Global Competition

Responding to the Challenge of HDTV

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The issue of U.S. participation in the emerging high-definition television (HDTV) market has attracted the attention of American policymakers. There are three main reasons for this. First, the HDTV market is projected to be large, and the potential effects of HDTV on national production, employment, and trade performance are estimated to be substantial. Second, HDTV is viewed by some as a way for the U.S. to re-enter television and VCR markets—which U.S.-owned firms, with a few exceptions, have virtually abandoned. According to some observers, the costs of this abandonment of a major part of the consumer electronics market have been lost production, sales, and employment and a dramatic deterioration in the U.S. trade balance in electronics.

However, the costs of a weak U.S. consumer electronics industry have also extended to linked industries, such as semiconductors. The dramatic drop in the U.S. share in world semiconductor sales is, in part, the result of the increasing content of semiconductors in consumer electronics (televisions, radios, disk players, electronic games, etc.), a business in which Japan dominates. At least 35 percent of Japanese consumer-electronics production has been sold to the U.S., and roughly as many semiconductors have entered the U.S. contained in consumer-electronics products as have been sold to the U.S. directly.

A third reason for growing policy concern about U.S. participation in HDTV are the technological spillovers that HDTV production may generate in a variety of related activities, including the development of new semiconductor components and new video display technology. These spillovers could affect the American competitive position in a variety of important industries, including computers and advanced telecommunications equipment. Spillovers with applications to defense are also considered likely.

To many the question of whether the U.S. will be able to occupy a competitive position in the emerging HDTV market and related technologies has become symbolic of the broader question of whether the U.S. will be able to regain its national competitive strength. Increasingly, the competitiveness of the United States has become associated with its ability to emerge as a winner in the HDTV market.

This symbolism is seriously misleading. The U.S. economy as a whole will not be made or broken on the wheel of HDTV or any other singly industry. Nevertheless, certain industries or activities may contribute more than others to national competitiveness over the long run. The electronics sector—broadly defined to include the semiconductor industry, the telecommunications industry, the computer industry and at least segments of the consumer electronics industry—appears to fall into this category. Many policy makers and industry participants believe that the long-term competitive health of many parts of the U.S. electronics sector will be adversely affected by a U.S. competitive failure in HDTV.

Even if U.S. policy makers and industry representatives are persuaded that the U.S. competitive position in the emerging HDTV area is important to the nation's long-run competitiveness, many unresolved policy issues remain. Two such issues are of paramount importance. The first arises because of the particular ownership configuration of television producers in the U.S. Currently, most producers are foreign-owned, and many of the foreign-owned facilities operating here have broad-based activities, ranging from R&D to distribution. Most foreign producers have also participated in national promotional efforts for HDTV development abroad. Whether as a result of these efforts or of their own substantial commitment of R&D resources, it is widely conceded that the foreign producers in the U.S. have the edge in many of the interrelated technological races related to successful HDTV development.

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This raises a fundamental question that must be addressed before policy decisions are made, to wit: if the objective of policy is to foster U.S. participation in HDTV, will participation by foreign-owned firms operating from U.S. locations promote this objective? In other words, does U.S. participation mean participation by domestically owned firms regardless of where they locate their production, employment, and research facilities or

does it mean participation by foreign-owned firms operating in the U.S. or perhaps does it mean a combination of both? The HDTV issue reveals the increasingly global nature of many high-technology industries and the difficulties of making public policies to foster national competitiveness in such industries. Starkly posed, a major policy question is whether U.S. policies to foster national participation in HDTV mean policies to foster the participation of foreign-owned producers operating in the U.S. market. To limit such policies to domestically owned companies is likely to delay the development and introduction of HDTV technology in the U.S. market and to discourage foreign producers from expanding their production and R&D operations in the U.S.

A second basic policy question is whether policies specifically targeted to HDTV are required to foster U.S. participation however defined. Perhaps a combination of broad-based pro-competitiveness policies—such as a change in the monetary and fiscal mix with lower interest rates, an R&D tax credit, further relaxation of antitrust limitations on joint R&D activity, and continued efforts to ensure fair competition in U.S. and international markets—is all that is needed.

Finally, even if special policies to foster U.S. participation are required, what form should they take? What are the appropriate roles of standards-setting, R&D consortia, Defense Department spending, and other policies?

The Role of Electronics in U.S. Competitiveness

Competitiveness is an economy-wide concept that is logically distinct from the competitive position of private producers in particular industries. However, we must also consider the possibility that certain industries or activities may contribute more than others to national competitiveness over the long run. It is just such a possibility that has motivated growing national concern about the health of the U.S. semiconductor industry and that is a factor behind growing concern about U.S. participation in HDTV.

From a national competitiveness perspective, the critical node of the electronics sector is the microelectronics or semiconductor industry. Semiconductors are at the heart of electronics products ranging from computers, telecommunications systems, and industrial robots to VCRs, video games, and state-of-the-art television receivers. More fundamentally, semiconductors are a major source of innovation in products and processes throughout the economy.

In particular, there are two categories of effects that the microelectronics revolution has had on the rest of the economy: *linkage impacts* and *technological spillovers*.[1]

- *Linkages* are effects that result in expending benefits for industries that use chips as inputs in their production processes or products. These ben-

efits are created because semiconductor production involves a cycle in which rising levels of capacity and R&D allow chip producers to manufacture and sell better-quality semiconductors at decreasing costs. Improvements in semiconductor price and performance lead to improvements in the price and performance of downstream products such as computers or telecommunications equipment. Such improvements may also lead to the creation of new markets for semiconductors (as in antiskid braking systems). As downstream markets expand, the demand for semiconductors increases, leading to further reductions in cost and greater incentives for more investment in R&D. Thus, a cycle is created that generates real externalities.

- *Technological spillovers* are those effects that result from the interdependence between precursor and complementary technological activities. The clearest example of this is the relationship between semiconductor chips and the systems that utilize them. Chips increasingly exhibit the same functions and performance characteristics as the products that incorporate them. That is, the chips themselves are now systems; consequently system innovation can and does take place in the chip itself. In addition, more general technological spillovers occur because advances in semiconductor technology both contribute to and benefit from innovation in physics, chemistry and materials sciences.

As a result of both linkage effects and technological spillovers, microelectronics has been a driver of both product and process innovation throughout the economy. Microelectronics-based technologies are already automating both primary commodity and goods production and transforming the activities that make up the service industry. Global competition—in a variety of both traditional industries, such as textiles and steel, and high-technology industries, such as aircraft—is increasingly based on microelectronic-driven innovations.

In addition to their effects on innovation and competitiveness in a wide variety of industries, the microelectronics industry and the broader electronics sector are important to national competitiveness in more direct ways. Between 1965 and 1985, the global output of the electronics complex grew by over 13 percent per annum in real terms, and by 1985 it equalled the global output of the automobile industry and surpassed the global output of the steel industry. In 1987, U.S. sales of electronics products exceeded more than one-quarter of total industries' shipments and have been growing at over 5 percent annually. Electronics in total employs more than a million and one-half Americans, many of them highly skilled. The wage of the average worker in the electronics industries is higher than the average wage of workers of similar skill, education, experience, and personal characteristics, such as age, sex and race, in many other manufacturing activities and in most service activities.[2]

The electronics sector is also tightly linked to many other portions of the U.S. economy. Not only do the nation's defense industries depend on electronic technologies but both manufacturing and service industries—ranging from the production of numerically controlled machine tools to banking and insurance—use electronic products both directly and indirectly. These products—which range from CB radios to satellite-based communications systems, carbon resistors to vastly powerful computers—are probably distributed more widely through the rest of the U.S. economy than the output of any other industry.[3] Because many electronics products serve as inputs in other sectors of the economy and because they are produced under conditions of increasing returns or declining costs, due to the significant learning curve economies realized in their production, the electronics sector gives rise to what economists call "linkage externalities"—increasing private returns in the electronics industry result in increasing social returns in downstream user industries.

Finally, as the global electronics industry has grown, it has become an increasingly important determinant of national trade flows and national trade balances. The U.S. trade position in electronics deteriorated between 1980 and 1987, although measures of the extent of the decline vary depending on how broadly electronics is defined.[4] All of the estimates indicate that the decline was broad-based, ranging from consumer electronics and components to office and computing equipment and sophisticated telecommunications equipment. Notably, the electronics trade balance continued to drop despite the dollar's decline. Even with further declines in the dollar's value, the U.S. will continue to run a significant deficit in many electronic products. This is true for many consumer electronics items. To illustrate, about 13.3 million VCRs were sold in the U.S. in 1987. Only 230,000 were made in the U.S. (assembled from imported parts), resulting in a total import bill of over $3 billion. Although by 1989, nearly 900,000 VCRs are expected to be made in the U.S., they will represent approximately 7 percent of estimated sales, and will likely rely heavily on imported components, implying a continued large deficit in this item for the foreseeable future.[5]

World production shares in electronics also indicate a drop in U.S. competitiveness relative to other regions. According to an analysis of data collected by the Electronic Industries Association of Japan, the U.S. production share of electronics dropped from 50.4 percent in 1984 to 39.7 percent in 1987. During the same period, Japan's share rose from 21.3 to 27.1 percent. The same trend was observed in a study by the European Electronics Industry Council.[6]

World production shares in semiconductors also indicate a drop in U.S. competitiveness in the last decade, particularly relative to Japan. Figures from Dataquest indicate that Japan produced slightly more than 50 percent

of world production in 1988 while the U.S. produced around 37 percent. In 1978, the U.S. had accounted for 55 percent and Japan less than 30 percent of world production.[7]

The Role of Consumer Electronics within the Electronics Complex

There are three important forms of linkage between the consumer electronics industry and the rest of the electronics complex. They are:

- upstream effects
- downstream effects
- manufacturing effects

Upstream effects derive mainly from the role of the consumer electronics production as a source of demand for inputs, and in particular for semiconductor components. The consumer electronics industry in the United States first contracted and then shifted from domestic to predominantly foreign ownership. The ability of U.S.-based semiconductor firms to service markets for consumer-related semiconductors virtually disappeared.[8] By the mid-1980s, only 6 percent of the production of semiconductors in the U.S. went to consumer applications, whereas in Japan the corresponding figure was 40 percent. In dollar terms, this meant that Japan was producing 7.2 billion in consumer chips in 1987 while the U.S. produced only 0.9 billion. The corresponding figure for Europe was around 4 billion.[9]

There is an honest dispute about how this occurred. Some U.S. firms claim that foreign-owned consumer electronics firms had preferential supply arrangements which excluded them from the market. The more vertically integrated foreign electronics firms often sourced their semiconductors from their internal semiconductor divisions. In all the major industrialized regions, there is a preference for working with regional suppliers of components wherever possible. The Japanese consumer industry, as represented by the Electronic Industries Association of Japan (EIAJ), claims that U.S. firms were unable to produce the necessary products, or to deliver them on time, or to match the quality/reliability of other (particularly Japanese) producers. The U.S. semiconductor firms accuse the Japanese of preferentially sourcing from Japanese semiconductor producers. Both of these claims are true. Of key importance for many U.S. firms was the fact that the consumer chip business was less profitable—because it involved standard devices for which markets were highly competitive—than business for industrial or defense applications.

The abandonment of consumer chip production made it difficult for U.S. semiconductor firms to produce certain kinds of generic circuitry at commercial volumes: e.g., charge-coupled devices (CCD), composite metallic

oxide on silicon (CMOS) circuitry,[10] and liquid crystal displays (LCD). Since VCRs use high volumes of random access memory (RAM) devices, the lack of a U.S.-based VCR industry made it more difficult for U.S. semiconductor firms to compete in RAM and other MOS memory markets. It is estimated that around 12 percent of the semiconductors produced in Japan are used in VCRs.

Downstream effects refer to the impact of consumer electronics on industries downstream from the semiconductor industry. The lack of commercially priced CCD chips helped to keep U.S. firms out of the video camera markets. The Japanese edge in CMOS circuitry helped Japanese firms to establish a strong presence in laptop computer markets. Japanese strengths in LCD helped to give them an edge in the emerging markets for laptop computers and personal TVs. It is widely recognized that Japanese firms are ahead of all their competitors in the development of CCD, CMOS, and LCD technologies.

Manufacturing effects involve the loss of strength in generic manufacturing skills and technologies associated with the reduced role of U.S.-owned firms in the consumer electronics industry. While a number of U.S. firms were able to match their international competitors in the adoption of advanced manufacturing techniques, such as automated insertion and surface-mount technologies, the majority failed to do this rapidly enough to meet the competition. These technologies are important not just for consumer electronics but for many other kinds of high-volume production. The decline of the U.S. consumer electronics industry, therefore, meant a narrowing of the manufacturing skill base of the U.S. economy.

The greater the U.S. participation in HDTV consumer markets, the greater will be the upstream, downstream, and manufacturing benefits for the rest of the U.S. economy.

There are reasons to believe that upstream, downstream, and manufacturing effects will be even greater in the next two decades than they were in the past. HDTV circuitry will be much more complex than NTSC circuitry. HDTV circuitry needs will contribute to advancing technology in some important areas, such as digital signal and image processing, and parallel processing. HDTV receivers will require video frame storage devices which are quite similar to RAMs. NTSC receivers did not require any frame storage devices. In addition, competition in the HDTV business will create large incentives for the development of large displays, and particularly for the development of flat panel displays—e.g., liquid crystal displays (LCD),

light-emitting diode (LED), and semiconductor-based projection systems.

The downstream spillover effects of HDTV technology will be significant in the computer, defense electronics, and telecommunications industries. The problems of image and digital signal processing that have to be solved for HDTV receivers also have to be solved for fast displays of color images on advanced computer workstations. The production of large, high-resolution displays for HDTV equipment will allow some firms to produce cheaper and more competitive displays for computers and workstations.

There is an important mutually reinforcing relationship between advances in HDTV and network (telecommunications) technology. The networking of advanced computer workstations creates network architecture design problems similar to those posed by the use of HDTV receivers as interactive terminals. Interactive video and interactive 3-D color CAD/CAM are both more demanding than existing interactive character and graphics networking.[11] If you can solve one problem, then you have contributed to the solution of the other. The unanswered question in this equation is how much demand there will be for "interactive" (two-way) as opposed to "passive" (one-way) television.

More important than the technological linkages between HDTV and telecommunications are the likely linkages between the two that arise with the building of a new national telecommunications infrastructure based on optical fibers. HDTV signals will be delivered to the home long before the fiber network is operational. Nevertheless, the sooner HDTV home delivery begins the sooner there will be demand for transmitting HDTV signals via fiber (because fiber can deliver a cleaner signal). By the same token, the faster high quality fiber delivery to the home is in place, the easier it will be to convince consumers to make the switch from NTSC, or interim products, to HDTV. Fiber home delivery can be speeded by adopting a policy of encouraging the local and regional telephone companies to compete with the cable operators in connecting homes to fiber networks.[12]

The greater is U.S. participation in HDTV consumer markets, therefore, the greater will be the upstream, downstream, and manufacturing benefits for the rest of the U.S. economy. Thus, policy measures should be aimed at maximizing U.S. participation. Because foreign firms already possess such an important stake in U.S. R&D and manufacturing of consumer electronics, they should be included in efforts to promote the HDTV industry.[13]

Special Policies to Promote U.S. Participation in HDTV Markets

The main objective of U.S. policies toward HDTV should be to use the promotion of HDTV to strengthen overall U.S. competitiveness in world markets. To maximize the positive impact of HDTV promotional policies on the rest of manufacturing, and particularly on the electronics complex, policies must be chosen with an eye to maximizing the technological

spinoffs from HDTV to other areas. Policies which favor HDTV at the expense of undermining the competitiveness of other key industries should be avoided.

HDTV Standards Policies—Adoption of uniform, national standards for HDTV program production and transmission will speed the development of a U.S.-based industry. Transmission standards should be developed through the FCC processes and through the development of industry consensus in other forums. Japanese MUSE and European HD-MAC transmission standards for HDTV were developed for broadcasting and telecommunications environments that are different from that in the United States. These foreign standards were developed for DBS (direct broadcast satellite) delivery. U.S. production and transmission standards will have to take into account its stronger dependence on terrestrial transmission and cable systems. The FCC has already ruled that the new HDTV terrestrial transmissions must be compatible with the existing stock of NTSC receivers—estimated to be around 140 million.

The probably coexistence of at least three distinct and incompatible HDTV transmission standards for the United States, Japan, and Europe will not prevent Japanese and European firms from building HDTV equipment for the North American market. These firms already have established a significant manufacturing presence in the United States. The large size of the U.S. market and the lower value of the dollar relative to Japanese and European currencies since 1985 make it possible for them to produce at globally competitive costs in the United States. In addition, Japanese and European firms have real advantages in HDTV-related product and process technologies relative to their current and future potential U.S. competitors.

U.S.-owned firms have to be willing to reenter the market knowing that the consumer electronics market is an international market and will remain highly competitive. For this reason, any effort to delay the adoption of HDTV standards until some specific group of U.S.-owned systems firms can catch up to the international state of the art in HDTV technology will only result in the building of a "hot house" industry that is unlikely to be internationally competitive. If U.S. components producers are limited to supplying "hot house" U.S. systems firms, then they are unlikely to be competitive suppliers to foreign HDTV producers.

Similarly, the proposal not to adopt a standard for HDTV until the development of digital TV is likely to fail to increase U.S. competitiveness in consumer electronics. It will be very difficult, if not impossible, to develop a digital TV industry without the technological and manufacturing base that will be developed for HDTV. In addition, many of the other electronics industries will be hurt if a technological and manufacturing base for HDTV is not allowed to develop.

At the receiver end, one major proposal has been to develop an Open Architecture Receiver (OAR). Some proposals for an OAR are for a set

that would be capable of processing an HDTV signal from any transmission medium to the HDTV display and would allow owners of receivers to add on a variety of devices, such as cameras, keyboards, printers, and so forth, on the model of contemporary personal computers. Current manufacturers of TV receivers are skeptical of this proposal because of increased cost and the potential for creating confusion among consumers (who will need much more information than they do currently to assemble a working system).

In essence, the specific OAR proposal discussed above begs the question of transmission and receiver standards. It will be possible to reach compromises among the producers concerning the types of signal inputs that all receivers will be able to handle. Receiver manufacturers must be permitted to design television sets to deal with the possibility of signals from different transmission media. This type of receiver design will be easier if the standards for production and transmission allow for reasonable levels of "interoperability"—i.e., uniformity and simplicity in interfaces and conversion methods. To this end, the Electronic Industries Association (EIA) supports a *friendly multiport* receiver, with separate inputs for RF and baseband, which is a form of open architecture. Such a system permits the necessary flexibility to accommodate all media without the costs and complexities of a more ambitious form of open architecture.

Nevertheless, there will be some opportunities for smaller and more innovative firms to produce OARs that go beyond the friendly multiport concept. This will be, at first, a niche market for consumer electronics enthusiasts. As experience grows among suppliers and consumers, the open architecture niche may develop into a mass market. If so, this will be a positive development for the U.S. electronics industry. That industry has shown itself to be highly responsive to the kind of demand that develops for specialized add-on products for high-volume, open-architecture systems—e.g., the Apple II and IBM-PC microcomputers.

The principal goals of the U.S. standard-setting process should be the development of an HDTV system which produces HDTV pictures (roughly twice the horizontal and vertical resolution of current NTSC pictures), permits a smooth transition from NTSC to HDTV broadcasting, and minimizes the use of scarce broadcast spectrum. These goals, taken together, constitute a major technological challenge. If this challenge can be met, then the United States will emerge with a very strong consumer electronics industry with major spinoffs for the electronics complex and the rest of American industry.

Meeting the Technological Challenge—The main technological roadblocks to the development and commercialization of HDTV equipment in the United States will be in four main areas:

- HDTV-related integrated circuits,
- large displays,

- new manufacturing technologies, and
- broadband switching technologies.

Much of the current interest in HDTV derives from the belief that there will be major technological spinoffs from HDTV for the rest of the electronics complex—and especially for semiconductors, computers, and telecommunications equipment. Proposed policies for the promotion of HDTV should be assessed in terms of their ability to generate such spinoffs.

TV sets, even HDTV sets, will never be major items driving total semiconductor demand. It is much more likely that HDTV will become an important factor in the development of integrated circuit technology because of the new types of circuitry it requires. There is an opportunity to use HDTV-related integrated circuits to promote the U.S. semiconductor industry because of the greater sophistication of circuitry in HDTV as compared with NTSC receivers. HDTV receivers will require more video memory, faster digital signal and video image processors, and more complex analog/digital hybrid circuits than NTSC receivers. Some of these circuit techniques will have uses outside consumer electronics. Video memories and video image processors will be important components in computers and computer workstations. Faster digital signal processors and analog/digital converters will be used in telecommunications equipment. To the extent that HDTV circuit technology has applications outside consumer electronics, there will be major spinoffs from its development.

The semiconductor industry in the United States is looking for a way of deepening its efforts to reestablish its preeminent position in the world. It recently participated in the formation of an R&D consortium called Sematech, which addresses the need to improve semiconductor manufacturing process technology. The U.S. semiconductor industry, by and large, has gotten out of the business of supplying the consumer electronics markets. Only 6 percent of U.S. semiconductor output goes to consumer electronics, while in Japan the corresponding figure is over 40 percent. In order to regain lost ground in consumer-related semiconductors, U.S. firms need to get an early start in the development of HDTV-related chips. Thus, one fruitful approach might be to form an R&D consortium for the development of video-processing circuitry.

To the extent that public funds are made available for the promotion of HDTV, they should be focused on generic technological problems the resolution of which will benefit a large number of industries. For this reason, R&D consortia for integrated circuitry, large displays, electronic manufacturing technology, and broadband switching technology seem particularly good candidates for public funding.

One characteristic of R&D consortia is that membership in them is purely voluntary. There does not necessarily have to be any public funding of R&D consortia. The main roles for the government in R&D consortia is

to serve as a broker for the negotiations that produce them (usually this is done by the Department of Commerce) and to monitor them to prevent antitrust violations (this is done by the Department of Justice). In Sematech, the government provided part of the funding through the Department of Defense because it felt that semiconductor manufacturing technology had important implications for national security. The Defense Advanced Research Projects Agency (DARPA) has already indicated interest in cofunding an R&D consortium for HDTV displays for the same reason. But other R&D consortia, such as the Semiconductor Research Corporation (SRC), do not involve government funds.

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Public funding of R&D consortia inevitably raises the issue of the participation of foreign-owned firms. In the case of HDTV technologies, it is quite likely that foreign-owned firms will want to participate and that domestic firms will want them to because of their strong technological base and their high usage of components. It would be counterproductive to exclude foreign firms from R&D consortia for HDTV technologies, for reasons stated above. The key is not ownership but the level of commitment to R&D and manufacturing in the United States.

Conclusion

Competitiveness is primarily an economy-wide issue. There is a danger connected with equating the competitiveness of a nation with that of a single industry. While particular industries may be symbolic of a broader problem of national competitiveness, policies to promote the revival of such symbolic industries may be prejudicial to the solution of the broader problem. For this reason, a combination of economy-wide measures and industry-specific efforts is called for. Economy-wide policies should focus on increasing investment levels in physical, human, and knowledge capital. In the case of measures specific to consumer electronics and HDTV, those which are likely to result in positive spinoffs for other industries should be the focus of public policies.

The development and commercialization of HDTV in the United States is an opportunity for the strengthening of U.S. competitiveness in the electronics complex, and more generally, in manufacturing. HDTV is not the

answer to all of America's problems in manufacturing, but it can contribute to their solution. Protectionist or exclusionary policies would be extremely unwise. Given the major presence of foreign firms in the United States, there is an opportunity to build U.S. competitiveness with the help of those firms.

Two main types of public policies are required to promote HDTV in the United States. First, timely adoption of HDTV standards will allow U.S. producers to approach HDTV development with more certainty. As mentioned above, delaying the adoption of a national standard is unlikely to add to U.S. competitiveness in consumer electronics. Until U.S. firms have some idea regarding standards, they have little incentive to devote significant resources to HDTV product development. In short, if the U.S. delays, the rest of the world will advance technologically to the relative disadvantage of American producers.

Second, public policy should encourage and assist the formation of R&D consortia to develop indigenous HDTV technologies, especially those generic technologies that have important applications to other industries. While the current DARPA focus on displays and display circuitry is important, it runs the danger of being blindsided by the telecommunications aspects of HDTV research.

Competitiveness is a national concept. It is concerned with the relative economic performance of nations, not companies. Consequently, indicators of national competitiveness (investment, productivity, R&D efforts, and educational commitment) rather than indicators of the competitiveness of individual firms or industries should be the primary concern of policymakers. Nonetheless, carefully-selected public policies to encourage strategic manufacturing and research activities can also contribute to the overall competitiveness of the nation.

References

1. The following discussion is a restatement of the argument in Michael Borrus, *Competing for Control: America's Stake in Microelectronics* (Cambridge, MA: Ballinger, 1988), pp. 36-38.
2. This conclusion is based on calculations in William Dickens and Kevin Lang, "Why It Matters What We Trade," in Laura D'Andrea Tyson, William Dickens, and John Zysman, eds., *The Dynamics of Trade and Employment* (Cambridge, MA: Ballinger, 1988).
3. Office of Technology Assessment, *International Competitiveness in Electronics* (Washington, D.C.: USGPO, November 1983).
4. It is important to emphasize that the electronics trade balance is heavily influenced by the decisions of U.S. multinationals. Some estimates indicate that as much as a third of the electronics imports from individual East Asian countries come from U.S.-owned operations.
5. Allen Lenz, "Slimming the U.S. Trade and Current Account Deficits," *The AMEX Bank Review, Special Papers*, No. 16 (October 1988).
6. Lawrence M. Fisher, "U.S. Share Declines in Electronics," *New York Times*, January 5, 1989, p. C1.

7. "Preliminary 1988 Worldwide Semiconductor Market Shares: Japanese Gain Share: Memories and Micros Dominate Market," Dataquest Newsletter, January 1989, pp. 1 and 3.
8. It should be noted that the decision of U.S. semiconductor firms to stop building chips for consumer electronics at the beginning of the massive growth in imports of consumer products and much earlier than the acquisition of major U.S. consumer firms by foreign firms.
9. Testimony by Jeffrey A. Hart before the Subcommittee on Telecommunications and Finance of the House Committee on Energy and Commerce, September 7, 1988, p.8.
10. It should be noted that several U.S. semiconductor firms, including Harris and National Semiconductors, remain highly competitive in CMOS circuitry.
11. Workstation firms are now introducing NTSC video image processing in the high-end of their product lines.
12. Current estimates suggest that installing a 600 megabit per second fiber optical link from the trunk to the average home will cost around 2,000 dollars. Telephone companies and cable operators are beginning to install fiber instead of wire cables because fiber costs, especially maintenance costs, have become much more competitive.
13. Joseph Donahue, of Thomson Consumer Electronics in Indianapolis, estimates that the annual R&D expenditures of Thomson, Zenith, and Philips in the United States are around 150 million dollars per year.