Let us note them, rather than examining them in great depth. First, is a semiconductor more like a ball bearing or an electronic system? If it is more like a ballbearing it can, for the most part, be simply imported. If it is more like a system, then crucial innovation occurs at the level of the chip and losing the ability to design systems can affect a wide range of industries. Standard older generation chips are like ball bearings. Advanced chips are systems. Most importantly, knowledge about them transfers in the ties between design and marketing engineers in the producer company and the engineers in user companies. In some case systems are designed in ANTICIPATION of semiconductor advances. Buying the product on the market puts user firms at substantial disadvantage. There are certainly policies to compensate for the absence of the most advanced firms but they are second best solutions if a viable and varied industry is a possibility -- as perhaps Europe's deteriorating positon in electronics demonstrates. Information does not adequately diffuse by product. Second, manufacturing and design expertise is largely embedded in the equipment supplier firms and only partly embedded in specific companies as learning experience. The most significant Japanese advances for the competitiveness of American firms may well be in the equipment end, and the greatest danger, consequently, is their potential domination of the manufacturing equipment business. Why? Because the equipment diffuses --by observed evidence-- most rapidly in the country of origin. Third, each current large segment of product demand represents a force for innovation --except, our analyses suggest, military demand.[15]

The critical segments are consumer electronic products, telecommunictions products, and computer products. Japanese domination of the consumer electronics industries gave them a real advantage in new technologies of general importance, like CMOS as argued earlier. Finally, the fact that the Japanese electronics industry is dominated by six large integrated firms poses quite significant issues. On the one hand, the firms depend for product advantage on innovation in semiconductors. In house developments will diffuse within Japanese companies more rapidly than outside them. Diffusion out from Japan of equipment knowledge and early product knowledge is likely to remain assymetrical, to the disadvantage of American industry, for some time. In short, our answer to the second question is that critically important spillover are indeed generated in their industry.

Telecomunications: The Basic Story*

The telecommunications story is a bit different than that of microelectronics. First, it is not one story but many. The label groups a range of equipment running from satellites to handsets. Second, until very recently, there was not a story about telecommunications trade among the advanced countries, though all sought to sell to the the rest of the world. The telecommunications system in each country was either a private monopoly regulated as a utility, as in the United States, or a public bureaucracy providing a utility service, as in much of the rest of the world. In the United States the utilities, primarily Bell and secondarily GTE and some of the other independents, manufactured equipment for their own use. Bell in particular was precluded from selling its equipment in open markets. The ministries of post and telecommunications around the world generally had a family of supplier companies that acted collectively as a privileged supplier. There was little trade.

The decisions by American regulatory bodies (the FCC, primarily) and courts -- and we should recall that the choice in this instance is a judicial/regulatory one and not a matter of legislative action -- to deregulate the U.S. telecommunications system has created a new international reality. Underlying the regulatory and judicial decisions in the United States is the strongly held belief that the deregulated marketplace should decide how new

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* The analysis in this section is based on BRIE research conducted by Michael Borrus. Much of the language is drawn from " The New Media, Telecommunications, and Development: The Choices for the United States and Japan" by Michael Borrus and John Zysman (BRIE, 1984).

changes in telecommunications will occur. Opening the system to domestic competition opens the American market to foreign competition. This in turn leads to American pressures for reciprocal treatment (e.g., the Danforth legislation), which in fact means that others are compelled to follow our lead in establishing at least a partly market-driven telecommunications network.

The deregulation has occured at the same time as, and in part as a result of, dramatic technological changes. Moreoever, the telecommunications equipment and services industries are now <u>strategic</u> industial sectors. Two inter-related elements are at the center of our concerns. First, innovative transmission and distributed digital switching technologies have proliferated as a result of many nations' industrial efforts. Technically and commercially viable alternative transmission techniques have undermined the traditional belief that transmission is a natural monopoly. Microwave, fiber-optics, cellular mobile radio, coaxial cable, and communications satellites all challenge the traditional copper wire. These alternative technologies retain the capacity to be interlinked, and consequently can constitute one telecommunications system. However, when combined with highly flexible and distributed digital switching systems, the alternatives represent competitive product packages offering a wide range of different services at different prices. This end to a technological justification for monopoly in communications is critical. Second, communications and computing have merged as the technologies underlying telecommunications and data processing have converged. During the 1970s the communications industry moved away from the pure provision of communication pathways for analog voice transmission toward the provision of enhanced communications (voice, data, video and facsimile) using computer technology. Simultaneously the computer industry moved away from stand-alone computers toward networks of geographically separate computers interconnected through communications pathways for data transmission. Consequently the relatively distinct boundary lines between the two industries were blurred by the decade's end. Indeed, telecommunications in the 1980s and beyond will be characterized by the digitalization of both national public-switched telephone networks and private communications networks, and by the increasing linkage of data processing systems to both the public and private networks. Network integration, both within firms and externally in the public and private networks, is the overriding orientation of the current upheaval in telecommunications. Today, the telecommunications industry must be broadly understood to encompass the provision -- for information networking -- of terminal, transmission, and switching equipment, and voice, data, video an facsimile services. The convergence changes the character of competition and alters the services and products offered. As a result these telecommunications industries will be a powerful, perhaps dominant force, in shaping the development of the computer and microelectronics industries in the coming years. It will be a matter of policy whether the regulation of the networks and services will be used to create competitive advantage in related industrial sectors.

In this new environment, differences in national government policies will affect the possibilities open to private manufacturers. We have established a new environment in which the evolution of critical high technology sectors will be shaped by trade, and in turn, telecommunications' trade may well be shaped by government policies, given the strategic importance of the sector. We proceed in this section of the paper to review the differences in the regulation of the telecommunications system in the Uni4ed States and Japan and to evaluate their consequences for trade and competitiveness. Perhaps, unlike in Japan, the new American regulation has not been shaped --for better or worse-- with attention to the promotion of American competitiveness

Regulating the New American Communications Infrastructure: The divestiture of the Bell System and the deregulation of American markets for telecommunications equipment and services has shattered the old monopoly basis of the old style regulation. From the mid-1960s on, American regulators attempted to grapple with user demands for change to permit competition in the delivery of telecommunications equipment and services, and with the blurring of distinctions between communications and computing. A series of regulatory decisions acknowledged that the old regulatory goals of rate-setting and universal access to service were simply not sufficient to meet user demands for development of the possibilities inherent in the new information technologies. Rather than attempting to formulate new policy goals to guide implementation of changes of the national communications infrastructure, regulators and policymakers simply abdicated responsibility to the market: Competition in the market would determine the evolution, new structure, uses and control of the nation's communications network.

To prepare for the market-driven phase of development, it was of course necessary to break up the monopoly structure that had developed during the regulatory phase. The divestiture of the Bell System accomplished that. The divestiture has spun off the entire local, Bell System public-switched and private line communications network and the 22 Bell local operating companies that run it, under the control of seven regional holding companies. Using those facilities, the Bell operating companies provide local exchange communications services, and permit carriers of long-distance (i.e., "inter-exchange" or between local exchange areas) communications to access the local exchange areas for the purposes of originating or terminating long-distance communications. The divested local companies are not permitted to carry communications between local exchange areas (that task falls to the interexchange -- e.g., ATT, MCI -- carriers), and are only permitted to offer enhanced information services through a separate subsidiary. The local companies retained the Bell name, logo, and yellow pages and are permitted to market but not to manufacture customer premises equipment (like PBXs and handsets), and may neither market nor manufacture the equipment that goes into building the communications network (like central office switches, or fiber-optic transmission equipment). Restrictions on their entering new businesses (including manufacturing) can be removed by the courts in certain cases.

ATT itself retained the rest of the Bell System operations, including the long-distance network and services, Western Electric's manufacturing operations, Bell Labs, ATT-International (the international business arm), and ATT-Information Systems (the arm which sells enhanced information services and equipment). Most critically, ATT is now permitted to manufacture for and compete in any markets it chooses to enter (whereas before, it was limited to traditional telecommunications equipment and services). The new ATT remains one of the largest industrial corporations in the world -- bigger in fact than IBM -- and is rapidly becoming a strong competitive force on world markets for information products and services.

Market competition is changing the communications infrastructure of the U.S., and the outlines of that change are fast becoming apparent. Intense competition has resulted in a proliferation of new long-distance carriers (like MCI) each of which is building a long-distance network to rival ATT's. There is thus a proliferation of nation-wide networks for carrying voice and data over distance, made up of a different mix of new transmission technologies, from fiber-optics to microwave and satellite systems. Major users can choose which carrier they want for each communication they make, and thus have a wide range of competitive choices for t(eir communications needs.

However, many major users have also begun to build their own private networks, so-called bypass systems, in order to tie together their wide-spread operations and gain control of the evolution, costs and structure of their own communications needs. A similar intense competitiveness is beginning to characterize local-level communications as well. Competitive service providers, utilizing cellular radio, CATV, digital microwave Termination and Electronic Message systems (DTS/DEMS) as well as fiber-optics, have begun to emerge to challenge the local-level monopolies of the divested Bell local operating companies. Hence, at the local level, too, competition in the delivery of services and in the construction of alternative local distribution facilities, is resulting in a proliferation of different networks offering different services for local customers. Indeed, private bypass systems are also being built by major users for their local communications needs.

Thus, what was once a relatively uniform, national, local and long-distance communications infrastructure is being rapidly changed under the force of market competition. The proliferating networks that result from this competition are all geared to serve the needs of major users of information. In the process, the long-held regulatory goal of universal service for all Americans at affordable prices, is being fragmented. At least over the short-term, as competition drives the evolution of the infrastructure, major users will have first and most complete access to the wide range of new voice, data, video and facsimile services, while the majority of users will have only limited access to a much smaller menu of services, or no access at all. In the U.S., then, te abandonment of policy control (over network evolution) to market forces, has therefore meant an abdication of responsibility to enure the fair and just development of the new communications for the benefit of the nation as a whole.

Also lost in the move to market-driven change, as mentioned in the semiconductor story, was the national R&D resource that Bell Labs represented. From the mid-1950s until the divestiture, Bell Labs played a crucial role in maintaining U.S. preeminence in high-technology. Industries like semiconductors, communications, lasers, computers and software, were all built in large measure on the base of research and personnel coming out of Bell Labs. Because foreign firms had comparable access to the Labs' technical innovations, Bell Labs also served to underwrite their competitive positions. With the privatization of Bell Labs, with the turning of its mission to serve ATT, these benefits have been lost to domestic and foreign firms alike. What the long-run impact will be on the U.S. competitive position in high-technology is an open question.

Similarly, it is a bit too early to tell how the generation of network standards will be played out under market-driven development in America. The proliferation of different communications networks and equipment threatens to lead to a situation of high incompatability. Of course, when the market decides these issues, as it has in the computer industy, de facto standards do emerge (IBM's operating systems in computers, for example). In the process, however, many producers and users of equipment can be obliterated in competition. This is the danger. However, there is also opportunity, for U.S. firms operating in a multi-vendor communications environment Finally, of course, the move to market-led change in the U.S. has thrown the U.S. market wide-open to foreign competition. This is a tremendous opportunity for foreign firms, one that Japanese companies in particular are taking advantage of in highly successful ways. But, in our rush to abdicate strategic policy-making in communications, we forgot to ask for quid-pro-quos from abroad when we opened our market. There is now a move in the U.S. Congress to require reciprocity in open market telecommunications opportunities -- foreign firms would only be permitted to sell in the U.S. to the same extent that U.S. firms are permitted to sell in foreign markets. Such a move will affect both European and Japanese companies, and is already provoking changes in policy abroad.

The New Japanese Infrastructure: The proposed evolution of regulation of the Japanese system is very different, reflecting in great measure the ways that policy has been used in Japan to generate comparative advantage on world markets for Japanese telecommunications firms. At the moment, Nippon Telephone and Telegraph is Japan's domestic, public, common carrier communications monopoly under the administrative control of the Ministry of Posts and Telecommunications (MPT). In addition to monopolizing common carrier communications, including data transmission, NTT offers data-processing time-sharing services, licenses all communications and runs four very advanced electronics R&D and systems engineering laboratories. Since its formation in 1952, NTT --under MPT's direction-- has engaged in joint R&D and systems engineering to develop network equipment for Japan's public-switched communications infrastructure with a favored 'family' of major Japanese electronics companies (NEC, Fujitsu, Hitachi and Oki). NTT has helped to develop and finance pilot and mass production systems for manufacture of the products jointly researched and developed. Crucially, NTT has procured high volumes of equipment and systems at premium prices from its family companies --not unlike the U.S. Defense Department-- which serves both to make demand highly predictable and stable, and to subsidize price competition for those Japanese firms on export markets. It has even engaged in direct exportmfinance. Of course, all of these developmental activities have been closed to foreign firms. In essense, NTT's industrial policy role has enabled favored Japanese telecommunications-computer-semiconductor companies to develop and commercialize new technologies in a protected and subsidized, risk-minimalized way. The resulting equipment has been procured in high volume at premium prices until quality and cost have reached world levels, enabling rapid competitive penetration of world markets by major Japanese firms. As data processing and telecommunications have converged, NTT has emerged as an important element in electronics development.

In microelectronics, for example, NTT developed Japan's first prototype 256K RAM --the next generation of semiconductor memory-- in late 1979. In late 1982, NTT transferred 256K dAM designs and process technology to Japan's major electronics producers, and entered into pilot procurement contracts in order to force them to gear up commercial production. As with all NTT procurement, premium prices are being paid to Japan's producers. This has created a dramatic acceleration of the pace of Japanese RAM development, as currently six Japanese producers --Hitachi, NEC, Fujitsu, Toshiba, Mitsubishi, and Oki-- are sampling 256K dRAMs to potential customers with a lead of about six to nine months over U.S. merchant firms. Whatever the degree to which NTT's technology transfer was responsible for the Japanese producers' early lead in 256K RAMs, its procurement of those products has speeded Japanese firm efforts to move to volume production for commercial markets. NTT has reportedly also developed a series of proprietary chips, including VLSI digital signal processing circuits and a 32-bit MPU, and it has begun work on a megabit RAM; once again, it appears certain to transfer these technologies -- semiconductor technologies that could gain increasing commercial importance in the late 1980s. Of equal importance is NTT's development work in photolithography. NTT has already develped an electron-beam pattern delineator capable of one-half micron line widths, and is conducting a program to develop extremely advanced step-and-repeat x-ray aligners for use in the mass producton of future-generation VLSI chips. In all of these areas, NTT absorbs the extremely high cost of development, diffuses the technology to Japanese firms, and then procures at premium prices semiconductors, or systems inorporating them, to speed commercial production. The process amounts to a direct public assist that greatly enhances the international competitiveness of Japan's semiconductor producers.

Given these competitive impacts of past policy, there is now a vibrant debate in Japan about the evolution of the Japanese telecommunications system. One possibility of course is that arrangements will be left as they are. If they are modified, several proposed laws, one of which was expected to be implemented this summer, was not passed but will be reintroduced in December, provide a guide to Japanese thinking. The proposed NTT law (which has not yet passed the Diet), is a substantially watered-down implementation of reforms recommended by Japan's Second Ad-Hoc Commission on Administrative Reform in its Basic Report of July, 1982. The Commission had recommended that NTT be divested in a form roughly paralleling the break-up of ATT in the U.S. -- a central company was to control the trunk lines network, and local companies were to operate local services; the government was to hold 100% of an initial stock offering, but then sell off up to 49% of ownership to Japanese holders over time; new entrants were to be permitted to compete with NTT in the delivery of enhanced and some common carrier services. The new NTT law scraps plans to divest NTT into the central and local companies, but implements the stock-holding and (in conjunction with the new Business Communications Law) liberalization of competition reforms. Thus, the new NTT will be initially held 100% by the government, which will gradually cede up to 49% ownership (with the approval of the Diet). Critically, no foreigners or foreign companies will be permitted to buy stock, although a Japanese company held less than 50% by foreign interests will be technically eligible as a shareholder. Moreover, NTT will now be free to compete aggressively in the delivery of enhanced services in the Japanese market (see following discussion of the Business ommunications Law) -- and may even be permitted to de-average its rate structure in order to compete with potential common carrier entrants on high density data transmission routes (e.g. Tokyo-Osaka). If and when the new NTT law goes into effect, NTT will be one of the largest companies in Japan, with about $40 billion in assets and annual revenues approaching the $20 billion mark.

Just as NTT's overall developmental activities have been closed to foreign firms, its procurement has been equally closed until recently. Until the U.S.-Japan Agreement on NTT procurement was implemented starting in 1981, less than one-half of one percent of NTT's annual procurement had gone to foreign firms. Since the U.S.-Japan Agreement, NTT procurement from foreign firms has risen steadily, from about $15 million in 1980 to about $140 million in 1983. The 1983 figure still represents less than 5% of NTT's estimated annual procurement of about $3 billion (we estimate traditional telecommunications equipment to account for roughly half of that total).* The U.S.-Japan Agreement was renewed for three years in December, 1983; and it was hoped that the renewal would help more fully to open the Japanese market

* With the exception of a few PBXs, one transportable digital switching system, pocket bell pagers, multiplexers and satellite communications components, there has been no foreign procurement of telecommunications equipment -- despite the acknowledged competitiveness of big-ticket items like digital switching equipment made by U.S. and foreign producers like ATT, Northern Telecom, and Ericsson. Most of NTT's current foreign procurement is data processing components, peripherals, computers and systems, and semiconductor manufacturing and test equipment. Thus, despite years of pressure from the U.S. government and the U.S.-Japan Agreement, the Japanese market for telecommunications equipment still seems to be largely closed to U.S. and foreign firms.

to U.S. suppliers (Rolm has sold a few PBXs, ATT many small computers, and Cray a supercomputer since the renewal). It is in this context that the new NTT law gains added significance: As the government's ownership of NTT is reduced over time, it is possible that NTT's procurement will fall gradually out from under the coverage of both the U.S.-Japan Agreement and the GATT Code on Government Procurement.

A crucial question in this context, is whether NTT will continue its comprehensive developmental role for Japan's major electronics equipment manufacturers. There are important signals that in many areas that developmental role will be more limited than in the past, especially as NTT enters the market in competition with its 'family' companies, in particular NEC and Fujitsu. For example, the percentage of NTT procurement accounted for by NEC, Fujitsu, Oki and Hitachi, has fallen from 60% in 1978 to 32% in 1983 -- although its value has remained relativl=ely constant. This self-conscious diversification of NTT's supplier base suggests that opportunities for U.S. and other foreign firms to participate in NTT procurement may well proliferate. In our view, the critical variable will be whether MPT will push NTT to continue its developmental role, or permit it to continue to diversify its procurement. If the developmental role continues, we expect it will center largely in the networking equipment area (since NTT itself will not become an equipment manufacturer for the forseeable future). Indeed, NTT's new digital switching system, the D70, has been developed exclusively with Japanese firms. Because NTT's foreign procurement may continue to be limited, a concern widely expressed in the United States is that as just another stock-held Japanese corporation, NTT will be much more immune to government-to-government negotiations to open its procurement.

Whatever occurs with NTT, however, there should be substantially increased opportunities for U.S. and other foreign producers in Japan because

Japan's private sector now actually procures more telecommunications equipment than does NTT. This fact both demonstrates the tremendous speed at which change is occuring in Japan, and signals the potential that is emerging for vast new market opportunities. Overall, then, it appears that most U.S. equipment manufacturers looking for opportunities in Japan might well flourish by looking toward NTT's competitors (domestic and foreign) in the services arena as they begin to build competing networks. It is to liberalization of competition in services that we now turn.

The Business Communications Law is our next concern. Since q971, MPT has gradually begun to relax restrictions on telecommunications in the domestic Japanese market, to take account of the convergence of data processing and communications. A revised telecommunications law in 1971 provided a legal basis for data communications, permitting users to connect with the public network and with leased lines (in some cases, only with the approval of MPT). However, message switching (the most simple kind of value-added network -- see below) was prohibited. In 1972, facsimile machines were permitted interconnection. In late 1982, on-line information processing systems were completely decontrolled. Under a ministerial ordinance MPT also liberalized some portions of the value-added network (VAN) market, permitting limited VAN services for small and medium enterprises, including internal corporate VANs for affiliated enterprises (e.g. Fujitsu F.I.P. provides administrative information exchange among Fujitsu-related software development companies). Of course, permitting internal corporate VANs provided the major Japanese corporations who might compete in a fully deregulated VAN market with substantial in-house experience in setting up and running VANs. In this simple way MPT policy helped prepare Japanese firms for the coming full deregulation of VANs. The concern outside of Japan is that this policy increased competition in Japan among Japanese firms but did not allow entry of foreign firms.

The new Business Communications Law takes liberalization a step further by deregulating the VAN market in Japan and even opening it to foreign competition. For purposes of the law, we must distinguish three types of VANs -- literally, networks where data transmission is enhanced but the contents of the data are not changed. The simplest VAN is message switching, in which data is transmitted and switched on to a final destination, but neither communication nor information processing occurs. The second type of VAN stores and forwards data adding communication processing (e.g. speed/code/protocol/format conversion) but not information processing (e.g. processing for cryptograph, statistical file, credit inquiry). The third type of VAN adds information processing to the network's functions. The new law clearly deregulates the first two VAN types. It is an open question whether the third type of VAN falls within the new Law's purview, or whether it will be considered an information processing system.

The distinction is important because unlike for information processing systems, there is a "notification" requirement for VANs under the new law: While entry into the VAN business is ostensibly deregulated, any potential entrant must "notify" MPT of its intent to offer VAN services. Crucially, "notification" is not self-activating; rather, it requires an acknowledgement from MPT. In effect, then, MPT permission to operate must actually be obtained. Hence, even though foreign firms are permitted for the first time to offer VAN services on the Japanese market under the new law, MPT will have the final say over which firms and which networks are permitted to operate. This is an interventionist rather than merely regulatory power: MPT's decisions permitting or denying VAN operations will structure the VANs market in Japan.

MPT fought long and hard against MITI to win the new law's notification requirement. During the battle, MPT was forced to drop a proposed 49% limitation on foreign ownership of VANs in Japan -- in part because of strong opposition from the U.S. Nevertheless, MPT's victory in winning the power to screen applicants over MITI's objections (combined with MITI's defeat by the Ministry of Education over MITI's proposed software law) reflects a partial reshuffling of policy control over the emerging information economy within the Japanese bureaucracy, and suggests some of the limits of MITI's power in Japan. MITI had wanted VANs to be considered as information processing subject to its own administrative guidence, and thus called for complete deregulation of the VAN market in Japan. Under the influence of some economists, MITI also seems to be invoking market generated economic efficiency more than in the past, and this factor also accounts for MITI's call for full deregulation. By contrast, MPT wanted to extend its own jurisdictional authority into the information processing realm, implicitly at MITI's expense. Because the distinction between VANs and data/information processing networks is increasingly less tenable from a technological standpoint, future policy control over the evolution of Japan's information-based economy lies hidden in the MPT-MITI fight over the new law. We can expect many similar bureaucratic battles over the next few years as information networking evolves in Japan.

The American concern is that the Japanese market will continue to be closed in strategic ways, and Japanese policy will continue largely to favor Japanese producers and help to prepare them for competition on world markets. The coming market battles in communications and information processing in Japan between Japanese and foreign firms will signal exactly how formidable emerging Japanese suppliers of end-to-end voice and data communications systems are likely to be on world markets. U.S. firms should find increased opportunities to sell equipment and services in Japan as a result of the partial liberalization of the domestic market effected by the new laws. However, the Japanese market business of U.S. firms will continue to be subject to regulatory control by the Japanese government`(in particular, the Ministry of Posts and Telecommunications (MPT)). Indeed, because that continued regulatory control will be less formal than in the past, U.S. firms worry that they will find their opportunities systematically limited in ways less amenable to resolution through government-to-government negotiations. If the domestic Japanese market continues to serve as an invaluable base for Japanese firms to fashion and hone competitive strengths in the delivery of enhanced communications services like value-added networks (VANs), Japanese policy will have strengthened the position of Japanese firms in competition on world markets, creating advantage yet again.

Telecommunications, Some Cases of Competition: We have already alluded to one excellent example of the role in affording enduring advantage that government policies can play in the telecommunications industry -- the story of fiber-optic light-guide cable. In the early 1970s, Corning Glass held generic patents on the production of light-guide which afforded it the industry's leading production role. In the mid-1970s, Corning attempted to register its patents in Japan so that it could begin to export light-guide into Japan without worrying that Japanese producers would copy its process and eliminate it from the market. The patent applications were stalled in Japan for nearly 10 years. During that time, NTT entered into a crash devlopment program with Japan's three leading cable producers, Sumitomo, Furakawa and Fujikura, to develop a wholly different method of producing light-guide. The result, the Vapor-Axial Deposition (VAD) method, did not infringe on Corning's proposed patents.

NTT then entered into major procurement contracts at high premium prices with the major Japanese cable producers. This forced them to reach a scale of production that brought their costs below world market levels, created excess capacity destined for export, and provided the profits to subsidize price competition on world markets. In short, by refusing to permit Corning Glass to patent and sell lightguide in Japan in the early 1970s, when Corning had a massive advantage as the world's first volume producer and would have easily captured the Japanese market, Japan bought its domestic light-guide producers time to develop an alternative production process and reach commercial-scale production. Today, Japanese producers own their domestic light-guide market, and have begun to penetrate the U.S. and world markets successfully. Corning's initial advantage has been eliminated, and enduring advantage was created for Japanese producers who are currently by far the world's largest producers of fiber-optic cable.

A very different outcome of government intervention, and one which must be acknowledged because it suggests that the lack of appropriate policy can disadvantage firms in competition, involves the performance of Japan's NEC in the U.S. market for digital central office switching systems. NEC entered the U.S. digital central office switch market relatively early in 1979 with its NEAX 61. After a quick start in sales to smaller independent and rural telcos primarily as a result of its habitual lowest-bid pricing strategy, NEC ran into trouble largely because of software problems with the switch. It was in fact forced to rip-out the switches it had installed for Rochester Telephone, a larger independent. NEC apparently ran into problems primarily because it had not had a chance to install and de-bug digital central office switches in Japan. This in turn, was the result of NTT's relatively late move to digital switching for Japan's public network. Indeed, the NEAX 61 was an export-only switch, the result of early prototype development by NEC and NTT for export markets, and it was never destined for use in Japan.

Thus, without the domestic market experience that NTT might have afforded it, NEC was at a disadvantage in competition on world markets. To be sure, NEC would never have been in the game at all if not for NTT's assist in developing the export-only switch; nonetheless, without the impact in helping to create advantage of procurement and debugging in the Japanese market, NEC suffered. Here then is an important example of government policies that afforded some assistance but were not comprehensive enough to leverage enduring competitive advantage on world markets. Government policy mattered, but its absence at a critical juncture of market competition mattered even more. Whether NEC will make a come-back in the U.S. on the basis of demand and the associated economies and knowhow in Japan for its version of NTT's new D70 switch (as NTT moves to digitalize its network) is an issue worth tracking in our context of government policies altering trade patterns.

An interesting parallel example, but one in which the assist from government policy was coincidentally timed with developments in the market far more successfully for generating advantage, is NEC's recent successful penetration of the U.S. PBX market. In the early 1980s, NEC moved into the U.S. market with the easily upgradeable, distributed, digital NEAX-2400. This occured just when the reputation of Mitel --the early dominant low-end analog PBX supplier-- had bottomed-out because of Mitel's failure to bring a digital PBX to market fast enough to manage the market's demand transition from analog to digital PBXs. NEC aimed its own digital PBX at the section of Mitel's potential customer base looking to upgrade to larger, digital systems, but frustrated by Mitel's delays in bringing such a product to market. The NEAX-2400 draws on NEC's expertise as one of the world's best, integrated computer and communications companies. The PBX offers a distributed modular architecture (incorporating silicon systems design in NEC's own VLSICs) that permits easy migration upward from simple voice uses to integrated office systems functions.

However, many of the NEAX-2400's software-driven, network integration features have not yet been completed, which implies a relative competitive deficiency in software development. In part, as with its CO switches, that problem stems from the very late development of its home Japanese market for digital PBX network interconnection. After jointly developing digital PBXs with Japan's major producers (in the manner described in the prior section) Japan's NTT only published technical specifications for digital PBX interconnection to the national network in late-1981. Thus, although they had benefitted from policy-assisted development, Japanese firms were not able to install digital PBXs prior to that time. In short, NEC had not had time to install, de-bug and develop experience with PBX digital network integration in its home market. However, this very same factor coincidentally permitted NEC to time its NEAX-2400 U.S. introduction to take advantage of Mitel's stumble. In this case, the late policy assist helped to afford NEC an important entry to the U.S. market. Whether policy will create the basis for enduring advantage, depends in our view on how quickly NEC's home market for network integration develops, and on whether that market is closed sufficiently by policy to permit NEC to develop the experience and economies necessary for continued success in the U.S.

We return again to the same questions: whether government policy affected corporate strategies in a manner which altered market outcomes and whether the process of international technological diffusion are such that it matters where innovation occurs and initial markets positions are established.

In this sector as in the one which proceeds it the conclusion is direct; governments matter and the pattern of technological innovation and diffusion favors the home country.

Conclusion

.Our argument, happily for us all, can be more succinctly summarized than presented. The conclusion is that governments can create the conditions for enduring commercial advantage for their firms in international competition and shape the patterns of comparative advantage. Because of the interconnections in the economy, the evolution of critical sectors, often high technology (such as microelectronics) or bearing a critical technology input to a range of user sectors (such as machine tools) can affect the wellbeing of an entire economy and the patterns of advantage within that economy. Consequently active policies for support of trade and industry development can, in specific cases, be justified.

Examining traditional trade theory we found that it could not address the dynamics of trade in manufactured goods amongst the advanced economies. The inherent shortcomings undermine its conclusions and policy perscription. Its presumption is that government cannot do more than temporarily distort trade flows from natural channels, rather than permanently reshape these patterns as we argue, and that non-intervention is automatically the optimal policy. The new trade theorists have substantially advanced the debate. Their analytic conclusions open the possibility that government policy can be used to strategically shape the national welfare. Here, though, there is a debate, because whether intervention helps or hurts suddenly depends on the market and technological circumstances. The discussion must turn on the systematic analysis of cases.

Our research on high technology trade over the last years has addressed two questions: First, can government policy affect market outcomes, or more precisely, how do different patterns of policy and business-state relations affect corporate strategy and hence market outcomes?; and second, do the sectoral outcomes affect trade patterns more generally? Our analysis of international competition and policy in micro-electronics and telecommunicatins leads us to answer with a strong yes to both questions.

FOOTNOTES

1 See for example BRIE studies such as ________________.

2 Department of Commerce, 1983.

3 Department of Commerce, 1983, p. 9.

4 Klein, see Borrus, et al.

5 Comparative advantage also sometimes depends on natural resource endowment, as in the case of trade flows of oil, raw materials, and agricultural products.

6 There are several contributions to the new literature on international trade. A representative example includes Krugman, (1981, 1983), Lancaster, (1980), and Grossman and Richardson, (1984).

7 Kenichi Imai, Hitosubashi University, "Japan's Industrial Policy for High Technology Industries", paper presented at Stanford University March 21, 1984.

8 In an industry in which the returns to R&D are easily affordable, there is no presumption of inadequate private investment. Indeed, in an imperfectly competitive industry, firms might well invest too much in R&D from a social point of view because of these attempts to use investment as a strategic move by potential competitors.

9 See, for example, Rosenberg, 1982.

10 Teece, 1984.

11 Teece, 1984; Imai, 1984.

12 Nelson, 1984.

13 This phrase is also used by Professor Murakami, of Tokyo University, in much the same way. See Kozo Yamamura, ...

14 William R. Cline, "'Reciprocity': A New Approach to World Trade Policy?" Policy Analyses in International Economics, #2 (Institute for International Economics, Washington, D.C.: September 1982), p. 14.

15 See Leslie Brueckner, ...

ENDNOTE:

The contributors to the new trade theory remove the presumptive conclusion that free trade is the optimal policy. They conclude that an activist policy is, nonetheless, a less attractive, second best alternative. Paul Krugman develops such an analysis in his paper, "The U.S. Response to Foreign Industrial Targeting." We think he poses the problem very well, though we disagree with his conclusions about the dynamics of high technology industries. Before turning to our cases, we consider his line of argument.

Although in this paper we focus on the analysis of trade dynamics in high technology, Krugman's general position requires some comment. Krugman argues that:

> Even where there is some evidence that foreign industrial policies affect trade, the more difficult task of assessing the consequences for the United States remains. The problem may be illustrated by the case of steel. Suppose that subsidized European steel is being sold in the U.S. market. One view would be that these imports are undercutting U.S. production and employment; the other view would be that the subsidies represent a gift to U.S. consumers. Whether one thinks the United States should retaliate or send a note of thanks depends on how one thinks the U.S. economy works. If one believed that the U.S. economy were characterized by competitive markets in which prices moved quickly to clear those markets, and that there were few serious dynamic costs and benefits, one would not be very worried about foreign targeting. Even if the practices of foreign government led to a significant distortion of U.S. trade, they could not do much harm to the country as a whole. The only channel through which foreign targeting could hurt the United States would be through a worsening of the U.S. terms of trade...
>
> In fact, the U.S. economy is not a neoclassical paradise. Not all markets clear quickly, not all industries are perfectly competitive, and dynamic factors are important. But to establish serious injury to the U.S. economy, one must show that foreign practices interact with the imperfections of our domestic economy in such a way as to aggravate them.

Krugman notes four imperfections that "might give rise to harm by foreign targeting." They are: 1) the failure of the U.S. labor markets to clear; 2) the large union induced wage differential that distorts labor allocation in the U.S.; 3) the reality of imperfect competition which opens the possibility that foreign governments can give strategic advantge to their firms; and 4) the importance of external economies in dynamic, technology intensive inustries.

Krugman correctly notes that while targeting may displace domestic resources or reduce wage premiums in particular sectors, it may not lead to general losses to the national welfare. His implicit assumption is that if the general welfare is not reduced, we should not intervene to protect domestic groups suffering from trade displacement generated by foreign targeting. This is finally a political and not an economic judgment. In the case of free trade one can argue that those displaced by trade are paying the price for increased national welfare. They should perhaps be compensated domestically, but the process of growth cannot be stopped. In the case of displacement by foreign targeting, there may be no loss to the general welfare, but there need not be any corresponding national gain. Why then should we ask domestic groups to accept the pain of dislocation?

Second, Krugman contends that the case that the gains from government strategic action in an oligopolistic industry can radically reshape market outcomes is not demonstrated. The implication is that the case for anactivist policy is therefore weak. We note that Krugman refutes a single formulation of a general proposition, one that hinges on particular strategies of government and firms, and does not develop a general counterproposition. From our vantage, it seems probable prima facie that when governments provide subsidies or protection, they increase the resources available to firms competing in oligopolies. Those increased resources will alter firm strategies, allowing them to pursue different market, pricing, production, and product tactics. Whether the firms can translate those resources and new strategies into improve$ and defensible market positions is an open question, of course. Yet the presumption must be that the hand they play is strengthened and that their strategy is therefore likely to change.

Finally Krugman notes: "Even those most skeptical about the alleged dangers of foreign industrial policies get a little nervous about the possible effects of foreign targeting on U.S. technological progress." He concludes two things: First, that there is no "wholesale" decline in the American trade position in high technology; and second, that while the real danger is the spillover effects of slower growth in critical technology sectors, on the ability to innovate nationally, there is little theoretical or empircal evidence that such effects have been significant in practice. Krugman has identified the right issues. We disagree with his analysis of them. Krugman argues that any decline in U.S. share in total world exports in high technology products is attributable to the increasing technological competence of our competitors. The pace at which our competitors catch up, however, is not a given of nature but rather a product of policy both at home and abroad. Therefore, we cannot conclude that the outcomes of the catch-up process are necessarily satisfactory.

Krugman's second line of argument focuses on the possible spillovers in the process of the diffusion of technological knowledge. Krugman argues that if the development of critical technologies occurs in foreign firms, there is a risk that the technological spillovers will be lost to American firms, but if spillovers pour past national boundaries, then American firms will benefit. Therefore, a problem exists for the U.S. only when foreign targeting promotes technologies with substantial spillovers, but spillovers that stop at national boundaries. Krugman points out that product advances can be reverse engineered or purchased -- so they are appropriable across international boundaries. He also contends that production knowhow is firm specific and cannot spill over. He does note that the capacity to innovate --knowing how to innovate-- is often embedded in a community and cannot diffuse. From this he concludes --and finds evidence in the semicondctor case-- that the dynamics of diffusion do not pose problems if foreign targeting gives market advantage in some sectors to their national firms.

Appendix A

CREATING ADVANTAGE*

Traditional trade theory tends to hide the constantly shifting and positively created character of advantage. In so doing, it hides both the real stakes in many trade conflicts and the role that government plays in plotting the course of national industrial development. According to the modern theory of international trade, free trade will encourage countries to export in sectors in which they have a comparative advantage and to import in sectors in which they have a comparative disadvantage. Comparative advantage is usually assumed to depend on relative factor proportions or availabilities, under the assumption that all countries have access to the same production technology and differ merely in their endowments of factors of production. The traditional theory, according to both its Hecksher-Ohlin and its Ricardian versions, posits the existence of mutual gains from free trade accruing "to national trading partners.** Even the country with an absolute disadvantage—a higher domestic cost of production for all traded commodities—gains from free trade by importing those goods in which its absolute disadvantage

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*This section is in large part excerpted from an article written by Laura Tyson and John Zysman, "Making Policy for American Industry in International Competition," to appear in John Zysman, Governments, Markets and Growth (Cornell University Press, 1983).

**The modern variant of comparative advantage theory, referred to in the eocnomics literature as the Hecksher-Ohlin Theory, assumes the existence of two or more factors of production (starting with labor and capital), and argues that countries will tend to export goods embodying their relatively more abundant factors and to import goods embodying their relatively more scarce factors. Ricardian trade theory, in contrast, explains comparative advantage in terms of a single key factor of production, usually labor, although in more recent usage it has been used to explain trade based on natural resource endowment as well. In Ricardian theory, the precise pattern of specialization in production and trade depend on comparative costs measured in terms of the factor of production in question.

is least. Not surprisingly, then, discussions based on these premises are likely to take a dim view of government policy that is intended to alleviate the difficulties of domestic industries in international trade. Interference with the market, it is thought, can only distort the pattern of free trade; the difficulties of specific industries can be eased only at the expense of national gains.

Traditional trade theory, however, is powerless to deal with questions that do not fit its static orientation and its assumption of perfect competition. As soon as technological evolution and market imperfections are allowed to enter the picture, both its theoretical models and its implied policy prescription become confused. The static nature of trade theory is reflected in the assumptions of fixed technology and fixed factor endowments that are part of both Ricardian and Hecksher-Ohlin theory. For example, the Hecksher-Ohlin theory assumes a given standard production technology to which all countries have access, and also assumes given amounts of factor endowments in each country. Under these assumptions, the theory posits that trade will lead to increasing specialization among trading partners, as both factor prices, and hence production costs of traded goods, converge. The theory treats the determinants of factor endowments as exogenous, and overlooks the important fact that technologies are not the same in all nations producing the same goods. As a consequence, critically important policy issues fall outside the scope of theoretical analysis.

The influence of government policies on the dynamics of comparative advantage over time becomes clear when one allows for the possibility of differing production technologies in different countries. To see this, one need only consider the impact of government policies on the gradual accumulation of physical and human capital. Such policies can gradually turn a temporary competitive disadvantage in capital-intensive or education-intensive industries into a comparative advantage. In short, national comparative advantage is in part the product of national policies over time. There are only a few industrial sectors in which comparative advantage is given in the form of fixed natural resource endowment. In most sectors, comparative advantage rests on relative capital endowments, and these are the result of accumulated investment.

The role of national policies in the process of creating comparative advantage is forcefully demonstrated in the case of Japan. Policy makers in Japan consciously approached industry policy with the notion of creating advantage and with a view of dynamic change. To understand the economic transition they have engineered, it is first necessary to distinguish between the notions of comparative advantage and competitive advantage. Comparative advantage refers to the relative export strength of a particular sector compared to other sectors in that same economy and it is usually measured after adjusting for the effect of government policies that distort the supposedly autonomous workings of the market. For the purposes of our discussion, competitive advantage refers to the relative export strength of the firms of one country compared to the firms of other countries selling in the same sector in international markets. According to this interpretation, the comparative advantage enjoyed by the firms of a particular country in a particular sector may be the result of the country's absolute advantage in that sector. In contrast to the usual notion of absolute advantage, however, the notion of competitive advantage allows for the presence of economic policies that help or hinder the international performances of different firms. Thus the competitive advantage of the firms of a particular country in a particular market may be the result of a real absolute advantage or they may be the result of a policy-induced and hence distorted absolute advantage. However, policy-induced advantage at one moment can accumulate over time into real absolute advantage, as when abundant capital and protection allowed the investment in steel development that made Japanese producers preeminent.

Whether competitive advantage is real or policy-induced, the competitive dynamics of industry form the link between static and dynamic comparative advantage. Over time, shifts in competitive advantage for particular firms in particular industries can accumulate into a change in national comparative advantage. We must understand that comparative advantage rests on the accumulation of investments, and that a long-run strategy can slowly alter a country's comparative advantage by altering its investment stock. The main point again is that accumulated investment, whether in physical infrastructure or the infrastructure of related markets and firms, is crucial to determining both competitive advantage at the moment and comparative advantage over time. In a wide range of industrial sectors, a nation creates its own comparative advantage by the efforts of industries and government to establish comparative advantage in the market. Where the eroding competitive position of individual firms unravels a web of domestic infrastructure, the outcome can be a change in comparative advantage. This is especially true in industries dominated by a few large firms. Although there may be no comparative disadvantage underlying the initial competitive difficulties of a particular firm, these difficulties can have a cumulative effect that leads to a national disadvantage. The costs of recapturing a lost market share will go up if the infrastructure, in the form of suppliers and distribution networks, is undermined. The collapse of suppliers, for example, may affect the industry's collective ability to sustain its technological position. As this discussion suggests, in advanced industrial economies, comparative advantage—a concept much in vogue and loosely used—is to be understood as the cumulative effect of firm capacities and government policy choices and not simply as the effect of resource endowments in capital and labor.

Although the determinants of changes in competitive advantage have been largely overlooked in most models of international trade, they have been the focus of at least one branch of trade theory—namely the product-cycle theory. Product-cycle theory focuses on the role of technology and innovation in the dynamics of trade. Developed in the 1960s to explain changes in the pattern of U.S. trade, it states that trade in manufactured goods typically follows a pattern in which a country that introduces a product first becomes a net exporter of it, but then loses its net export position when manufacture of that product becomes standardized and moves to countries that have a comparative advantage in the factor intensities required by the standard technology. In the period before technology becomes standardized, the innovating country enjoys the benefits of imperfect competition that accue to a single seller; and if increasing returns to scale exist, these benefits may persist for some time before competitors are able to enter the market and eliminate the monopoly rents. As might be expected, given the critical role of innovation in the product-cycle theory, and given the apparent links between innovation and the process of both physical and human capital accumulation, the countries that pursue investment policies in both arenas are likely to be the ones that are product innovators and the ones that earn the resultant rents. Moreover, in addition to investment policies, a variety of national policies—from tax policies on capital income to depreciation policies to support research and development—may influence the pace of technological change, and thus affect a nation's competitive advantage in high-technology industries. In simpler terms, policy can clearly affect the number and variety of products in which a country initiates the product cycle.

Policy will also affect the pattern of trade that each product cycle produces. How long one country will hold an advantage in the production of a particular good—or conversely, how quickly a follower producer can catch up with competitors—is not determined by some inevitable economic process. Markets can be manipulated, and imperfections created, to influence these outcomes. In these dynamic conditions, there are no automatic mutual gains from exchange.

Consider, first, potential imperfections resulting from production economies of scale. Significant competitive advantages may be gained by the firms of a particular country if their home market is protected and they are allowed to develop a scale large enough to capture cost advantages. Under these protected conditions without foreign competitors, a greater portion of market demand will appear stable to domestic producers. Greater market predictability should lead them to standardize and automate production more rapidly, with an eye to capturing maximum scale economies, because the risk of being stuck with unneeded capacity will be reduced.

Second, learning-curve economies, like production economies of scale, can be the source of competitive advantage in imperfect markets. In the presence of learning-curve economies, rapidly changing final products (such as integrated circuits), quick market entry, and an initial dominant position, may provide the producer with a market advantage during a long phase of the product's life cycle. Or, more ominously for those who follow the leader, early entry may provide advantage through a long phase of an industry's development. Thus as production volumes increase, costs decline because of modifications in product and process technology. This argument applies most powerfully to the rapidly expanding advanced technology industries. Once again, in sectors where learning-curve economies are likely to be signficant, government policy can play an important role in stimulating or hindering their realization in domestic firms and hence in affecting the competitive advantages of these firms in international markets.

The conclusion of this argument, again, is that comparative advantage is a dynamic concept and government policies can alter its pattern over time. Politics will shape market demand as well as the technologies of product and production.

Of course, while government may help a few industries gain competitive advantage within several industries or segments of them, this does not mean that the country will have a comparative advantage in all of them or that it will use up the economic breathing space of its partners. However, a single country may lose its competitive advantage over a wide range of industries. Then the risk is that those sectors in which it loses will be high-employment industries in which competitive decline will have a significant aggregate effect on dvelopment and trade. Clearly this is the stake in autos and steel. The real danger is that a country may lose comparative advantage not simply in a single business or even in a range of businesses, but rather in a type of business. In that case, a country may turn onto a slower growth path than its partners. Conversely, a country may lever itself onto a fast route. Japan, for example, can be said to have gained an advantage in industries in which high-volume standardized production gives quality and cost advantages. Comparative advantage in modern mass-production sectors will hinge not simply on wage rates, but on the operational control of complex systems that reduces per unit labor costs substantially. The Japanese, by comparison with Americn producers, for example, have stripped the labor content out of a wide range of products. Arguably, the Japanese government strategy of controlled competition and targeted consumer booms contributes to this advantage. Nonetheless the advantages created are real.

APPENDIX B

GLOSSARY

A/D Converter — Analog-to-digital converter. A device to convert variable or analog signals to digital representation. Also called ADC.

Access Time — The time interval between the instant that data is called from or delivered to a storage device (memory) and the instant the requested retrieval or storage is complete.

Algorithm — A prescribed set of well-defined rules for the solution of a problem. Algorithms are implemented on a computer by a stored sequence of instructions.

Alignment — The arranging of the mask and wafer in correct positions, one with respect to the other. Special alignment patterns are normally part of the mask.

Analog — Indicates continuous, non-digital representation of phenomena. An analog voltage, for example, may take any value.

Binary — A system of numbers using 2 as a base in contrast to the decimal system, which uses 10 as a base. The binary system requires only two symbols: 0 and 1.

Bipolar — Refers to transistors formed with two (N- and P-type) semiconductor types.

Bit — A binary digit. A bit is the smallest unit of storage in a digital computer and is used to represent one of the two digits in the binary number system.

GLOSSARY

Bus	A circuit or group of circuits which provide a communication path between two or more devices.
Byte	A set of contiguous binary bits, usually eight, which are operated on as a unit. A byte can also be a subset of a computer word.
CMOS	Complementary Metal Oxide Semiconductor. A logic family made by combining N-channel and P-channel MOS transistors.
CPU	Central Processor Unit. That part of a computer that fetches, decodes, and executes program in-instructions and maintains status of results.
D/A Converter	A device to convert digital representation into an analog voltage or current level. Also called DAC.
Data	A general term used to denote any or all facts, numbers, letters, and symbols. It connotes basic elements of information which can be processed or produced by a computer.
Depletion Device	A type of MOSFET which is "on" when no input signal is present.
Development System	Microcomputer system complete with peripherals, memory, and software, used to write, compile, run, and debug application programs for one or more target microprocessors.
Die	A single square or rectangular piece of semiconductor material into which a specific electrical circuit has been fabricated. Plural is dice. Also called a chip.
Diffusion	A method of doping or modifying the characteristics of semiconductor material by "baking" wafers of the base semiconductor material in furnaces with controlled atmospheres or impurity materials.

GLOSSARY

Discrete	A semiconductor device containing only one active device, such as a transistor or a diode.
Dynamic RAM	A type of semiconductor memory in which the presence or absence of a capacitive charge represents the state of a binary storage element. The charge must be periodically refreshed.
ECL	Emitter-Coupled Logic. A form of current-mode logic in which the output is available from an emitter-follower output stage.
EPROM	Erasable PROM. Similar to ROM, but enables the user to erase stored information and replace it with new information when necessary. Most EPROMs are erased through exposure to ultraviolet light.
EAROM	Electrically Alterable ROM. A read-only memory whose contents may be altered on rare occasion through electrical stimuli.
EAPROM	Electrically Erasable PROM.
Enhancement Device	A type of MOSFET which requires a control signal input to turn on the device. The device is "off" when no input signal is present.
FET	Field Effect Transistor.
FPLA	Field Programmable Logic Array. A PLA that can be programmed by the user.
Firmware	Software in hardware form. Refers specifically to computer microcode in ROM.
HMOS	High performance MOS.
Hybrid Circuit	Any combination of two or more of the following in one package: Active substrate integrated circuit Passive substrate integrated circuit Discrete component.

GLOSSARY

I^2L	Integrated Injection Logic. A bipolar structure characterized by an integrated PNP load device and inverted operation of the NPN logic transistor.
Input/Output(I/O)	Relating to the equipment or method used for transmitting information into and out of a computer.
Integrated Circuit (IC)	A semiconductor die containing multiple elements that act together to form the complete device circuit.
LED	Light Emitting Diode. A semiconductor device that emits light whenever current passes through it.
LSI	Large Scale Integration. LSI devices contain 100 or more gate equivalents or other circuitry of similar complexity.
LS TTL	Low-power Schottky TTL logic. The power dissipation of LS TTL is typically one-fifth that of conventional TTL.
Linear IC	An analog integrated circuit, as opposed to a digital integrated circuit.
MESFET	Metallic Schottky FET. A field effect transistor whose gate structure consists of a metallic Schottky barrier.
Microprocessor	Computer central processing unit on a single chip.
MOS	Metal Oxide Semiconductor. Devices using FETs in which current flow through a channel of N- or P- type semiconductor material is controlled by the electric field around a gate structure. MOSFETs are unipolar devices characterized by extremely high input resistance.
MOSFET	A type of Field Effect Transistor. See MOS.

MPU	See microprocessor.
MSI	Medium Scale Integration. ICs containing ten or more gate equivalents but less than 100.
Mask	A patterned screen, usually of glass, used to expose selected areas of a semiconductor (that has been covered with a photoresist to a light source that causes polymerization).
Microcomputer	A microprocessor complete with stored program memory (ROM), random access memory (RAM), and input/output (I/O) logic. If all functions are on the same chip, this is sometimes called a microcontroller. Microcomputers are capable of performing useful work without additional supporting logic.
Microcontroller	See microcomputer.
Microelectronics	Microscopically small components or circuits made by means of photolithography techniques.
Micron	Synonymous with micrometer: one millionth of a meter.
Microprocessor	The basic arithmetic logic of a computer. See CPU.
Monolithic Device	A device whose circuitry is completely contained on a single die or chip.
PLA	Programmable Logic Array. A general purpose logic circuit containing an array of logic gates which can be connected (programmed) to perform various functions.
PROM	Programmable Read Only Memory. A read-only memory which can be programmed after manufacture by external equipment. Typically, PROMs utilize fusible links which may be burned open to produce a logic bit in a specific location.

GLOSSARY

RAM	Random Access Memory, which stores digital information temporarily and can be changed by the user. It constitutes the basic storage element in a computer. Also called a read/write memory.
ROM	Read Only Memory, which permanently stores information used repeatedly—such as microcode or characters for electronic display. Unlike RAM, ROM cannot be altered.
SOS	Silicon-On-Sapphire. A faster MOS technology in which the silicon is grown on a sapphire wafer only where needed. Each device is thus isolated by air or oxide from other devices.
SSI	Small Scale Integration. ICs containing fewer than ten logic gates.
Schottky TTL	A form of TTL logic in which Schottky diodes are used to clamp the transistors out of saturation, effectively eliminating the storage of charge within the transistor, allowing increased switching speeds.
Semiconductor	A material with properties of both a conductor and an insulator. Common semiconductors include silicon and germanium.
Static RAM	A type of RAM which does not require periodic refresh cycles, as does dynamic RAM.
TTL (or T^2L)	Transistor-Transistor Logic.
Transistor	The basic solid-state device used to amplify or switch electrical current.
VLSI	Very Large Scale Integration. VLSI devices are ICs that contain 1,000 or more gate equivalents.
Wafer	A thin disk of semiconducting material (usually silicon) on which many separate chips can be fabricated and then cut into individual ICs. Also called a slice.

GLOSSARY

Word	A set of binary bits processed by the computer as the primary unit of information.

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