Directorate of Intelligence

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Rapid Diffusion of Technology: Some Implications for the United States [redacted]

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An Intelligence Assessment

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Rapid Diffusion of Technology: Some Implications for the United States [redacted]

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An Intelligence Assessment

This paper was prepared by [redacted] 25X1
Office of Global Issues. Comments and queries are welcome and may be directed to the Chief, Economic Analysis Branch, OGI, [redacted] 25X1

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Rapid Diffusion of Technology: Some Implications for the United States

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Key Judgments

Information available as of 3 January 1984 was used in this report.

In the past few years the high-technology revolution has begun to have an increasing impact on the world economy. Thus far, most attention has been focused on how rapid technological change will alter specific production processes and bilateral trade relations. While technological change per se will have profound effects, the pace at which it is diffused around the world will directly and indirectly affect national economies, military capabilities, and government policies.

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Although the United States, Japan, and, to a lesser extent, the key West European countries will continue to dominate production and trade in the most advanced high-technology goods, the rapid pace of technology diffusion will generate numerous challenges:

- Technology diffusion will contribute to economic strains within key US allies. While, in time, the new technologies will generate a net addition to labor demand, the adjustment period could be fairly long in some countries, in part because entirely new skills will be needed in the work force.

- Political tensions will mount in and between European Community states as governments try to cope with both technologically generated job losses and intra-EC labor migration.

- West European governments could introduce new trade barriers in an attempt to limit increases in unemployment and to support domestic high-technology businesses. Further protectionistic measures not only would strain US relations with Western Europe directly, but could involve the United States in disputes between Western Europe and Japan as well as other Pacific allies of the United States.

- Communist countries will have greater opportunities to obtain commercial technologies with potential military applications as the newly industrializing countries and other LDCs increase their high-technology capabilities.

- If export markets in the developed world are restricted, competitive pressures, coupled with neutral political stances, could encourage some of the more advanced LDCs to become overt suppliers to the Communist Bloc.

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- The spread of technology will make it easier for more countries to produce sophisticated weapons and military components. As this trend accelerates, arms proliferation risks will rise, while the leverage of the United States and other leading arms producers will be reduced.

- The relative demand for some primary commodities probably will drift downward, lowering export earnings and economic growth in some Third World countries. As this happens, the risks of domestic instability and opportunities for Soviet interference will rise.

- The LDCs will not be immune to the impact of new technologies on traditional industries and employment. Since they cannot afford large subsidies, the debt-troubled LDCs in particular may be forced to shut down capacity. Any job losses will come at a time when the LDCs will be coping with major additions to their labor forces.

- Finally, the United States could become more dependent on imports of important high-technology products as foreign capabilities and competitive pressures increase. 25X1

Almost certainly the process of technology diffusion will continue to be a crucial trend, molding the shape of the world economy over the decade and beyond. While we believe the issues raised in this paper will be key issues in the years to come, new concerns which cannot be predicted at this point are likely to emerge as time goes on. Despite how things unfold, rapid technological change will raise the costs of managing the fallout affecting US interests and also cut leadtimes for making effective responses. 25X1

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Scope Note

Periodically, the Directorate of Intelligence publishes reports that attempt to examine key international trends from a broad and longer term perspective. We believe the ongoing global diffusion of high technology will become of increasing concern, especially when it overlaps with other emerging economic, financial, political, and demographic trends. At the same time, the great volume of detailed information on specific instances of technological change and diffusion around the world makes it difficult to identify key trends and impacts. This paper attempts to address this problem by suggesting a conceptual framework for organizing some of this information. As a result, the discussion is necessarily less concrete and more speculative than studies done at the level of individual industries or even countries. It is meant to stimulate thinking and research as much as to inform. Aside from a review of press and trade journals, the report draws on a wide array of work already done in the Directorate on technological change and its impacts.

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Rapid Diffusion of Technology: Some Implications for the United States

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The Pace of Technological Diffusion

The world has entered an era in which international technological diffusion is occurring at a faster pace, involving many more countries, and transmitting higher levels of technology than ever before. For example:

- Japan has become the world's largest producer and user of industrial robots by making widespread and innovative applications of Western technology. Japan's ability to piggyback on US accomplishments also has helped the Japanese to narrow the computer technology gap.

- Foreign aerospace firms are increasingly competing in world markets for jet engines, avionics, and airframe components through a strategy of joining with more advanced partners—usually US—to acquire technology and expand manufacturing capabilities.

- Beginning with one black-and-white television assembly plant in 1965, Singapore's electronics firms have steadily upgraded their technological capabilities. Singapore's industry made a quantum jump in 1981 when two firms made investment commitments for plants to fabricate semiconductor wafers.

- In Israel, exports of locally developed science-based products in recent years have grown twice as fast as overall exports, according to data from the Ministry of Industry and Commerce.

International trade data indicate that these examples are not isolated. Export statistics suggest that total trade in high-technology products rose slightly more rapidly over the past decade than did overall manufactured trade.[1] In 1972, for example, total exports in the trade categories containing high-technology goods—including transistors, plastics, computers, aircraft, and jet engines—amounted to 14.4 percent of total manufactured trade from 40 key exporters.[2] By 1980, the latest year for which data are available, the share had increased to 15.9 percent. This increase occurred despite the fact that the relatively poor economic performance of the last decade depressed investment demand and purchases of consumer durables—both of which are more likely to embody high technology than other trade categories such as industrial materials and light industry goods. 25X1

Over the same period, high-technology trade became more dispersed among producers (see figure 1):

- The United States continued to dominate high-technology exports, but its share fell, as did that of Western Europe.
- Japan increased its share from 7.4 percent in 1972 to 8.5 percent in 1980.
- The newly industrializing countries (NICs) doubled their share of high-technology exports during the same period. By 1980 they exported one-half as much in the high-technology field as Japan. 25X1

If anything, these data understate the degree to which technology is spreading. To the extent that more basic items are contained in the high-technology trade categories we have used, the growth in more sophisticated products is masked. Even if high-technology

[1] *Technology* as used in this paper refers to knowledge that provides the ability to design, produce, and innovate. *High technology* is such knowledge which also is relatively new, stems largely from scientific breakthroughs, and is almost entirely produced in the highly industrialized nations. Finally, *high-technology goods* refer to products that embody this advanced knowledge, whether producer goods (for example, business computers) or consumer goods (for example, new pharmaceutical products).

[2] In defining an aggregate for traded high-technology goods, we have relied on research done at the United States Department of Commerce. This work identified 10 product categories which embodied significantly higher amounts of applied research and development than other less technology-intensive products. See Lester A. Davis, *Technology Intensity of US Output and Trade,* Office of Trade and Investment Analysis, July 1982. We have attempted to approximate the categories in the Davis report by using the following Standard International Trade Classification (SITC) categories in our definition of high-technology trade: aircraft, jet engines, business machinery (including computers), scientific instruments, medicines, plastics, transistors, telecommunications equipment, and firearms. 25X1

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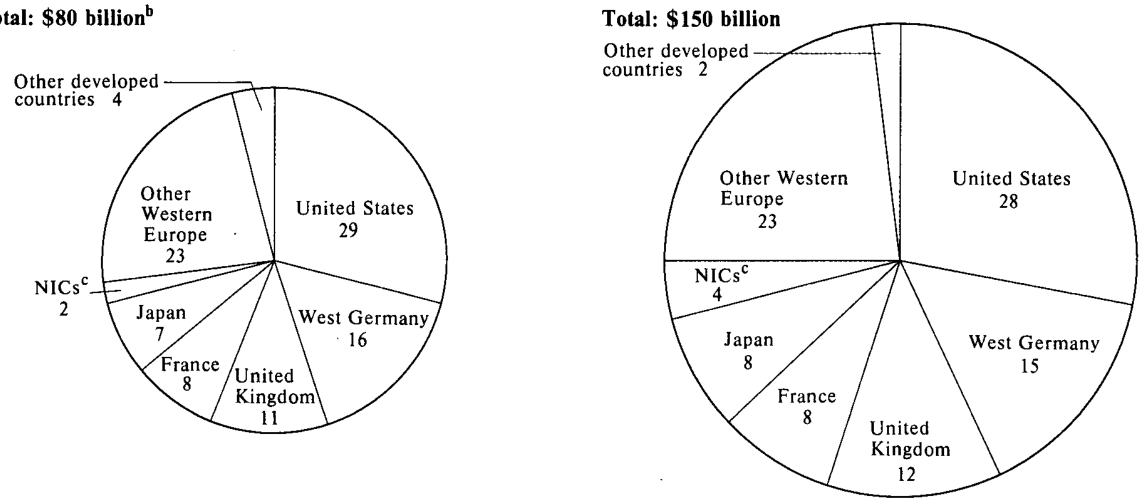
Figure 1
Exports of Internationally Traded High-Technology Goods[a]

Percent

1972
Total: $80 billion[b]

1980
Total: $150 billion



[a] Internationally traded high-technology goods are defined as aircraft, jet engines, business machinery, scientific instruments, medicines, plastics, transistors, telecommunications equipment, and firearms. The group of exporters includes most of the OECD plus selected LDCs.

[b] To roughly account for inflation, the nominal total for 1972 was adjusted to reflect 1980 prices using a world consumer price index.

[c] Hong Kong, Singapore, South Korea and Brazil. Data limitations prevented including Mexico and Taiwan.

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goods could be broken out, it would be almost impossible to measure the importance of high-technology inputs which are incorporated into more traditional goods. Finally, trade data fail to capture the increasing share of high-technology goods in domestic markets.

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Unlike traditional economic forces—such as GNP growth and inflation—no systematic measure has been developed to gauge the speed of technology diffusion. As a result, it is difficult to "prove" that diffusion is accelerating. Thus, there is a divergence of opinion among analysts about the current diffusion pace, with some arguing that it is not out of the ordinary and others that it indeed is increasing and even revolutionary.

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Those observers who believe that current technology diffusion trends are not extraordinary base their position on several observations:

- From a historical perspective, technology diffusion has always occurred, and recent trends are just part of a continuous, ongoing process.
- Many of the impacts and policies associated with the current diffusion have historical precedents; for example, in the past governments have frequently attempted to manage technology transfer through foreign investment policies.

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- Finally, even if there has been some speedup in diffusion, it is probably mostly explained by expanded world economic activity; technology diffusion would be remarkable only if it could be shown that it was outpacing world economic growth.

Several factors, however, favor the view that, indeed, a speedup in diffusion has occurred, even compared to overall economic activity. First, rapid strides in communications technology, coupled with the information explosion, have greatly encouraged technology transfers. Second, the completion of the postwar reconstruction periods in Japan and the West European countries some years ago has allowed them to resume their more "normal" active roles in the global technology diffusion process. Finally, although again hard to prove, technological change itself—particularly in the United States and Japan—seems to be occurring faster and in more fields than in earlier years. This faster change naturally increases the opportunities for international transfers, tending to raise the rate of diffusion.

Economic Underpinnings: Past and Future

A number of reasons for the spread of technology can be identified. Foremost perhaps is the nature of technology itself. In contrast to natural resources, labor, and physical capital—which are relatively immobile—technology, consisting largely of technical information and teachable skills, is highly mobile. A number of institutional phenomena also have contributed to the more rapid pace of international technological diffusion.

Multinational Corporations, Joint Ventures, and Coproduction. Direct investments by multinational corporations, joint ventures, and coproduction agreements increasingly have become mechanisms contributing to technological diffusion. Multinational corporations seeking low labor costs, for example, often install some of their best production technologies in foreign subsidiary plants. Similarly, many joint ventures involve technology transfers. For example, to escape restrictions on imports or majority-owned foreign investments, a foreign firm with advanced technology will combine with a domestic firm. The foreign company agrees to transfer some technology to its partner and in return may receive access to low-cost labor, market access, and perhaps distribution channels and a service network. The close business relationships often developed in joint ventures and similar agreements tend to pave the way for further transfers of technology over time and, therefore, are encouraged by some governments. 25X1 25X1

Trade journals and press reporting provide numerous examples of these processes:

- In Singapore throughout the 1970s foreign investors accounted for more than 70 percent of the total commitments in manufacturing and now dominate key industries. The presence of a trainable and disciplined labor force particularly has attracted American and West European electronics firms, which have been in the forefront of Singapore's technological advance.

- Similarly, South Korea's relatively low-cost but skilled and motivated labor force has attracted many foreign investors. With the startup of its joint- 25X1 venture plant with Corning Glass in March 1983, South Korea's Samsung Company, Ltd., overnight became a world-class competitor in one of the most difficult glass technologies—picture tubes for color televisions. Another South Korean firm, the Kolon group, recently joined forces with Japan's Fanuc Corporation to set up a plant to manufacture industrial robots.

- In late 1981, Fujitsu entered into a cooperative agreement with financially troubled International 25X1 Computers, Ltd., the leading UK computer firm. Although not all of the terms of the agreement between ICL and Fujitsu are known, we believe that Fujitsu will provide technical assistance, possibly in the semiconductor area, in exchange for which ICL will market Fujitsu's large-scale computers in the United Kingdom. 25X1

In coproduction agreements, firms from different countries each manufacture components of a finished product. As in the case of joint ventures, there frequently is one technological leader among the

Coproduction and Technology Diffusion in the Aircraft Industry: A Case Study

Coproduction agreements have been particularly popular in the aircraft industry. Because aircraft are large and costly products with many components, coproduction offers special advantages of risk sharing and division of tasks. It also serves as a tool in selling planes: countries buying new aircraft often are offered the chance to produce subcomponents for the firm or consortium building the planes. Furthermore, in countries with national airlines, governments are the major customers for civilian aircraft, and they have taken advantage of their buying power to foster coproduction agreements to acquire technology and employment:

- *In the development and production of the 767, Boeing's foreign partners, Italy and Japan, will contribute about 35 percent of the airframe value, the largest foreign involvement ever agreed to by Boeing. Japanese aircraft companies and Aeritalia will obtain access to some of the latest aircraft manufacturing technologies by working with Boeing, the industry leader.*

- *Pratt and Whitney's new engine for the Boeing 757 includes foreign participation by Motoren und Turbinen of West Germany and Fiat of Italy amounting to about 15 percent.*

- *Rolls-Royce negotiated a 50-50 partnership with Japan in 1981 to develop and produce a medium-size jet engine.* 25X1 *this deal provided engineers in Japan's engine companies—Mitsubishi, Kawasaki, and Ishikawajima-Harima—with access to state-of-the-art technology and the experience needed to develop their own designs using new materials and coatings.*

- *The nationalized French avionics firm SFENA, along with Smiths Industries (UK) and Bodenseewerk Geratechnik (FRG), developed flight control systems for the Airbus.*

The resulting technological diffusion has helped Western Europe's Airbus Industrie to develop civilian airliners that are competitive technically with those produced by US firms. Japan also is relying on these agreements to advance its aerospace industry to a world competitive level. 25X1

participating companies that agrees to transfer technology to its partners. In return, they share the risks of research and development and also provide market access.

Increasing Absorption Capability of the LDCs. Successful technology transfers to LDCs often depend crucially on the knowledge and skills of the labor force. Over the last 20 years, literacy rates and upper-level school enrollments in the LDCs have grown substantially (see table 1), thus increasing their ability to absorb technology. Some of the LDCs that have been most aggressive and successful in acquiring technology have also made major strides in upgrading the technical skills of their labor forces. For example, vocational school enrollment rates have skyrocketed in Brazil, Singapore, Taiwan, and South Korea.

Outlook. The rapid pace of technological diffusion, particularly to the LDCs, probably will be maintained into the 1990s, as both the technology pool in the developed countries expands and the absorption capability of the LDCs grows. However, as in the past, this diffusion will be uneven, depending on the economic conditions in individual countries: 25X1

- The Asian NICs have ambitious plans to continue upgrading the skills and knowledge of their labor forces and the general technological base of their economies; it seems almost certain that they will rapidly increase their technological capabilities.

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Table 1
LDC Regions: Increases in Average Education Levels, 1960-80 [a]

Region	Average Literacy Rate (*percent of adult populace*)		Average Secondary School Enrollment Rate (*percent of 12-17 age group*)		Average Vocational School Enrollment Rate (*percent of 12-17 age group*)	
	1960	1980	1960	1980	1960	1980
East Asia–Pacific	57.0	74.7	19.4	47.5	2.3	6.2
Southern Europe	69.0	78.8	26.4	66.0	6.9	12.2
Latin America	64.5	77.5	19.1	42.0	4.9	8.5
Middle East–South Asia	26.0	42.9	14.8	36.1	1.8	4.1
Sub-Saharan Africa	14.0	31.8	2.5	14.0	0.5	1.1
All regions	37.6	53.5	12.5	32.4	2.4	4.8

[a] The data in this table represent the simple averages of figures for the individual countries in each region.

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- Gains by the South American NICs—Mexico and Brazil—will depend heavily on the international debt situation, at least for the medium term. Funding problems are likely to slow indigenous efforts to improve the technology base. In fact, the import retrenchment, especially in producer-good categories, is already under way. At the same time the emphasis on hard currency exports, coupled with import restrictions, could provide numerous opportunities for foreign investments, especially if local governments added special incentives.

- The recent leveling and decline in oil prices will reduce the earnings of the oil-exporting countries and are likely to slow the diffusion of technology to the Middle Eastern LDCs and other key oil exporters.

- The financial troubles of many other LDCs and the East European nations will tend to dampen the diffusion of technology into these countries.

Economic Impacts
The most immediate impact of technology diffusion is on the economic front. Some of the forces that will come into play will accelerate present long-term trends, while others will result in the emergence of new economic patterns.

Growing Competition in High-Technology Products. The spread of sophisticated technology has increased the global availability of and competition in the production and export of high-technology goods. Although the United States, Japan, and the key West European countries continue to dominate production and trade in the most advanced items, the NICs and other countries have started to become significant exporters of less advanced but still moderately sophisticated goods. During the 1970s NIC high-technology exports to Western Europe grew at a rate of about 25 percent per year in real terms and to Japan at 18 percent per year (see table 2). Much of this trade consists of exports of electrical apparatus from the East Asian NICs, reflecting their advantage in relatively low-cost, skilled labor. We believe the level of competition in industrial-country markets for high-technology goods will continue to grow as the NICs expand their product lines. This will be even more true if other LDCs are able to emulate the NICs successfully. 25X1

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While the larger and more innovative producers in the industrial world are unlikely to be threatened, many of their product lines may come under growing pressure. The major impact is likely to be felt by firms

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Table 2
NICs: Growing Suppliers of High-Technology Goods, 1972-80[a]

	High-Technology Imports From NICs (*billion 1980 US $*)		Average Annual Growth Rate (*percent*)
	1972 [b]	1980	
World [c]	1.3	6.0	21
United States	0.6	2.2	18
Japan	0.1	0.5	18
Western Europe	0.1	0.8	24
LDCs	0.4	2.2	24

[a] High-technology goods are as defined in figure 1. The NICs include only Hong Kong, Singapore, South Korea, and Brazil because of data limitations.
[b] To account roughly for the impact of inflation on trade values, the 1972 figures were converted to 1980 dollars using a world consumer price index.
[c] Because of data limitations, world imports are represented by imports into 40 key countries, including most of the OECD and selected LDCs.

[redacted]

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with a narrow product line and whose products have become standardized, which allows time for the NICs and other countries to acquire the necessary technology and to compete, based on low labor costs. For example, those industries in the West and Japan currently facing greater competition from the NICs produce such standard products as steel, ships, and textiles. Regardless of where the competition is felt, the risks are high that economic pressures will quickly make their way into the political arena. [redacted]

The impact of technology diffusion will not be limited to home markets. Industrial-country producers will also find themselves under pressure in exporting to Third World countries. For example, between 1972 and 1980 the NICs increased their share of all high-technology exports to the LDCs from 2.5 to 6 percent. The NICs' success in expanding sales to this market may reflect efforts to tailor their products to the less demanding performance requirements often encountered in LDCs, coupled with lower prices. The NICs would not be alone in doing this. Israel, for example, has carved out a niche in the world high-technology market by adapting technology to the specialized needs of small users, which are often ignored by large Western firms. A US Government official was shown a sample of the circuitry in an Israeli electronics product by its manufacturer; the circuitry was installed on a pegboard that the manufacturer claimed would make repair and maintenance simpler for a relatively untrained technician in a Third World country than the soldered circuitry in a similar US product. [redacted] 25X1

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More Suppliers of High-Technology Arms. Increased technological capability in their civilian economies has permitted a small number of Third World countries to begin to assimilate Western technology for producing sophisticated arms. This group includes several of the NICs—Brazil, Singapore, and South Korea—plus such advanced nations as Israel and South Africa. The manufacture of sophisticated weapons in these countries generally follows a pattern whereby West European and US producers, through licensing agreements, provide design and production assistance and also complex subassemblies like electronics and propulsion systems, and the Third World producer performs the more basic and simple tasks such as metal forming and assembly. [redacted] 25X1

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Diffusion of Technology for Producing Sophisticated Arms

Few Third World states possess the ingredients necessary for successful weapons development programs: production technology, strong management, skilled labor, access to materials, professional design teams, and adequate funding. To overcome these difficulties, Third World states have attempted to acquire technology directly from more advanced weapons manufacturers. Efforts to produce weapons with direct foreign assistance, under license, through codevelopment and through "reverse engineering" have had mixed results. [redacted]

Direct Foreign Assistance. *Manufacturing technology often has been directly acquired from foreign arms industries, especially where sophisticated arms are involved. West Germany has been a major source of this type of assistance.* [redacted]

Licensing. *Most of the licensing agreements signed by Third World countries have been for the production of ground forces equipment. Licensing agreements for complex aerospace, naval, and communications systems are of more recent origin. For example, according to academic studies and trade journals, Israel, South Africa, Brazil, and South Korea all have begun the licensed assembly of jet engines for fighter aircraft in the last decade.* [redacted] 25X1

Codevelopment. *Joint development of sophisticated arms in which one of the partners is a Third World country is still uncommon because of the relatively low design and manufacturing capabilities of even the advanced Third World states. It may occur with more frequency as these countries increase their expertise. Brazil, for example, has nearly completed the first AMX jet attack aircraft codeveloped with Italy.* [redacted] 25X1 25X1

Reverse Engineering. *Several Third World countries have attempted to "reverse engineer" advanced weapons, particularly those developed in the Soviet Union because of their relatively simple designs. Egypt, for example, has attempted to develop infrared guided surface-to-air missiles by copying weapons previously purchased from the USSR. Always hard to accomplish successfully, particularly in Third World countries, this method will be increasingly difficult to follow with the rapidly growing complexity of sophisticated weapons.* [redacted] 25X1 25X1 25X1

While these countries have started to assimilate the technology needed to produce moderately sophisticated weapons, in the near future most will have to continue to depend heavily on Western assistance.[3] Moreover, the rapid pace of advance in weapons technology in the West is probably increasing the technology lag of the Third World suppliers. Nevertheless, they are likely to continue to move into the production of advanced arms on a selective basis as a means of increasing the domestic pool of technical expertise, obtaining ready access to such weapons, and expanding exports. For example:

- Brazil probably will move beyond the production of light armored vehicles and trainer aircraft to the manufacture of fighter aircraft and tactical missiles.

[3] Israel and South Africa are much further advanced than the other countries in this group. They have reached the point, for example, of being able to design and produce on their own some less complicated and less costly sophisticated arms such as air-to-air missiles [redacted] 25X1

- Singapore will complement its small-arms industry with the assembly and refurbishment of jet attack aircraft, missile patrol boats, and armored vehicles.

- South Korea plans to develop an antiship missile.

While these new products will first be used by the armed forces of the manufacturing country, the pressures to gain the scale economies of larger production runs undoubtedly will push these countries to seek foreign markets for their products. 25X1

Reduced Earning Power of Primary Commodity LDCs. A long-term fall in the average real prices of some primary commodities is another potential fallout of technological advance and diffusion (see figure 2):

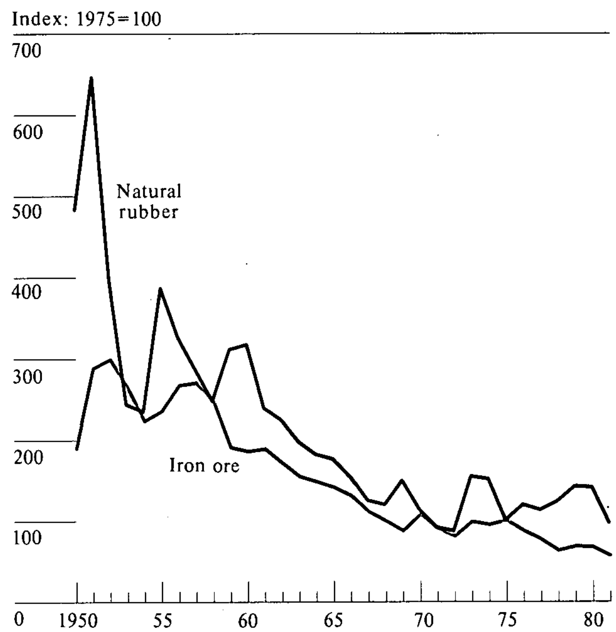
- The development and spread of new production techniques and products will allow the substitution of cheaper raw materials or synthetics for more expensive ones. For example, cheaper synthetic rubber, whose supply is also more reliable, has substantially reduced the market share of natural rubber (see figure 3). Moreover, fiber-reinforced composites, structural ceramics, and other high-technology materials probably will replace metals in a wide variety of applications.

- Technical advances are leading to increased conservation of raw materials, tending to result in reduced demand for primary commodities. Fiber optics, for example, could largely eliminate the use of copper wire in telecommunications.

- Increased recycling—in part an offshoot of technological advance—also will lower the demand for raw materials. For example, the National Materials Advisory Board estimates that within 10 years technological innovations could make possible the recycling of 5 percent of the chromium used in US metallurgical applications, 6 percent of that used for chemical purposes, and 65 percent of that used in linings of US metallurgical furnaces.

To the extent that technological change shifts the structure of demand from goods to services, the impact on some primary commodity prices may be even more unfavorable. 25X1

Figure 2
Trends in Real Price of Selected Commodities[a]



[a] To roughly account for the impact of inflation, nominal prices were converted to real prices using a world consumer price index. 25X1

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Because of the pace and variety of technological change, it is difficult to identify those primary commodities that will be most vulnerable to slackening relative demand. For those commodities affected, however, any price shifts will have different impacts on different countries. In countries where costs of production for the commodity are relatively high, a price decline will encourage a move into other fields. Malaysia probably falls in this category.[4] 25X1

[4] Malaysia, long dependent on exports of tin and rubber, has adopted an economic strategy that emphasizes heavy industry domestically and labor-intensive manufacturing for exports. Prime Minister Mahathir Mohamad touts Japan and South Korea as role models. 25X1

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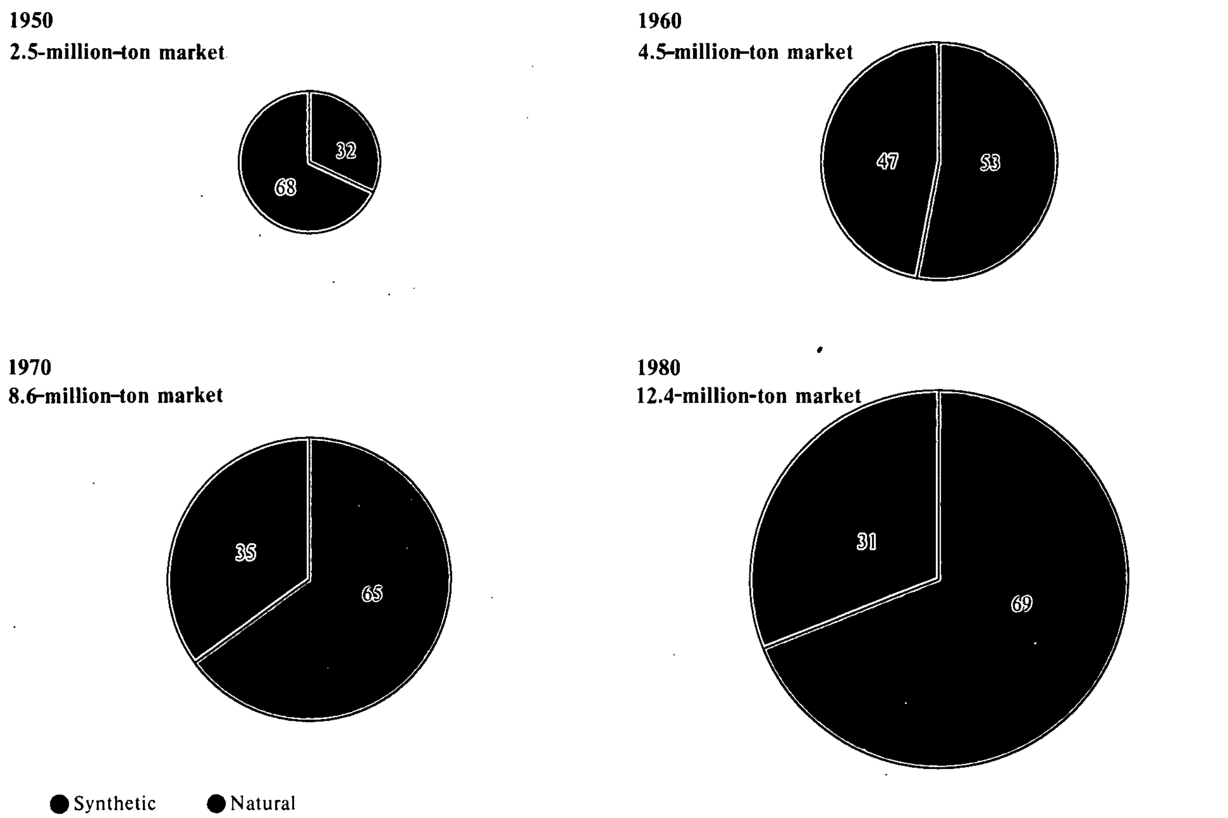
Figure 3
Market Shares of Synthetic and Natural Rubber, 1950-80
Percent



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On the other hand, in economies where costs are low because resources are very accessible, agricultural conditions are excellent, or labor is cheap, the difference between the world price and supply cost may continue to be substantial for many years, even though diminishing. Countries facing these cost conditions can continue to specialize in commodities production and trade, even though they have to export more volume to maintain real earnings. This interaction could lead to a vicious circle whereby a country exports more to offset price reductions, but the increased volume puts additional pressures on prices.

While many of the LDCs with favorable cost conditions may continue to develop processing facilities that will allow them to increase the value added to their exports, continued advances, particularly in the area of high-technology materials, may increasingly make such investments uneconomic. 25X1

Many of the countries that will probably continue to specialize in primary commodities are in Sub-Saharan Africa. Indeed, these African countries have become

Impact of Technological Change on the Demand for Copper

Impacts From Substitution:

- *In plumbing applications, plastic pipes and tubes have made strong inroads on copper. For the most part plastics are cheaper, lighter, and easier to work with than copper, and their use is becoming more widespread with the gradual easing of local construction codes.*

- *Sizable amounts of copper could soon be displaced in heat exchanger applications, particularly automobile radiators. Since automotive manufacturers are concerned with reducing vehicle weight to increase fuel economy, lighter aluminum radiators pose an attractive option. If technical problems such as weldability can be eliminated, a rapid shift could easily occur. At present, only VW Rabbits use aluminum radiators.*

- *Another challenge comes from fiber optics. Optical fibers are technically superior to copper coaxial cables in telecommunications, which account for about 15 percent of copper usage in the United States. Although copper is still somewhat cheaper than optical fiber, as demand for the latter increases, prices could drop. By the late 1980s these technological innovations could make substantial gains at the expense of copper in communications applications.* [redacted] 25X1

Impacts From Conservation:

- *Improvements in the design and performance of telephone equipment have permitted the use of thinner gauge wires. Currently the telephone systems in most countries are shifting down to 0.4-mm or 0.32-mm wire as the standard gauge, and it is estimated that by 1990 in the United States this process will have eliminated around 40 percent of the copper required for a given volume of traffic. In addition, improvements in multiplexing—the process of sending multiple conversations through a single telephone circuit—are reducing the need for additional cables.*

- *Savings in the use of copper have also been encouraged by the drive toward lightness and miniaturization. For instance, the potential widespread use of lighter aluminum in automobile radiators has spurred copper fabricators to develop thinner gauge strip and walled tube.* [redacted] 25X1

more dependent on a small number of commodities for exports in recent years, whereas countries in Latin America and Asia have generally reduced their concentration on commodities (see figure 4). For example, the World Bank reports that coffee, cocoa, and cotton exports as a share of total Sub-Saharan agricultural exports rose from 46 percent in 1964-66 to 63 percent in 1978-80. [redacted]

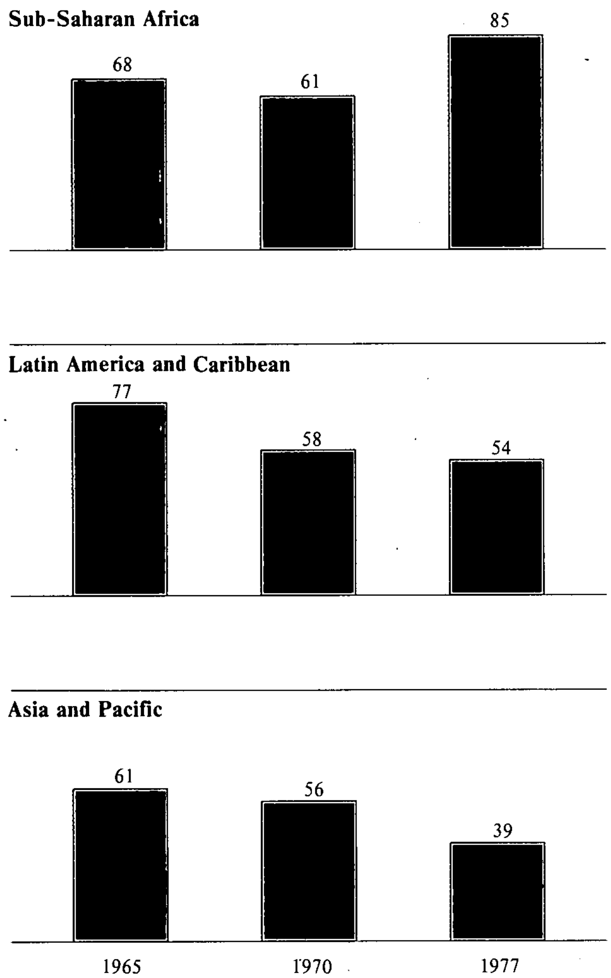
Increased Unemployment in Traditional Industries. An important element of the worldwide diffusion of high technology is the increasing use of robotics and other automated equipment in manufacturing processes. While this substitution of machinery for labor has been an ongoing phenomenon, we believe recent rapid advances in computer-aided manufacturing may encourage an acceleration, particularly where potential returns from such investment are high because of relatively steep labor costs. [redacted] 25X1

The use of robots and automated equipment has a twofold impact. It increases productivity and lowers costs but also inevitably displaces workers in the industries that shift to automated production.[5] While 25X1

[5] This does not mean that employment would necessarily be higher without automation. On the contrary, since automation often is pursued by a firm to ensure its survival in the face of tough competition, automation may in fact minimize the loss in employment caused by changes in market demand, imports, or other factors. [redacted] 25X1

Figure 4
LDC Regions: Trends in Commodity Exports Concentration

Percent of countries where three major commodities account for 50 percent or more of total exports.



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the boost in real earnings for the economy as a whole will lead to additional jobs in other sectors, this may occur with a fairly long lag, during which unemployment would be significantly higher. During this adjustment period governments will also have to cope with a shift in the desired skill mix of the labor force toward more technically trained workers. 25X1

This process has already started in Western Europe, where surging labor costs in the 1970s have encouraged companies to introduce laborsaving equipment. Between 1970 and 1980 the price of labor relative to plant and equipment advanced 45 percent in Western Europe; in the United States during the 1970s, labor costs increased relative to capital by only 25 percent. The increasing availability of industrial automation technology coupled with very high labor costs probably will exacerbate structural unemployment—a major source of the 18 million jobless now in Western Europe. 25X1

Even if labor costs level off, we believe Western Europe may have difficulty in responding to the fallout from the spread of automation. The major West European countries have large traditional manufacturing sectors, which makes the labor force at risk from job displacement through automation relatively large. We estimate that about 100,000 to 400,000 manufacturing jobs could be eliminated during the 1980s in each of the Big Four countries, representing as much as 1.6 percent of total civilian employment (see table 4). Moreover, higher income taxes, coupled with generous unemployment and other social program benefits, have reduced work and investment incentives and will tend to slow employment increases in other sectors.[6] 25X1

In Western Europe the impact of automation will be superimposed on a rapidly changing labor force structure (see table 5). Later in this decade and well into the next, the inflow of new entrants into the labor market will drop off dramatically in northern Europe. By contrast, southern Europe will see the real bulge of its baby boom reach working age during this period.

[6] The average tax-to-GDP ratio for 17 West European countries rose from 28.4 percent in 1965 to 37.5 percent in 1980, while the average share of total tax receipts accounted for by individual income taxes increased from 25.3 percent to 30.6 percent. On the other hand, consumption taxes, which are thought to have smaller impacts on work incentives, had a smaller increase from 13.8 percent of total tax receipts to 16.1 percent. See OECD, *Long-Term Trends in Tax Revenues of OECD Member Countries, 1955-1980*, 1981. 25X1

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Table 4
Big Four: Estimated Jobs Impact From Industrial Automation

Country	Civilian Manufacturing Employment, 1980 *(millions)*	Projected Jobs Displaced by 1990, Assuming 1- to 5-Percent Impact on 1980 Civilian Manufacturing Employment [a]	
		Millions	*Percent of Total Civilian Employment, 1980*
West Germany	8.9	0.1-0.4	0.3-1.6
France	5.4	0.1-0.3	0.3-1.4
United Kingdom	6.9	0.1-0.3	0.2-1.2
Italy	3.8	0.1-0.2	0.1-1.4

[a] The OECD Secretariat has estimated that 0.5 to 3 percent of the manufacturing work force in key industrialized countries could be affected simply by the introduction of robots by 1990. A recent study by W. E. Upjohn Institute for Employment estimates that robots alone could eliminate 1 to 2 percent of all production jobs in the US manufacturing sector by 1990. A 1- to 5-percent impact from *all* sources of industrial automation by 1990 thus seems reasonable. These estimates are gross impacts in the sense that they do not reflect new jobs that could be created by the producers of automated equipment or new jobs in other sectors as the result of greater incomes from using automated equipment.

[redacted]

Table 5 *Millions*
OECD: Projected Increases in Labor Force, 1980s [a]

	1981-85	1986-90
OECD	18.3	13.3
United States	5.9	4.4
Japan	2.5	2.1
Western Europe	8.3	5.6
Scandinavian countries [b]	0.3	0.2
North European countries [c]	3.7	1.1
South European countries [d]	4.4	4.2

[redacted] 25X1

[redacted] They assume no change in age-sex specific labor force participation rates from 1980 levels. 25X1
[b] Denmark, Finland, Iceland, Norway, and Sweden.
[c] Austria, Belgium, France, Ireland, Luxembourg, Netherlands, Switzerland, United Kingdom, and West Germany.
[d] Greece, Italy, Portugal, Spain, and Turkey.

[redacted] 25X1

This shift in demographic trends will complicate attempts to adjust to the impact of high technology on employment levels, if further labor migration between EC states intensifies current guest worker problems. [redacted]

At the other extreme, Japan is positioned to benefit—or at least not lose as much—from these trends. As the world's leading producer of robots, Japan probably will be able to secure many of the new jobs created by this industry. This should help Japan adjust to lower employment levels in such traditional industries as steel, aluminum, and shipbuilding, currently suffering substantial overcapacities, although the problem of shifts in required labor skills will have to be overcome. Any net gains will come at a time when the flow of new entrants into the labor force is likely to slow. [redacted]

The LDCs will not be immune to the impact new technologies are likely to have on traditional industries and employment. With the development of new materials that probably will offer cheaper substitutes, real prices for a number of traditional metals are not likely to grow and could continue to fall. Some LDCs, for example, probably will either have to provide large subsidies for the production of steel and other metal products or shut down capacity and lay off workers. Any moves by the developed world to protect their own steel producers from foreign competition would only intensify the problems faced by Third World producers. Since some of the LDCs with the greatest steelmaking capacity are among the key debt-troubled countries (for example, Brazil, Mexico, and Argentina), reduced ability to afford large subsidy bills could favor idling capacity as the most likely option. Any job losses will come at a time when the LDCs will be trying to cope with rapid labor force growth. During this decade these countries as a group will see 550 million people added to the working-age populations (see table 6). [redacted]

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Table 6
Increases in Global Working-Age Population, 1951-90

Millions

	1951-60	1961-70	1971-80	1981-90
Africa	28	38	59	84
Asia	124	216	324	399
Latin America	24	35	52	64
Industrial countries	58	73	75	59
Total	**234**	**362**	**510**	**606**

Source: United Nations.

[redacted]

Government Responses

Because of the broad-ranging impacts of technological advance and diffusion, governments are increasingly responding to the technological boom. In some cases they are attempting to speed their countries' entry into high-technology industries. In others they are attempting to insulate their countries from the impacts of rapid technological change [redacted]

Foreign Investment Policies. A number of governments have already introduced policies designed to attract foreign direct high-technology investment. Singapore is perhaps the best example of a country that has pursued this strategy successfully. Throughout the 1970s foreign investors accounted for over 70 percent of the total commitments in manufacturing. Furthermore, using tax incentives, the government's Economic Development Board has guided investment toward the new knowledge-intensive industries. As a result Singapore has moved rapidly up the technology curve, from specializing in such labor-intensive export lines as textiles and footwear to electronics and oil-drilling equipment. The other East Asian NICs—Hong Kong, South Korea, and Taiwan—have also instituted policies to attract foreign investment in high-technology industries, though on smaller scales than Singapore. [redacted]

Based on the rapid progress of the NICs, other countries in the second-tier group of LDCs are now beginning to reexamine the impact foreign investment can have:

- Primarily through government financial assistance, Malaysia is encouraging foreign investment and joint ventures and is exploring the possibility of encouraging basic "smokestack" industries operating in developed countries—especially in Japan—to relocate in Malaysia.

- In India procedures for approving nonequity "collaborations" have been simplified, increased royalty rates are allowed, and a somewhat more accommodating approach toward new equity investment is also evident. 25X1

We believe it will be only a matter of time before such countries focus on high-technology investment as well. Attempts by Western firms to increase their market share through selected licensing in Third World countries purchasing their goods will accelerate this process. [redacted] 25X1

As a less direct means of encouraging technology transfers, governments are subsidizing domestic firms 25X1 participating in joint ventures with foreign technology leaders. More commonly practiced by governments in 25X1 the developed countries, these efforts have provided subsidies to numerous domestic firms participating in coproduction agreements in the aerospace field. [redacted]

[redacted]

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Special Incentives for Foreign Investment in High-Technology Industries: Case of the Asian NICs

The East Asian NICs—Hong Kong, Singapore, South Korea, and Taiwan—have developed a range of policies designed to encourage foreign investment in high-technology industries. These countries have a special interest in upgrading their economies' technical capabilities because of their lack of natural resources. Like Japan, they must depend on imports to obtain raw materials, and, therefore, it is essential for the further development of their economies that they expand exports. With the growing competition in their traditional export markets—textiles, footwear, and similar products—from other LDCs, they have sought to move up the technology curve as a way of improving their position in international trade.

*According to press reports, the focal point of **Hong Kong's** drive to attract high-technology industries has been the Taipo Industrial Estate, which at little cost to entrepreneurs provides basic facilities for firms manufacturing high-technology products. In addition, the government is opening industrial promotion offices in San Francisco, Tokyo, London, and Stuttgart.*

***Singapore** has established the Economic Development Board to assist private investors. It has targeted tax incentives to encourage investment in high-technology industries such as electronics, aircraft components, and advanced medical equipment. Firms investing in these industries are eligible for:*
- *Accelerated depreciation on fixed investment.*
- *Tax holidays for five to 10 years.*
- *Tax exemptions on export profits.*

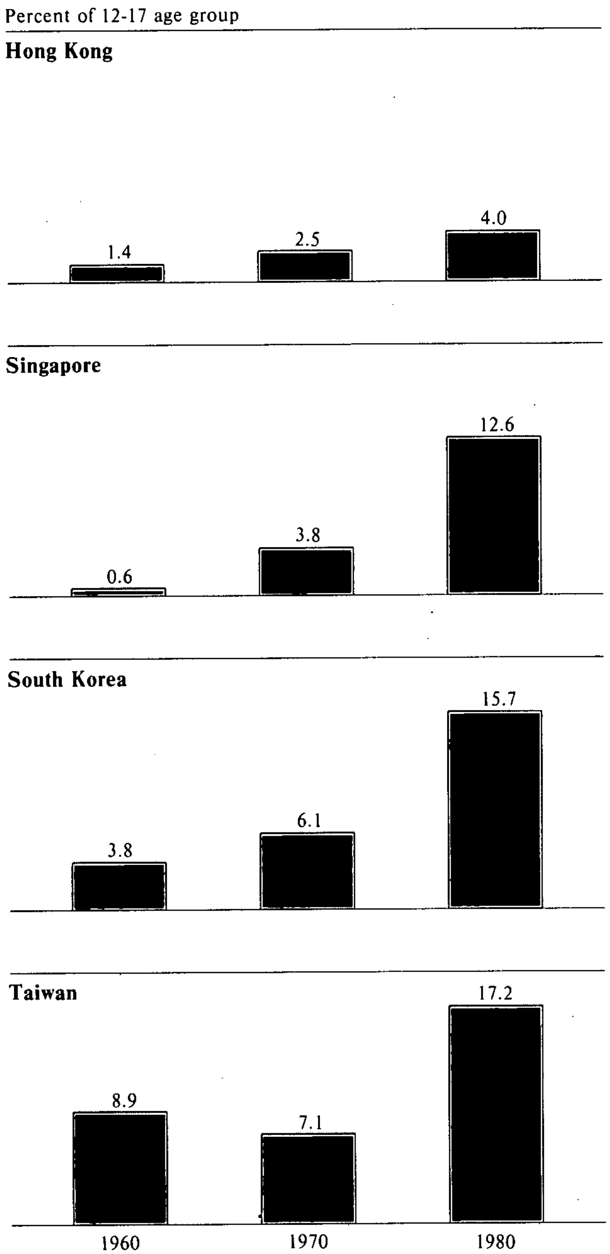
The Economic Development Board also has established a science and technology park adjacent to the National University of Singapore to encourage investors to establish research and development facilities in Singapore. 25X1

***South Korea's** Ministry of Finance announced several policies late last year to improve the foreign investment climate, including an expansion in the number of industries eligible for foreign investment, reduced red tape, and an increase in the foreign equity share permitted in selected industries. Seoul also views joint research projects as a way to attract foreign technology. Projects in mechanical engineering, genetic engineering, semiconductors, and communications technology are under way or planned with MIT, Bell Laboratories, and ITT.* 25X1 25X1

*An important element in **Taiwan's** strategy is the Hsinchu Science-Based Industrial Park. It offers two universities, a research center, schools for foreign children, and a computer center. To ensure that technology-intensive industries are attracted to Hsinchu Park, Taipei has offered a number of incentives to prospective investors, including subsidized rents, special financing arrangements, duty-free imports, tax holidays, freedom to repatriate profits, and, in some cases, up to 49-percent government funding of venture capital.* 25X1 25X1

Education Policies. Governments have also placed increasing emphasis on educational and training programs to aid entry into the technological mainstream. According to World Bank statistics, the East Asian NICs—Hong Kong, Singapore, South Korea, and Taiwan—are in the forefront of this effort (see figure 5). Official government and press reports indicate that Singapore has established four industrial training centers since 1972 with assistance from foreign firms and governments to provide two-year courses in such fields as precision machining, tool and die making, optics, and instrumentation. Singapore's Vocational 25X1

Figure 5
Asian NICs: Vocational School Enrollment Ratios



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Institute Training Board now operates 17 institutes covering the entire spectrum of technical skills. Even in Hong Kong, despite its basic stance of limited government activity, enrollment in technical schools expanded rapidly. These countries' efforts in this area have been abetted by high rates of growth in the relevant age groups.[7] 25X1

These governments also have ambitious plans to continue this upgrading process. For example, by 1985 Singapore plans to graduate 1,200 engineers annually, compared to 300 now. In South Korea university enrollment is being expanded significantly, scholarships and research subsidies are being increased, and military exemptions are being granted to graduate students. Malaysia is just beginning to focus on technical education; it is building six new trade schools that will provide training in engineering and machine tools. 25X1

Increased Protectionism. On the other side of the coin, several countries are pursuing a variety of protectionistic measures to defend their industries—both infant high technology and traditional—from foreign competition. For the most part, these measures consist of nontariff barriers such as government subsidies, procurement restrictions that favor domestic firms, and negotiation of voluntary export restraints (VER) with trade partners. To the extent these barriers apply to investment goods such as sophisticated machinery and computers, they will tend to slow the adoption rates of new technologies or at a minimum encourage alternative forms of technology transfer based on, for example, joint ventures and coproduction agreements. 25X1

Western Europe may be the region most susceptible to increased protectionism in high-technology goods because of its severe unemployment problem. The rate of unemployment in this region has risen from about 3 percent in 1970 to over 10 percent currently. Furthermore, Western Europe's competitive position in high-technology goods compared to Japan and the NICs has declined significantly in the 1970s; growth

[7] According to United Nations data, growth rates of the age group 15 to 24 for Singapore, South Korea, and Hong Kong during 1971-80 were 2.3, 4.6, and 4.6 percent, respectively. 25X1

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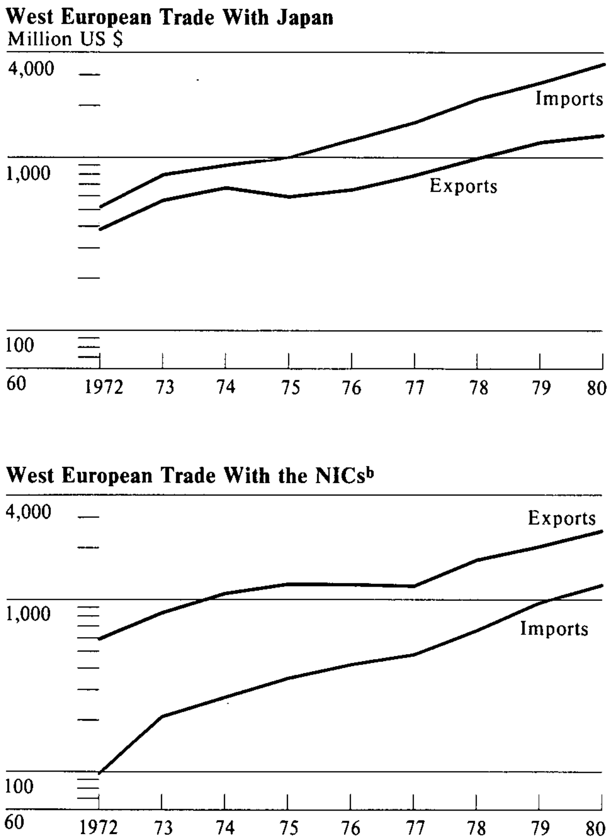
Figure 6
Western Europe: Trends in High-Technology Trade[a]



[a] High-technology goods are defined as in figure 1.
[b] The NICs are Brazil, Hong Kong, Mexico, Singapore, South Korea, and Taiwan.

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of Western Europe's imports of such goods from these countries easily outpaced the growth of exports (see figure 6). Partially as a result, there are some indications of greater protection for domestic high-technology industries in Western Europe:

- In mid-February the EC secured from Japan a three-year VER agreement covering a number of products. These include some that reflect advanced technology, such as color television picture tubes, numerically controlled machine tools, and video tape recorders.

- In the United Kingdom major financial commitments have been announced to support British production of high-technology goods. A $25 million grant went to British microchip manufacturer Inmos International. London has reiterated its support for computer maker ICL by pressing local governments to boost spending on British computer and office equipment.

- The Mitterrand government is continuing to try to identify markets, especially in high-technology areas, where an effective French presence may be secured. Going beyond their predecessors, the Socialists are making an effort to use the expanded nationalized industrial and banking sectors and substantially increased levels of government funding to back this effort. The government has also not been reluctant to impose new barriers against some more technically oriented products—the now-rescinded administrative delays directed at Japanese VCRs being a case in point. 25X1

Implications for the United States

Given its widespread impacts, continued rapid technology diffusion could pose numerous challenges for the United States. Many of these will involve particular instances of technology transfer or their impacts—requiring attention to specific firms, technologies, and countries. At the same time, there appear to be a number of broadly based potential problems, ranging from increased opportunities for greater access to sophisticated technologies by Communist countries to greater pressures for protectionism in Western Europe. 25X1 25X1

Easier Communist Country Access. While Communist Bloc access to critical technology has been a longstanding security issue for the United States, a new challenge in this area will arise if the list of countries that are not members of COCOM, but have developed or acquired COCOM-restricted techniques, expands.[8] The NICs, in particular, as they continue to

[8] Austria, Switzerland, and Sweden, which are not members of COCOM, have been important suppliers of advanced tools and controlled equipment to the USSR in the past. For example, since the late 1960s Austria has sold at least 26 automated rotary forges to the Soviet Union, which are used to produce gun barrels for tanks and artillery. 25X1

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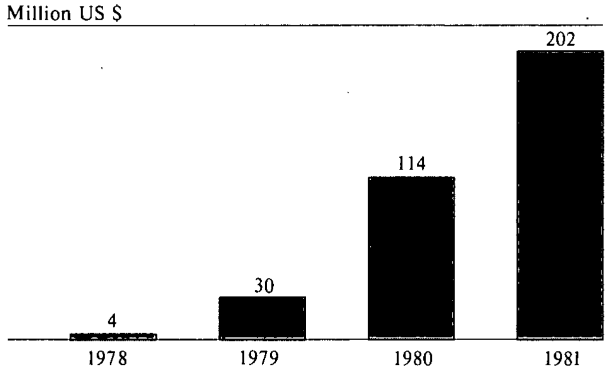
Figure 7
Growth of Hong Kong Exports of High-Technology Goods to China[a]

Million US $



[a] High-technology goods are defined as in figure 1.

[redacted]

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move up the technology curve could, perhaps within five to 10 years, offer the Communist countries promising sources—or targets—for obtaining such technologies. At the same time we believe the pressures for the Communist Bloc to obtain Western technologies is likely to grow rather than diminish. For instance, the Soviet lag in computer technology—a vital part of military preparedness—is currently three to seven years. [redacted]

The NICs' responses to overtures from Communist countries are likely to differ. For example, political differences currently limit economic exchange between South Korea and Communist countries to small amounts of indirect trade. On the other hand, Hong Kong—both as a producer and as a transshipper—has been a growing source of high-technology goods for China since the beginning of Beijing's modernization drive in 1979 (see figure 7). In 1978 Hong Kong accounted for about 1 percent of high-technology exports to China; by 1980 Hong Kong's share was running at 10 percent, even though total high-technology exports to China were growing rapidly in the meantime. In particular, Hong Kong has become a key supplier of telecommunications equipment and transistors. [redacted]

Besides becoming potential overt suppliers of high-technology exports to Communist countries, the NICs, or even some of the other rapidly developing LDCs, may offer easy targets for illegal acquisition of technologies. These governments may be unconcerned about the possibility of industrial espionage and other illegal means of technology acquisition, given their economies' relatively new status as possible targets. China's efforts in Hong Kong illustrate some of the possibilities. [redacted] 25X1

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Increased Economic Tensions. Rapid technological change and its diffusion internationally could increase economic and political strains among some countries and regions. Although the pace and wide variety of change make it impossible to suggest a complete list of possible trouble spots, some of the key ones probably will involve Western Europe and LDCs' exporting primary commodities vulnerable to slackening demand. [redacted] 25X1 25X1

Western Europe probably is lagging countries such as the United States, Japan, and the East Asian NICs in moving rapidly into the high-technology fields. West European officials openly admit they are far behind the United States and Japan in high-technology products and argue that they need quantitative restrictions to catch up. Further protectionist measures not only would strain US relations with Western Europe directly but could involve the United States in disputes between Western Europe and Japan as well as other US Pacific allies. It also could lead Japan and the NICs to focus on non-European markets where the United States competes, or on the US market itself. 25X1
[redacted] 25X1

Although Western Europe is moving into most new technologies relatively slowly, high labor costs will encourage quick adoption of the new automation technologies. Structural unemployment probably will increase, further straining the domestic fabric in these

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countries. In addition, since foreign workers are likely to be a particular target of resentment, guest worker and labor mobility problems among European Community members could mount.

If the longer run demand for some primary commodities drops, Third World countries producing these goods for export will face lower trade earnings and slower economic growth. The economic fallout could easily become a political issue if, for example, severe austerity measures were imposed. As a result, such countries could become more subject to domestic instability and perhaps Soviet interference. This is especially true for some countries in Sub-Saharan Africa that, apart from heavy reliance on commodity exports, also face many other economic and political problems. In addition, even though concentration on a small number of commodity exports has fallen somewhat in Central America, most countries in this region still depend heavily on such trade and therefore also continue to face extra economic risks.

Increased Proliferation of Sophisticated Arms. The diffusion of technology to Third World suppliers for producing moderately sophisticated arms poses increased risks of arms proliferation to other Third World states. As competition in the international arms market intensifies, Third World suppliers will be tempted to expand the range of military assistance they can provide to potential customers. In some cases, this may include introducing less than state-of-the-art weapons into a region, thereby giving recipients new capabilities which are threatening to their neighbors, to US interests, or to US allies.

In the immediate future, these increased risks from diffusion of production technology will be fairly small. Usually the licensing agreement that permits a Third World producer to manufacture complex arms contains provisions that restrict third-party sales. Furthermore, because the manufacturing process usually depends on Western provision of key subassemblies, production and sales to third parties could always be limited through embargo of these essential components. Finally, the risks from sales of less than state-of-the-art weapons from Third World suppliers will continue to be overshadowed by the threat of transfers of Western or Soviet state-of-the-art arms from an approved purchaser to potential Third World adversaries.

Nevertheless, over the long run and with sufficient effort, some Third World producers could approach the capability of manufacturing selected state-of-the-art weaponry, especially near the less complex and less costly part of the weapons spectrum. At the same time some Third World producers have or in other cases can develop the expertise needed to produce parts which can be used in existing weapon systems. Given existing and future potential, arms proliferation risks could rise while the leverage of the United States and other leading arms producers through arms exports and production assistance could be reduced.

Dependence on Imports of High-Technology Goods. Japan soon may be able to reach a leadership position in some high-technology fields with defense applications. For example, the leading Japanese computer firms, Fujitsu and Hitachi, have developed and soon will be marketing supercomputer systems that match, and in some cases surpass, the performance levels of present and near-term US products. Because these systems have a number of military applications—such as advanced aerodynamic modeling, cryptanalysis, and strategic battle management—this outcome could place the US defense establishment in a position of reliance on Japan for this equipment.

With the rapid diffusion of technology throughout the world and growing capabilities for indigenous innovation, over the long run other countries also could eventually become technology leaders. If this happens, the United States could have to rely on foreign sources for important components of weapons and other defense goods. Such a reliance on imports as a source for state-of-the-art technology would be more risky than reliance on imports for other goods, even such strategic ones as oil. Particularly if the technology leader is substantially ahead of competitors, any supply cutoff would be complete, in contrast to standard goods where close substitutes usually exist or purchases can be switched to alternative exporting countries, though perhaps at higher costs and with some time delay.

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A Final Note

This paper has explored some of the key economic changes and policies likely to result from the spread of modern technologies internationally. Many others probably will emerge given the rapidity of the change occurring. Issues involving technological diffusion thus will continue to be important in the near future. Moreover, the rapid change means that the management of the fallout from technology diffusion will become more difficult. For example, greatly improved and expanded communications and transportation links have created numerous channels for technology transfer that will make it much harder to restrict the flow of technology to the Communist Bloc. Furthermore, the faster pace of change means that leadtimes for government actions will be considerably shorter. These and other problems point to much greater costs of managing the national security impacts of the continuing worldwide technology diffusion.

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