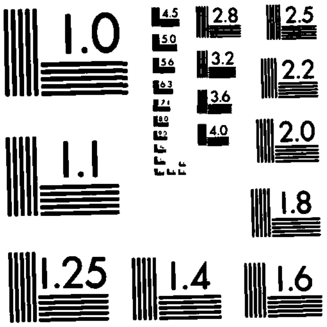
AD-A123 325 THE INTERNATIONALIZATION OF INDUSTRY ANNEX B OFFSHORE 1/4
PRODUCTION IN THE I..(U) DEPARTMENT OF STATE WASHINGTON
DC OFFICE OF EXTERNAL RESEARCH.. J GRUNWALD ET AL.
UNCLASSIFIED NOV 81 FAR-284-GP-ANNEX-B F/G 5/3 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

FAR 284-GP-

(2)

Annex-B

THE INTERNATIONALIZATION OF INDUSTRY

ANNEX B

Joseph Grunwald
Kenneth Flamm

Basic + Annex A - AD-A113966

This paper was prepared for the Department of State as part of its external [illegible] [illegible] [illegible] conclusions contained herein [illegible] [illegible] official opinion or [illegible] of State.

The Brookings Institution

November 1981

ANNEX B

Offshore Production in the International Semiconductor Industry

Kenneth Flamm

A

Contents

[redacted]

1. Introduction

We are barraged with news of the technological advances currently taking place in electronics, and what they promise for the future. Optimists paint rosy visions of a world without drudgery, where cheap and abundant machines master the simple tasks that make work repetitive and boring. The skeptical worry over a gloomier picture of redundant and dissatisfied workers, doomed to unemployment in a society where machines can function with less cost than the wage to which people are accustomed.

These issues lie before us. A different sort of technical revolution, of no less importance, has already fundamentally altered the way work is divided among the developed industrial countries and their less developed neighbors. The low-cost, solid-state semiconductor devices (SCDs), which are the building blocks of the sophisticated new electronics, are the product of a qualitative change in the way firms operating in world-scale markets have been able to organize their production, as well as of technical progress.

The research, development, and initial production runs of new products are generally carried out in the industrial countries with relatively cheap and plentiful supplies of skilled workers, technicians, and scientists. Once a standardized product with a potentially large market is developed, however, the labor-intensive stages of production are often moved into developing countries with an abundance of cheap, unskilled labor. As shall be seen below, factors other than a reliable supply of low wage labor are important to the economics of offshore production; still, the essence of these arrangements is specialization based on international differentials in the costs of labor services. The availability of low-priced labor has also influenced the selection of production techniques in manufacture.

The use of cheaper foreign labor inputs to reduce production cost, and the international trade flows generated by this practice, are neither a completely new phenomenon, nor confined to the semiconductor industry. In fact, it is the rapid spread of these arrangements to other industries -- particularly among certain dynamic industries in the advanced industrial countries -- that makes the international semiconductor industry (and its most important product line, integrated circuits) 1/ as illuminating to study from the viewpoint of industrial structure, as from the viewpoint of technological diffusion.

2. Offshore Production and Industrial Policy

The U.S. semiconductor industry represents a distinct set of responses to a whole series of problems afflicting the Western industrial economics. Its past success and current challenges make it an excellent example of the readjustments that take place as industry comes to terms with the changes that have made the postwar decades a distinctive stage in the evolution of the modern world economy: a dramatic decline in all sorts of trade barriers; including among these an enormous cheapening of the cost of international transport and communication; the quickening of the pace at which technology diffuses across national boundaries; widening international disparities in wages and standards of living; the great leap in the importance of the multinational firms which accompanied these changes.

But it is not the only model. The Western European and Japanese semiconductor industries represent different paths taken on critical policy issues, and each illustrates potential strengths and weaknesses of those alternatives.

All the different national policies have resulted in an essentially global industry, with product, capital, or technology flowing across national boundaries while, for the most part, internalized within the limits of a single multinational firm. In a certain sense, since the trade associated with offshore production is largely the internal transfers of multinational corporations, the rise of the global semiconductor industry reflects a shift in the functions of the multinational firm. Until the early 1960s, multinational firms were largely oriented toward producing for foreign markets (with tariff and tax barriers determining whether to export through a foreign sales affiliate, or to produce behind foreign tariff walls), or securing natural resources in foreign economies. Superior management, marketing skills, technical knowledge, or preferential access to capital markets made multinationals competitive with foreign entrepreneurs overseas. Foreign operations, however, were basically little (or big) versions of big national companies in the home market.

Technological advances in transport and communication, along with the development of a basic industrial infrastructure in many developing economies, and the creation of what amounts to a free trade zone in unfinished manufactures in the developing world (through the widespread promotion of export processing zones, drawback schemes, and similar institutions), have made new forms of organization possible. Multinational firms can now effectively transfer the production departments supplying their output on major markets to distant regions with comparatively lower costs. Foreign affiliates, rather than being scaled-down versions of home operations, or sales offices, can now specialize in the production or assembly tasks of the organization, while home offices can specialize in the skill and technology-intensive operations in which their costs are lower. These changes in the structure of multinational operations may not necessarily be in the long-term interest, nor even under the effective control, of developed and developing nations.

This essay will focus on offshore production as a strategy for industial reorganization. The international semiconductor industry is the clearest and most pronounced example of a pattern of international trade and production flows that has already spread to key sectors of the western industrial economies. The international structuring of industries across national boundaries presents problems and possibilities to both the developed economies supplying components and technology, and the developing nations supplying the labor to assemble these products.

The next sections discuss the economics of microcircuit production and its relation to current industrial problems, and how different national solutions to these problems have created competition and complexity in international markets for semiconductors. A subsequent discussion traces the development and growth of offshore operations in the industry.

Later sections analyze the motivations for offshore investment in production facilities, and the determinants of plant location. Assessments of the impacts of offshore operations on U.S. industry, and on the economies of LDCs playing host to such plants, follow. Finally, the prospects for the further internationalization of production within a single industry are examined, and conclusions drawn about the probable choices faced, and their likely effects.

3. Semiconductors and their Importance

The transistor, invented at Bell Labs in 1947, was the first semiconductor device (so-named because its principle of operation involved the application of electric currents to normally non-conductive crystalline materials which were treated with small amounts of impurities, permitting the flow of electric current). The transistor is a semiconductor amplifier, in which the application of an input regulates the flow of another electric current through the semiconductor medium.

The transistor quickly replaced many types of vacuum tube amplifers, which it dominated in reliability, size, power consumption, and cost. It soon became clear that devices constructed with semiconductor materials could perform most other electronic functions, including those of rectifiers and diodes, resistors, and capacitors 2/ In 1959, the first integrated circuit was developed; it consisted of several different electronic devices constructed on the surface of a single piece of semiconductor material. 3/

Size and reliability are critical in military applications, and semiconductors were an essentially military technology until the 1960's. In fact, the development of semiconductor technology can be traced back to World War II, when the unreliability of silicon detectors used in radar prompted the U.S. government to sponsor a huge research program into the fundamental properties of germanium and silicon, involving thirty to forty U.S. research laboratories, and directed by the Radiation Laboratory at M.I.T. 4/ Nevertheless, the transistor was actually invented at the civilian Bell Labs which did not receive a semiconductor R&D grant from the military until after its invention.

At the start it was recognized that the transistor was an enormously important invention, and of great strategic value. The development of a wristwatch radio, for example, excited early military interest. 5/ Military users funded a large portion of the research and development expenditure that went into semiconductors in the 50s, directly through grants, and indirectly, through sales at premium prices for new devices. In addition, roughly $36 million was spent between 1952 and 1959 on grants to provide funds to individual firms to build semiconductor production capacity far in excess of current requirements. 6/

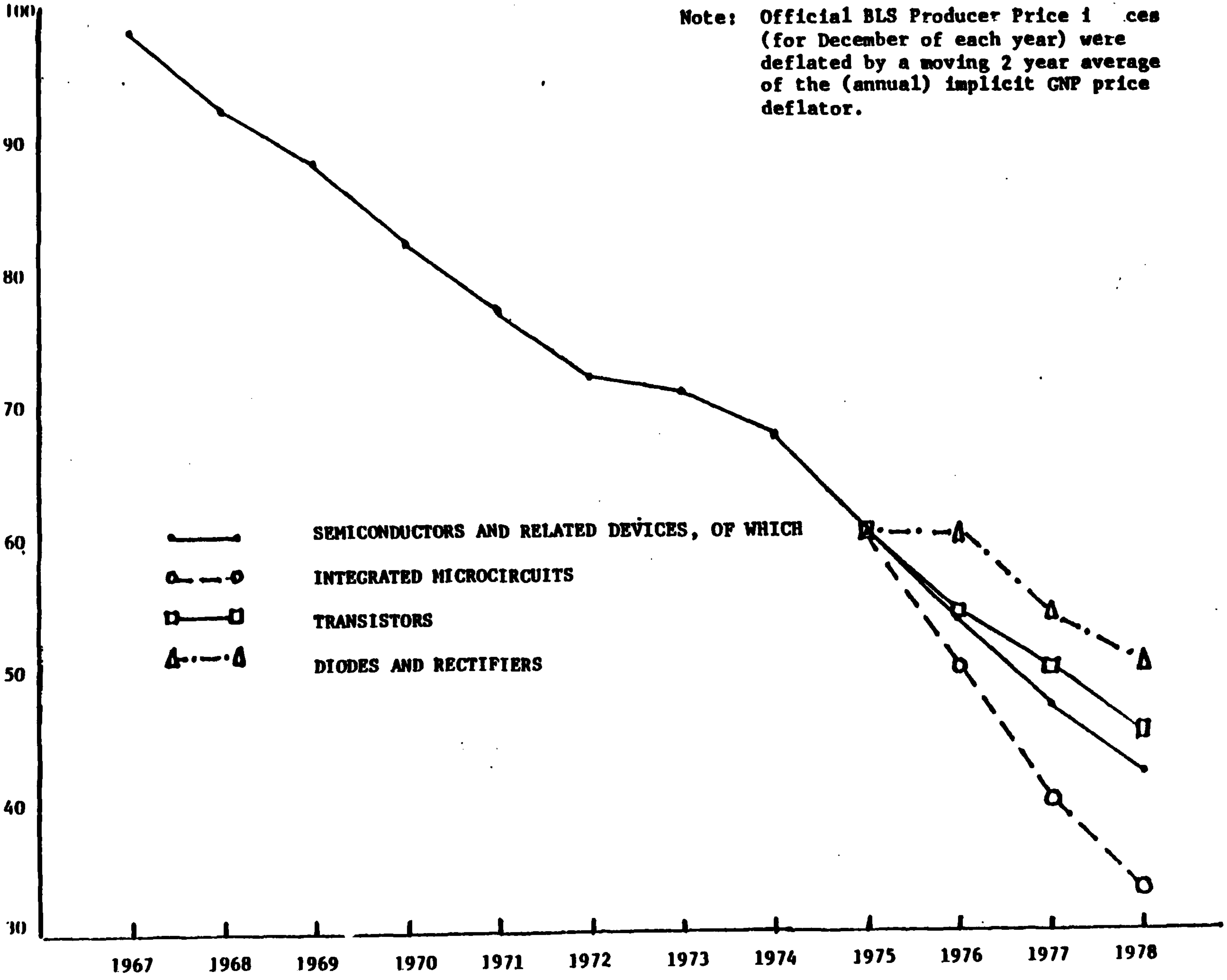
The decision to use integrated circuits in the Air Force's Minuteman ICBM missile, and in NASA's Apollo space program, gave the industry another big push in the 1960s. Industry sources variously estimate the government to have paid far between forty-four (in the period 1958-74) and forty-seven (over 1958-69) percent of all R&D done in the industry over the years in which the integrated circuit was developed and brought to the mass market. 7/

The importance of semiconductors quickly spread beyond purely military applications. As price dropped and production increased, they became a major input into the young computer industry. Cheap semiconductors, lowered the cost of moving and storing data, dropped the cost of the computers into which they were built, and played a major role in stimulating demand for computers. By the early 1960s, IBM was probably the largest single customer of every American semiconductor company, with the Minuteman missile finishing in second place. 8/

The decline in the price with improvements in technology was quite remarkable. Chart 3.1 gives semiconductor price indices over the 1967-1978 period in real terms (deflated by the implicit GNP price deflator). Furthermore, as more and more circuit elements were crammed onto a single semiconductor chip, integrated circuits went from under 64 components per circuit in the early '60s (small-scale integration), to in excess of 256 components in the late '60s (medium-scale integration), to more than a thousand in the early '70s (large-scale integration), and finally to more than sixteen thousand in the la '70s (very large scale integration or VLSI). Hence, the price p electronic function has declined on the order of 100 to 1000 time the decline shown in Chart 3.1. It is claimed, for example, that the ice of an electronic function in a computer memory declined from $50 in the mid-1960s, to under $.005 in 1979. 9/

As the price of chips dropped, the density of components on a chip increased, and the price of an electronic function plummeted, non-military demand for semiconductors surged. Table 3.1 shows that in the early '60s military consumption in the U.S. accounted for most SCD demand, and all of the demand for the first integrated circuits. But commercial usage increased much more rapidly until, by 1979, military sales accounted for only 14 percent of the U.S. semiconductor market.

The economic and strategic importance of semiconductors is as related to their role as a critical input to the computer and telecommunications industries, as it is to any purely military impact. As Table 3.2 makes clear, the largest consumption of semiconductors, since at least the early 1960s, has been in those two sectors. When corrected for changes in SCD and output prices, as in Table 3.3,



Note: Official BLS Producer Price 1 ces (for December of each year) were deflated by a moving 2 year average of the (annual) implicit GNP price deflator.

CHART 3.1

REAL SEMICONDUCTOR PRICE INDICES

Table 3.1

Military Sales as a Percentage of all Sales in the U.S. Semiconductor Market

Year	% Military Sales	
	All Semiconductors	Integrated Circuits
1958	39	-
1960	48	-
1962	39	100
1964	28	85
1968	25	37
1972	24	-
1979	14	-

Source:	1958-68	from Tilton (1971), pp. 90-91.
	1972	from Finan (1975), Table 6-3.
	1979	from U.S. Dept. of Commerce, Office of Producer Economics (1979), p. 77.

Table 3.2

Semiconductor Usage, by Important* Sectors

User Sector	As % of Value of Output in User Industry			As % of Value of Semiconductor Prod.		
	1963	1967	1972	1963	1967	1972
Computer and Calculators	5.0	2.8	5.5	21	11	16
Electrical Measurement Instruments	1.6	1.9	2.9	2.1	2.1	1.8
Radio and T.V. Receivers	1.3	1.8	2.1	5.0	6.0	3.3
Telephone and Telegraph Equipment	3.6	3.1	5.3	9.0	6.3	9.4
Radio and T.V. Communications Equipment	2.2	2.9	4.7	24	21	18
Semiconductors	.51	1.1	1.8	.51	1.1	1.8
Other Electronic Components	1.6	3.0	2.9	6.5	12	6.2
Aircraft and Parts	.17	N/A	1.1	3.8	N/A	7.7
Photographic Equipment	.034	.040	1.8	.097	.11	4.
Communications, other than Radio & T.V.	N/A	.075	.13	N/A	1.1	1.7
Personal and Repair Services	.32	.72	.91	4.0	6.2	6.8
Business Services	N/A	.040	.46	N/A	.70	7.3
Deliveries to Final Demand:						
Net Exports				4.8	11.2	4.2
Federal Defense				5.6	5.4	3.7
Federal Non-Defense				.61	.86	.95

* Greater than 1% of SCD output in 1972.

Source: U.S. Dept. of Commerce Input-Output Tables, 1963, 1967, 1972.

Table 3.3

Index of SCD Use per Unit Output
(1972 = 100)

User Sector	1963	1967
Computers & Calculators	33	44
Electrical Measurement Instruments		
Radio & T.V. Receivers	23	76
Telephone & Telegraph Equipment	21	43
Radio & T.V. Communication Equipment	15	45
Semiconductors	28	61
Other Electronic Components	N/A	N/A
Aircraft and Parts	4.5	N/A
Photographic Equipment	.61	1.9
Communications, other than Radio & T.V.	N/A	45
Personal Repair Services	10	58
Business Services	N/A	6.1

Source: "Percent of value of output in user industry" in Table 3.2 divided by ratio of SCD price index to output price index (1972 = 100). Output price indices based on 4-digit SIC output price indices (cross-weights used) published by Bureau of Census with Census of Manufactures data corresponding to year; except for Computers, Aircraft and Parts, Communications, and Services, from U.S. Dept. of Labor, Bureau of Labor Statistics, Time Series Data for Input-Output Industries (Washington, D.C., 1979).

figures show that real consumption of semiconductors per unit of output tripled in computers over the 1963-1972 period, and increased five to seven times in various types of telecommunications equipment. Growth in usage in other types of equipment was even more spectacular. 10/

Since semiconductors are, arguably, one of the most technologically dynamic sectors of the U.S. economy, it is not surprising to find both the semiconductor industry and its major customers in the ranks of the most rapidly growing U.S. industries. Table 3.4 was constructed by selecting from 161 U.S. input/output industries, defined by the U.S. Department of Labor, those sectors with annual growth rates exceeding 7 percent in either the 1958-1976 or 1959-1973 periods (the latter period presumably excludes the distorting effects of the 1973 oil price rises and the 1975-76 recession). This criterion was met by 22 industries, of which 17 were in manufacturing, 2 in transportation and communication, and 3 in services.

Of the 17 "high-growth" manufacturing industries, three were based on cheap petrochemicals (plastic and synthetic fiber products), and two based on new products whose demand was associated with postwar affluence (floor coverings and bicycles). Of the remaining 12 manufacturing sectors, five were major SCD users, and three more significant users of electronic equipment containing semiconductors. 11/ Communication and business services, also on the "high-growth" list, are major SCD purchasers. This indicates that semiconductor devices are not only a highly important growth industry, but also one with important linkages to other growth industries.

Table 3.4

High Growth[1] U.S. Industries (by sector, and size of output)

Sector (SIC)	Product Description	Constant$ Growth Rate of Output		%Jobs Growth Rates		Output (million $ 76)	Employment (1000 jobs, 1976)
		58-76	59-73	58-76	59-73		
nufacturing							
307	Plastic Products	11.5	12.4	7.4	8.5	20,480	351
2821-2	Plastics&Synthetic Rubber	9.7	9.7	1.6	2.0	20,240	100
283	Drugs	8.2	8.3	3.0	3.1	14,746	168
367	Electronic Components	7.9	8.8	3.8	4.3	11,349	372
358	Service Ind. Machinery	7.6	9.3	3.8	4.4	10,235	163
351	Engines, Turbines&generators	6.2	7.3	2.1	2.8	10,058	113
3573-4	Computers & Peripherals	9.5	9.5	5.2	5.8	9,825	248
3861	Photo Equip & Supplies	10.2	11.0	4.3	4.8	9,192	130
225	Hosiery & Knit goods	7.3	8.6	1.4	1.8	8,870	259
365	Radio & T.V. sets	8.4	9.3	1.6	2.6	7,275	129
2823-4	Synthetic Fibers	9.3	9.6	3.2	4.2	6,497	105
3661	Telephone & Telegraph App.	6.8	8.7	2.7	3.6	5,832	133
384	Medical & Dental Inst.	8.7	8.9	5.6	5.8	5,554	109
379	Other Transport Equip	12.3	16.0	11.8	14.7	5,437	123
227	Floor Coverings	9.8	11.8	3.9	4.6	3,657	60
383,385	Optical & Opthalmic Equip.	8.9	9.0	3.1	3.0	2,151	64
375	Cycles, bicycles, & parts	11.4	12.5	3.1	3.4	1,054	24
rtation							
45	Air Transportation	9.1	10.2	5.1	5.9	20,798	370
munication							
48(-438)	Communications (radio,T.V.)	7.6	7.7	2.2	2.6	48,069	1,028
rvices							
73(-731,7396), 7694 pt. 7699	Fee + Contract Business Services	7.9	8.6	6.7	7.1	63,279	2,173
806	Hospitals	7.7	7.8	5.2	5.4	43,480	2,490
0722,807,809(pt.8099)	other medical services	8.1	8.5	10.6	10.8	17,610	1,139

Notes: 1. Greater than 7%

Constant dollar annual growth rates over 58-76 or 59-73 periods.

Growth rates are estimated by regression method.

Sources: All figures based on data in U.S. Department of Labor, Bureau of Labor, Bureau of Labor Statistics, Time Series Data for Input Output Industries (Washington D.C., 1979).

Casual observation would suggest that many of these are "forward" linkages to other growth industries, with cheaper and innovative products generating new demands in new markets. Industry analysts claim that, on average, the value of the semiconductor content of electronic equipment went from .5 percent to about 4 percent between 1970 and 1979. 12/ In computer applications, that percentage has risen from about 1 1/2% to about 6% of the value of equipment in those ten years; in consumer/automotive applications, from almost zero to six percent; in industrial applications, from nil to close to 2%; and in government/military applications, from 1 1/2% to about 2 1/2%. Since SCDs were rapidly dropping in price relative to the general level of producer prices, as well as in relation to almost all specific industrial product prices, the real SCD content of all these products was rising even faster than these percentages would indicate.

Nevertheless, the most important use of semiconductors is in lowering the cost of computer and telecommunications equipment. In 1977, for example, the single most important product line was computer memory chips, which accounted for at least 17 percent of all U.S. SCD shipments, or about 28 percent of integrated circuit production; microprocessors (the processing unit of a minicomputer) accounted for another 4 percent or so of SCD output. 13/ Of the sixty percent of U.S. semiconductor output consisting of integrated circuits, in fact, some 86 percent were some form of digital logic circuit.

It is this critical link to the computer and telecommunications industries, rather than their military uses, that has led to the keen international competition that now grips the industry. Billions of dollars in public resources are invested as a matter of national policy, by wide variety of governments, in semiconductors. It is increasingly clear that semiconductor technology is at the very heart of the radical changes that microelectronics promises for the very structure of the modern industrial economy; to quote Herbert Simon, "we are now in the early stages of a revolution in processing information that shows every sign of being as fundamental as the earlier energy revolution (the Industrial Revolution)." 14/

It is this (now) widely perceived promise of rapid technological advance that explains the depth of worldwide interest in the promotion of national semiconductor industries. Before examining the nature of a variety of national policies, and how they have affected the structure of production in different countries, it is first useful to look at the economics of semiconductors and their manufacture.

4. Semiconductor Economics

Certain physical features of semiconductors, and the production processes used in their manufacture, are important determinants of the pattern of international trade and production in the industry. The most important physical feature of semiconductors is that their manufacture involves a number of physically discrete and separate production steps. In the beginning, of course, a firm must first invest in the research and development of the design for a new device, which we shall assume to be some form of integrated circuit (the sequence of production steps is generally similar, though considerably less complex technologically, for discrete SCDs like transistors and diodes). The production process itself can be broken into three distinct steps: chip fabrication, chip assembly, and testing of the finished device. 15/

A second crucial feature of semiconductors, that allows the distinct stages of production to be separated geographically, is their great value relative to their weight. Transports costs are a much smaller fraction of value than for almost any other major good traded internationally. In a sample of 155 4-digit industries taken from the 1963 U.S. Census of Manufactures, SCDs had the highest value-to-weight ratio of any industry. 16/ Richard Moxon's estimates of value-to-weight ratios for electronic industry products show SCDs, again, with the highest such ratios, 17/ based on 1967 U.S. Census data. A recent Japanese study found integrated circuits to have the highest price per kilogram of major Japanese exports: double that of computers, and over 50 times that of color T.V. sets. 18/

Value-to-weight ratios are so low, in fact, that insurance costs probably dominate the cost of transport. If freight and insurance costs per unit are examined, for example, one finds that such charges per unit shipped generally vary more from product to product, for a single country, than they do from country-to-country for a single product. Transport costs generally run from one to 2.5 percent of the value of a shipment, for a wide variety of products having vastly different unit values (see Table 4. 1).

The inference to be drawn is that insurance charges dominate transport costs, and are roughly proportional to the value of the shipment. Variation in that percentage across countries probably reflects the risks of shipping out of different ports, as well as the procedures of the companies involved in offshore production in different locations.

The economic implication of this rough proportionality between transport cost and the value of an item is important. In absolute terms, a high value item (like a complex IC) is likely to have much larger transport costs than a low value item, so that these costs are a much more significant barrier to trade for more expensive types of chips. Nevertheless, even for the most expensive items in the most remote location, transport costs rarely exceed two percent of the value of a shipment.

Very low transport costs make a widely-dispersed geographical pattern of production specialization economic. As we shall see in the next sections, the industry response has been to develop an extensive two-way trade in semiconductors, with components being shipped out of developed countries to low-wage LDCs, and returning as assembled

Freight & Insurance Costs

% Freight & Insurance/Customs Value, 1978

TSUSA:	6876031 Linear IC's	6876036 Bipolar, TTL IC's	6876043 MOS IC's	6876025 1 watt or less Transistors	6876027 1 watt + Transistors	6876066 .5 amp or ls. Diodes + Rect.	6876062 Thyristors	All SCD
(Unit Value (¢), All Countries*	33	31	118	7	20	3	38)	
Country:								
Mexico	.2	.1	0	.1	.2	0	0	-.1
El Salvador	.5	.4	-	-	-	-	-	.4
Haiti	-	-	-	-	-	.9	-	.9
Barbados	-	-	.9	-	1.3	-	-	1.0
Brazil	.4	1.4	.4	-	2.1	3.9	-	.9
Hong Kong	1.4	1.0	.8	1.2	1.3	1.6	-	1.3
Korea	1.2	1.0	1.0	1.4	1.4	-	-	1.1
Taiwan	.9	1.5	1.4	1.2	-	3.5	-	1.9
Singapore	.9	.9	.5	1.2	1.8	-	2.1	.7
Malaysia	1.3	1.4	.9	1.9	2.7	.3	1.8	1.4
Thailand	1.0	1.3	.9	-	-	-	-	1.0
Indonesia	1.5	1.0	1.0	-	-	.9	-	1.1
Philippines	2.3	1.5	1.6	2.7	2.4	-	-	1.7
All Countries	1.1	1.1	.9	1.6	1.9	1.3	1.5	

Source: Calculated from data furnished on magnetic tape by the U.S. International Trade Commission.

(* Related Party Transactions only, to control for variation in customs valuation practice. They accounted for 91% of value of SCD imports in 1978.)

devices to be marketed in the major industrial economies.

Semiconductors are also a highly research-intensive product. For every $10,000 in sales of electronic components, the industry spent $700 on research and development in 1977. Table 4.2 shows this to be well over the average of $306 per $10,000 in sales spent by all U.S. manufacturing in 1977. Interestingly enough, almost all the industries which show up as highly R&D intensive, by this definition, are also high growth industries that appear in Table 3.3.

The semiconductor industry, in fact, spends considerably more on research and development than the average for all components, in Table 4.1, would indicate. Estimates of research and development costs as a percent of SCD (and IC) sales in 1977 are about $8.50 (and $16.50) per $10,000 of sales, 19/ placing the industry near the very top of Table 4.2.

Electronic components - and particularly semiconductors - are also major employers of skilled scientific and technical manpower. Although no direct estimates are available for scientific and technical employment, by industry, one can use nonproduction employment as a proxy for skilled manpower usage. Among our "high-growth" industries, only the computer industry employed relatively greater numbers of nonproduction workers in 1976. Of the 120,000 nonproduction employees in electronic component manufacture (compared to 138,000 in the computer industry), some 43 percent work in semiconductor manufacture. 20/

The design of a new semiconductor device, like more basic types of research, makes intensive use of highly-skilled scientific manpower. The development of an advanced microprocessor chip, for example,

Table 4.2

Expenditure for R & D in Manufacturing Industry, 1977
(Net industry sales in parenthesis, Billion$)

	Total R&D /	Basic Research
	per $10,000 of sales	
Aircraft and missles (55)	1298	10
Office, computing & accounting machines (23)	1175	18
Communications equipment & communication (37)	755	39
Electronic components (11)	700	6
Drugs and medicines (19)	620	70
Optical,surgical, photographic, & other inst. (17)	620	7
Scientific & Mechanical Measuring Instruments (7)	554	15
Radio & T.V. receiving equipment & all other electrical equipment (47)	515	6
I[illegible]strial chemicals (41)	355	35
Motor vehicles and motor vehicle equipment (106)	311	1
Total (All Manufacturing) (947)	306	9
Rubber products (24)	244	4
Nonelectrical machinery (excl.office equipment) (53)	219	16
Other chemicals (31)	210	20
Fabricated metal products (32)	120	1
Stone,glass, & clay, products (24)	121	17
Non-ferrous metals and products (24)	113	4
Paper and allied products (36)	93	2
Lumber, wood products, & furniture (17)	77	4
Petroleum refining & extraction (138)	66	3
Ferrous metals and products (45)	58	1
Food & kindred products (95)	39	2
All other manufacturing industries (63)	13	8

Source: National Science Board, NSF, Science Indicators 1978 (Washington, 1979) Appendix tables 4-2 and 4-10.

requires roughly one to two years of the time of six design engineers; in 1978, there were a little over two thousand engineers in the entire U.S. with the requisite skills. 21/ The design facilities for major producers of semiconductors are generally located in areas with concentrations of trained electrical engineers or near universities producing these skills: "Silicon Valley" near Stanford University, and the clustering of design and research facilities in the northeastern Washington -Boston urban belt are prime examples of this phenomenon.

The availability of highly skilled manpower, then, is the prime determinant of the location of SCD design facilities. There are numerous examples of companies locating research facilities far from their major area of operations; most recently a new British firm (Inmos), with headquarters in England and production facilities in Wales, located its main design center in Colorado Springs, Colorado. 22/ Other major U.S. semiconductor firms have design facilities in Israel and Japan, thousands of miles from their major production locations; the attraction is the large concentration of research engineers. 23/ Naturally, small-scale pilot production facilities are often sited with research and design centers, and considerable support employment clusters around them.

Of the various stages of actual production, chip fabrication is probably the most costly and capital-intensive. Extraordinarily expensive machinery is required for the creation of the etched silicon chip containing a microcircuit; a typical production line which in 1965 required about $1 million in equipment, now requires an expenditure of $50 million or more. 24/ Very highly automated chip fabrication lines run by computers have recently been placed in production by IBM. 25/

The assembly of the silicon chip -- bonding it to its leads and packaging it -- is where the greatest technological choice exists, and where the impact of offshore production is most often felt. Since the mid-1970s, most of the major semiconductor firms have experimented with machines that automate the bonding process. 26/ The alternative is manual assembly, with workers bonding and encapsulating chips by hand under a microscope.

The predominantly manual nature of the technology used until recently by most U.S. firms in the assembly and packaging of semiconductors is apparent when compared to aggregate statistics for other industries. In 1976, SCDs were estimated to have required roughly 54 man-years of direct labor input per million dollars of output. Of all the manufacturing industries found in the 367 sector U.S. input/output tables, only lace goods, combing plants, and pottery -- all much less important industries -- had greater labor input requirements. 27/ Motor vehicles and computers, by way of contrast, required about 9 and 23 man-years of direct labor, respectively. Apparel manufacture using purchased material required about 35 man-years per million dollars of output in 1976.

Two features of manual and automated assembly processes are important determinants of their economic usefulness. First, since automated assembly involves substantial fixed expenditures on equipment and its setup, the key factor in the profitability of automated assembly is the volume of production to be undertaken. 28/ For long production runs it makes sense to carry out a large fixed investment in an automated line. Manual assembly methods, with much higher variable costs per unit assembled, have much smaller fixed costs, and therefore make much more sense for shorter production runs.

Since average product life, historically, has tended to be rather short in the semiconductor industry, due to the constant rhythm of technological advance in SCD design, automated assembly facilities have not been in widespread use through most of the history of the industry. Over half the transistors introduced during the late 1950s, for example were obsolete within two years; semiconductors used in computer systems during the mid-1970s reportedly had about the same 24 month life span. 29/ This rapid rate of obsolescence in products leads to relatively short lives for producer equipment as well; the average life of equipment in the industry is probably on the order of 3 to 5 years. 30/

The dangers of investing in highly automated production equipment were graphically illustrated to the U.S. industry by the experience of Philco, a major producer, in the late 1950s. It developed a highly automated production line for transistors, with a considerable reduction in costs, only to find its products, and its stock of technology and equipment, obsolete after only a few years, and so ended up quitting the transistor business. 31/ The relatively short lives of new semiconductor devices have historically been a healthy deterrent to automation for most U.S.-produced semiconductors. An important recent exception is that of some computer-oriented chips, whose very large market size makes automated assembly economically feasible. 32/

Length of production run, of course, is not the only determinant of optimal assembly technique. As capital becomes cheaper relative to labor, automation becomes more and more economically attractive. A thorough examination of the economics of choice of technique in semiconductor assembly is provided in the Appendix to this section.

We would then expect the use of automation to be positively correlated with the level of output, and the relative cheapness of capital. Because large firms are likely to have both large production volumes and ample amounts of cheaper internally-generated capital, we might expect larger firms to generally be more automated, and such appears to be the case in the U.S. semiconductor industry. 33/

The other major factor in the choice between manual and automated assembly is quality, which is usually measured in terms of the number of defective assemblies produced. While there is no inherent reason why a human being must produce more defects than a possibly delicate and easily misaligned machine, their detection is certainly much easier with an automated process. With a person doing manual assembly work, defects tend to be more or less randomized, while a machine tends to produce acceptable output until it produces its first defect, and after which it generally produces nothing but defects until diagnosed, and fixed. This serial correlation among defective pieces reduces the cost of detecting defects from a machine-run process. Thus, it is probably cheaper to produce with extremely low defect rates for the finished product with an automated assembly line. On the other hand, it may be more costly to produce this way, in which case the economic benefit of a low reject rate to final consumers, and how much they are willing to pay for a lower rejection rate, become the crux of the matter. 34/

The last stage of semiconductor production is testing of the finished product. Testing of a complex integrated circuit requires the use of expensive computerized test equipment, and thus tends to be a rather capital-intensive process. Simpler devices can be tested on less sophisticated equipment, but since integrated circuits have become a progressively larger part of the semiconductor market, the testing stage as a whole has probably become more capital intensive in recent years.

These four basic steps -- design, chip fabrication, assembly, and testing -- are characterized by important "learning" effects. That is, important reductions in unit cost are obtained as production experience is accumulated. The so-called "learning" or "experience" curve is estimated to lower the unit cost of producing an SCD 20 to 30 percent every time cumulated production doubles. 35/ These economies are thought to be mainly the product of improvements in yields from basic production processes, rather than learning by doing on the part of production workers. The learning economies occur mainly in the wafer fabrication and processing stages of manufacture, which are capital-intensive.

This, incidentally, means that assembly costs tend to be more important in the cost of producing a mature product, than in a recent innovation. Since process yields improve much more quickly than any other factor affecting production cost, chip fabrication costs drop relative to assembly costs as a product matures. 36/

The large fixed overhead in these fabrication processes also creates certain economies of scale, as well; the same sorts of economies of scale can exist in final testing, which requires costly testing equipment for complex devices. 37/ Manual bonding, assembly, and encapsulation operations, on the other hand, are labor intensive, and afford no significant scale or learning economies to U.S. producers. 38/ Research and development expenditure is another important source of economies of scale, as are the fixed costs of an automated assembly facility.

Assembly costs play an important role in determining the lowest cost density of components to be used in a single microcircuit. the Appendix to this section makes several important points:

1. Lowering the costs of assembly also lowers the optimal number of circuit elements packed on a single chip (chip density, or the level of integration); it becomes cheaper to spread a fixed number of functions over more chips.
2. Technological advance which lower the costs of chip fabrication and design increase the optimal density of components on a single chip.
3. Since the costs of detecting and replacing a defective chip in the manufacture of electronic equipment vary with the complexity and cost of the equipment, a differentiated market for chips of varying densities, for use in different sorts of applications, will exist.
4. Manual assembly techniques will be most economical in the manufacture of low density chips to be used in less complex electronic products, while automated techniques (which are assumed to produce lower defect rates for finished microchips) will be used more frequently in more complex and expensive products, using higher density chips.

There are noticeable international differences in the types of assembly techniques used in the manufacture of semiconductors. Japan and France, for example, are said to lead in the use of automated bonding, while U.S. firms lag. 33/ To explain these differences, as well as even more significant variations in the characteristics of different national semiconductor industries, we must first examine the national industrial and trade policies affecting the industry.

Appendix to Section 4

The Economics of Production Technique

Relative Prices

As discussed in the text, the length of production run is a major -- but not the only -- factor affecting the choice between manual and automated assembly technologies. The relative costs of labor and capital inputs will play an important role in the selection of techniques. Figure 4-1 illustrates the choice of an assembly technology by a producer. The "+"s represent the combinations of labor and capital required to produce various levels of output using automated assembly techniques, while the "."s represent the labor/capital combinations needed to assemble those same volumes of output manually. The dotted lines, labelled Io through I7 represent isoquants for different levels of output (a point on the isoquant represents the amounts of labor and capital used for a given level of output if maximum output is produced with any given combination of labor and capital). The least cost technology is that in use where the isoquant is just tangent to a line having a slope proportional to the ratio of the price of capital to the price of labor, such as the solid line in Figure 4-1.

The way the figure has been drawn, there are some fixed labor costs, as well as fixed capital costs, so that at low levels of output (such as the level corresponding toIo) manual assembly dominates automated technology, no matter what the relative prices of capital and

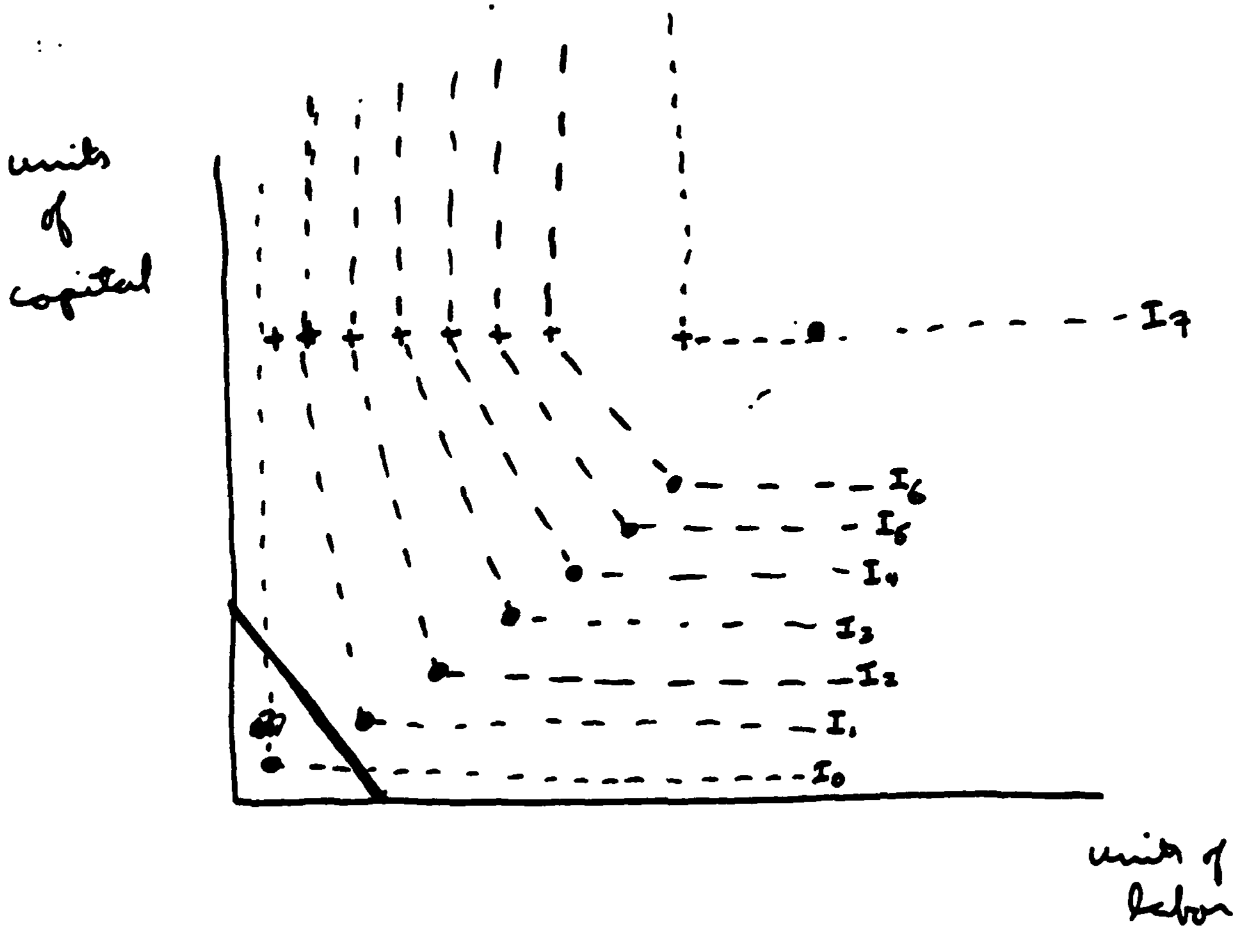


FIGURE 4-1

Optimal Choice of an Assembly Technology labor are. As production levels increase, the labor required by manual assembly increases much faster than that required by automated assembly, and the portion of the isoquant joining the two methods rotates slowly to the left. Manual assembly continues to be less costly until output level 5 is reached, at which point both methods produce at the same cost (and the entire portion of the isoquant joining them has slope exactly equal to negative the price ratio). At the output level corresponding to I6, automated assembly has become more economic. At I7, it now dominates manual assembly at any relative prices.

Figure 4-1 illustrates some stylized facts about the economics of assembly technology. At very small levels of production, manual assembly is likely to be cheapest no matter what the relative costs of labor and capital. At higher levels of output, the relative costs of inputs are the key determinant of the technique used, with the use of automated methods eventually cheapest at some large volume of production. Also, the cheaper the price of capital relative to labor, the sooner it becomes economic to switch to automated techniques.

Chip Density

Given any volume of chip production (which determines what economies of scale are enjoyed), assembly and testing costs are approximately fixed per chip, no matter how many elements are crammed into the circuit. Research and fabrication costs, to a close approximation, are basically proportional to the number of elements in the circuit. 40/ Taking into account that the probability that the circuit functions correctly declines with the number of elements on the chip, cost curves like those depicted in Figure 4-2 are appropriate for describing the technology. 41/

Curves AC_{at} and AC_{df} refer, respectively, to the average cost per circuit element of assembly and testing, and of design and fabrication. Curve ATC represents average total cost, the sum of AC_{at} and AC_{df}. Curve MCdf is the marginal cost per circuit element of research and chip fabrication, but is also total marginal cost per circuit element, since chip assembly and test costs are essentially fixed. The intersection of curve MCdf with ATC gives the point where ATC is at its minimum, where cost per electrical function is lowest. Robert Noyce has argued that competitive producers eventually tend to produce with the level of circuit integration that minimizes cost per function. 42/

A decline in the cost of assembling and testing a chip shifts AC_{at} to the left, and hence ATC as well, but leaves MCdf unchanged. Thus, a drop in assembly and testing costs moves the intersection of MC_{df} and ATC to the left, and the cost per electrical circuit element is minimized at a lower level of integration. Or, to put it more intuitively, as assembly costs per chip decline, it becomes more economic to spread a given number of circuit functions over more chips.

Similarly, as technological advances make it cheaper to manufacture densely packed chips, both MC_{df} and AC_{df} shift to the right, as does ATC and its minimum. It becomes more economic to cram more functions on a chip.

Changes in the volume of chip production will displace the AC_{at}, MCdf, and AC_{df} curves, if scale economies exist in either the design and fabrication, or assembly and testing phases of production. In general, it is impossible to predict the net effect of changes in

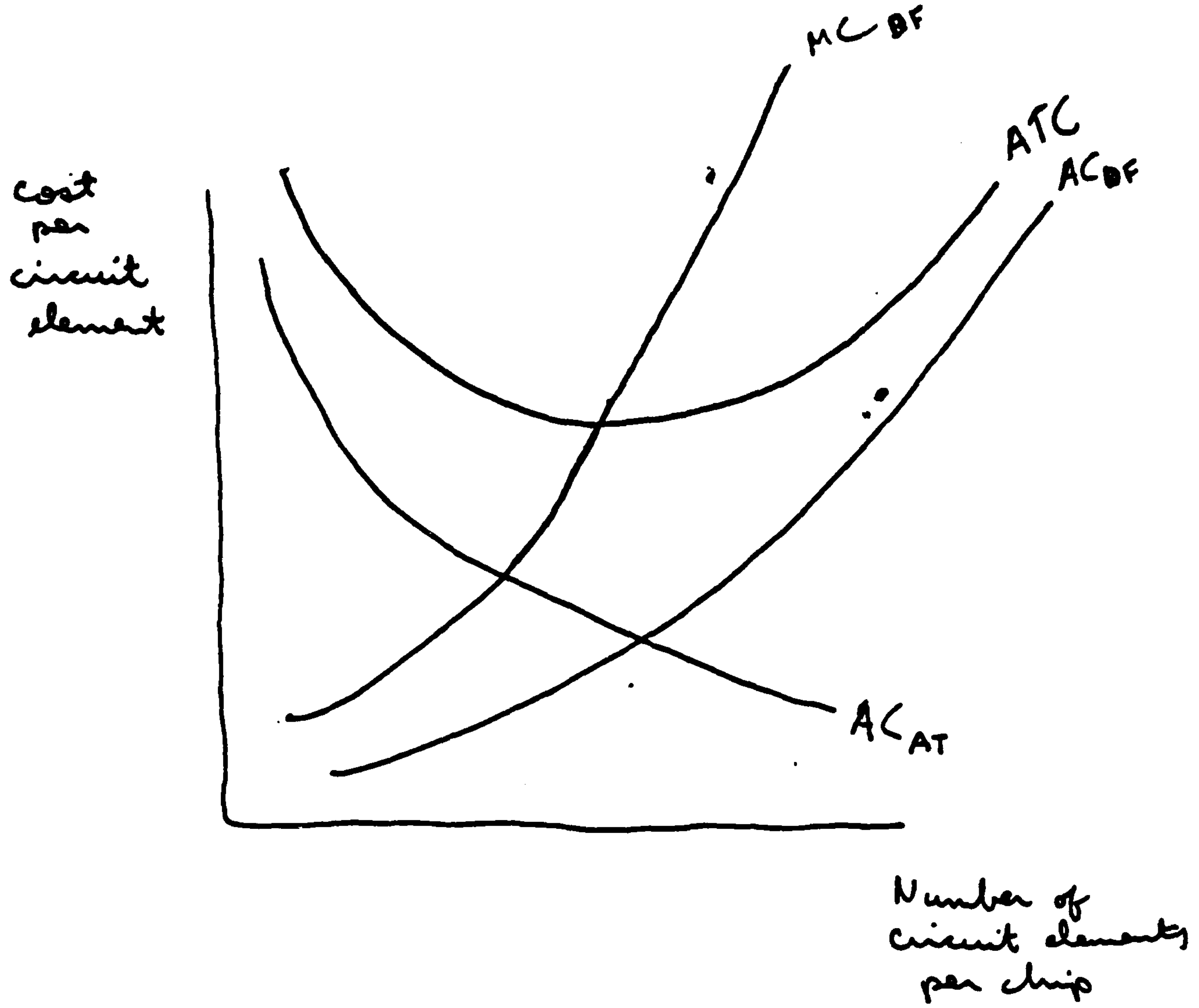

MC_BF
ATC
AC_BF
cost per circuit element
AC_AT
Number of circuit elements per chip

FIGURE 4-2

production volume on chip density.

Within this simple framework, it is also possible to analyze the relation between chip quality and the assembly process used in bonding and packaging the chip. As mentioned before, it may often be cheaper to assemble chips (with smaller production volumes) using manual techniques, but quality (in terms of rejection rates) of the finished product may be lower because of the greater difficulty in detecting substandard chips on a manual line.

When a substandard chip is incorporated into a piece of equipment by a producer who uses microchips in his product, a cost -- call it M -- is imposed, which reflects the cost of scrapping the malfunctioning equipment, or of locating and replacing the bad chip. This cost (M) is probably much higher for a chip used in a complex or expensive piece of equipment. If the probability of a bad chip (the rejection rate) is r, this "quality cost" per chip to the user of a chip will be rM, with M varying from user to user.

Figure 4-3 illustrates that the effect of this "quality cost" is economically indistinguishable from an increase in the fixed assembly and test cost per chip, and has the effect of shifting out the curve. In Figure 4-3, AC at greater than AC at (with superscripts A and M referring to automated and manual assembly methods, respectively), reflecting our assumption that at the given volume of chip production, automated methods are more expensive than manual methods. The "quality cost" of an automatically assembled chip is lower, however, because of a lower rejection rate (r), and therefore shifts out the total assembly cost much less. For "cheap" equipment (low M), however, this makes no difference in the selection of assembly

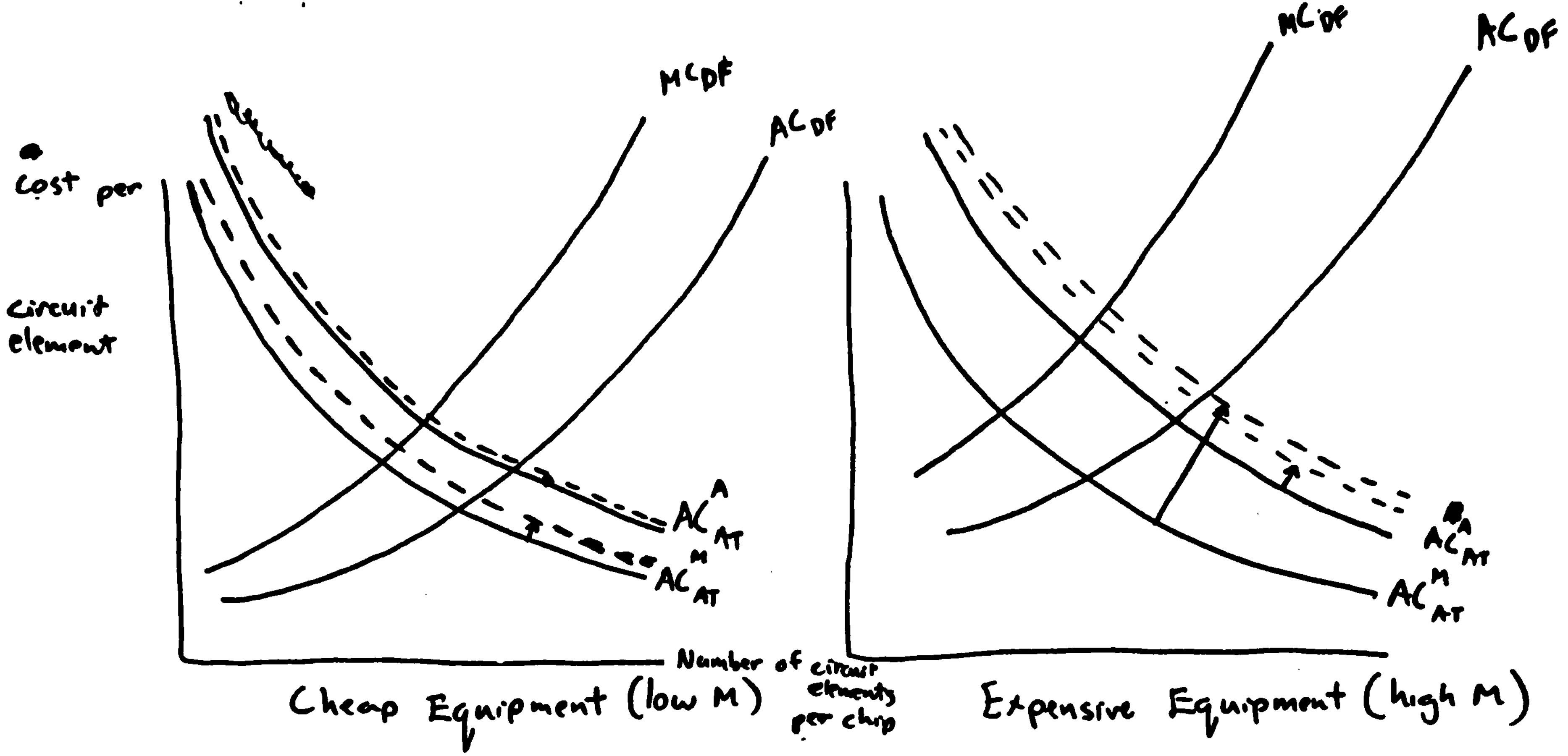

Cost per circuit element
MC_{DF}
AC_{DF}
AC^{A}_{AT}
AC^{M}_{AT}
Number of circuit elements per chip
Cheap Equipment (low M)
MC_{DF}
AC_{DF}
AC^{A}_{AT}
AC^{M}_{AT}
Expensive Equipment (high M)

FIGURE 4-3

technique (though it will increase optional chip density). With expensive equipment (high M), though the shift due to "quality cost" will be much greater so that when net costs per installed electrical function are calculated, automated assembly may end up being cheaper to a maker of complex and expensive electronic products. Note also that optimal levels of integration (density of circuit elements on a chip) rises for the more expensive equipment.

We conclude that automated assembly is more likely to be less costly than manual assembly for component installed in more complex and expensive user products, and that the optimal level of chip integration is thus likely to be higher for more expensive user products. Conversely, uncomplicated, cheaper products are more likely to use manually assembled chips with lower levels of integration on the chips.

This analysis assumes that the volume of chip production is small enough so that the average cost of assembling a chip is lower with manual bonding and packaging, and that a quality versus cost tradeoff therefore exists. If the volume of chip production is such that automated assembly is cheaper than manual assembly, no such tradeoff exists, and automated assembly will always be used.

Less complex products will still, however, be produced with the cheapest circuit elements at a lower level of chip density, while more complex products will be most economically produced with higher levels of chip density. Thus, a differentiated market for chips with different levels of integration may quite plausibly continue to exist. To put it more intuitively, a producer of comple equipment, for whom it is very difficult to locate a bad component, ought to be willing to pay more for higher levels of integration so that there are less components to check.

Mathematical Addendum to Appendix, Section 4

The Economics of Chip Density* and Quality

Let N = number of electrical functions per chip;

dN = design costs per chip, d a constant;

fN = fabrication costs per chip, f a constant;

d^N = the probability that a fabricated chip will function correctly, with d the probability that any single element functions correctly, with statistical indepence of functioning circuit elements assumed;

a = average assembly cost per fabricated chip, constant;

t = average testing cost per fabricated chip, constant.

Then total cost for a chip with N elements on it is

$$\frac{(d + f)N}{d^N} + (a + t), \text{ or}$$

$$(d + f)N e^{\beta N} + (a + t)$$

with $e^{-\beta} = d$ by definition.

Since d lies between 0 and 1, β must be greater than zero, and decrease as d increases. Marginal cost per function (of design and fabrication) is

$$MC_{DF} = (\beta + \frac{1}{N})\ (d + f)N e^{\beta N} \quad ;$$

---

* The ideas on the shape of the cost curves for electrical circuit elements are based on Robert Noyce (1977). The comparative statics are mine, as are the ideas on "quality costs" and their relation to assembly technique and [illegible]

average cost per function is given by

$$ATC = AC_{AT} + AC_{DF}$$

where $AC_{AT} = \frac{(a + t)}{N}$

$$AC_{DF} = (d + f)\, e^{\beta N} \quad ;$$

so we can rewrite

$$MC_{DF} = (1 + \beta N)\, AC_{DF} \; .$$

Minimum ATC is at the point where (since $MC_{AT} = 0$)

$$ATC = MC_{DF} \; , \text{ or}$$

$$(a + t) = \beta N^2 \; (d + f) \; e^{\beta N} \; .$$

clearly,

$$\frac{\partial N}{\partial a} = \frac{\partial N}{\partial t} = \frac{1}{AC_{DF} \; (2 \beta N + \beta^2 N^2)} > 0$$

$$\frac{\partial N}{\partial d} = \frac{\partial N}{\partial f} = \frac{-N}{(d + f)\,(2 + \beta N)} < 0$$

$$\frac{\partial N}{\partial \beta} \quad \frac{-(N^2 + \beta N^3)}{(2\beta N + \beta^2 N^2)} < 0$$

In other words, the optimal number of circuit elements per chip (N)

- increases (decreases) as assembly or test costs per chip increase (decrease)

- decreases (increases) as design or fabrication cost per element increase (decrease)
- decreases (increases) as the probability of a malfunctioning element increases (decreases).

Quality Adjustments

Suppose a user of semiconductors must detect and replace malfunctioning chips. The cost of a malfunctioning chip is M, which presumably reflects the cost of scrapping malfunctioning equipment containing the chip, or the cost of finding, detecting, and replacing the bad chip. It is reasonable to assume that the more complex and expensive the equipment containing the chips, the greater M.

The "quality cost" to a chip user of the chip used will be r with r the reject rate for chips purchased. The quality cost per electrical function is just $\frac{rM}{N}$. Differences in chip quality (rejection rates), from the viewpoint of the chip user, amount to a surcharge of rM added on to the assembly and testing cost $(a + t)$ for the chip. It will be different, for different users, however, since M varies with the type of equipment in which the chip is used.

5. The Role of National Industrial Policy

Because of the importance of SCD production as a growth industry, as a primary user of technical and scientific resources, and as a key source of technological innovations linked to many other important sectors of the economy, it has become a focus for economic policy debate in most Western economies. Certain characteristics of the industry -- especially, the significance of learning and scale economies for cost reduction, and extensive research and development programs -- have led to various proposals for rationalization of the industry, protection from international competition, public investment, and other forms of national industrial policy.

The implication of significant learning and scale economies for firm competitiveness is that the best strategy for reducing production cost is to concentrate experience and output in as few a number of firms as possible; this may, however, have negative effects on innovation if, as Tilton found, 43/ small firms are leaders in the development and diffusion of new and untried technologies. Market share will be a critical determinant of how fast production experience can be accumulated. Hence, a variation on the "infant industry" argument for protection can be made for erecting trade barriers around national markets in order to allow national firms to acquire the volume of cumulative output that will make them competitive with established foreign producers. 44/

Finally, the fixed costs of research and development present a public goods problem to producers, given that new technologies diffuse rapidly to competitors. The temporal "window" in which a producer can charge a premium over the cost of manufacture for a new device or technology, to pay back the generally large R&D costs incurred in its creation, may be brief. Government financial support for research programs, tied perhaps to centralized coordination and sharing of research among competing national firms, is a rational policy response when new technology cannot be appropriated by the firm undertaking the research. The historical record indicates that firms cannot generally prevent competitors from swiftly acquiring new techniques, and that patent and licensing barriers are an ineffective means of protecting proprietary information in this industry. 45/

In fact, it may be argued that market failures to guarantee innovators a period of rents on their new technology long enough to stimulate the socially correct amount of risky investment, but not so long as to impede further technical progress or to prevent price from eventually dropping to the (socially-efficient) marginal cost, are an important reason for state intervention. An optimal policy might compensate innovators for developing a cost-reducing innovation, then distribute it free of charge to all producers in a competitive national industry, who would charge consumers their new marginal cost of production for the product. 46/

Also, because individual firms may have limited abilities to bear risk due to the imperfections of financial institutions, government intervention may be required merely because of the great riskiness of research investment that is nevertheless socially desirable. We conclude that government intervention in the research and development phases of the semiconductor industry is readily explained, since, to quote Arrow (1962), "We expect a free enterprise economy to underinvest in invention and research (as compared with an ideal) because it is risky, because the product can be appropriated only to a limited extent, and because of increasing returns in use." 47/

The remainder of this section briefly outlines the main industrial policies that have been pursued in Western Europe, Japan, and the United States, which affect the semiconductor industry. These policies have had important effects on the international patterns of specialization in semiconductor production that will be the focus of the remainder of this paper.

Western Europe

The European Economic Community's common external tariff on semiconductors -- 17 percent -- is high enough to afford a significant protection to producers within the boundaries of the Common Market. There are, moreover, a number of additional policies in different member countries that further restrict imports: 48/ France and Britain reportedly had a system of informal administrative quotas; both the British and French used their military procurement activities to selectively favor domestic production on national security grounds; much of the EEC governments' procurement, including the purchases of state telecommunications enterprises, reportedly offers similar incentives to national producers; and EEC "Rules of Origin," limiting intra-EEC duty-free trade to electronic products with less than a five percent imported component content, effectively limit demand for foreign components.

There are also some carefully controlled ways to evade these high EEC tariffs. First, the tariff rate on silicon wafers not yet cut into chips, and other SCD parts, is only 9 percent, encouraging the establishment of assembly operations to cut, bond, test and package chips for the European market within the EEC tariff walls. In fact, of 34 U.S. -owned European SCD operations inventoried in the spring of 1974, 49/ 18 were so-called "point-of-sale" assembly operations. Fifteen U.S. operations were complete manufacturing facilities, and one an offshore assembly facility servicing third-country markets.

Semiconductors were also eligible for duty-free import into the EEC from designated LDCs under the Community's Generalized Tariff Preferences Scheme (GSP). In addition to per-country 50/ preferential trade ceilings (20% of total EEC imports as of 1978), 51/ SCDs have been subject to special quotas, and a 40 percent maximum on the value of imported inputs processed into the final product. 52/ In 1971, the entire EEC GSP quota on transistors and parts amounted to $1.3 million (compared to total EEC imports of $186 million in 1968, of which $160,000 came from potential beneficiary countries). 53/ In 1978, the entire EEC semiconductor GSP quota was set at about $9 million (7.6 million EEC units of account), or a little less than .35 percent of the estimated European consumption of semiconductors (found in Table 8.1). As has been the case with earlier EEC GSP quotas, the main effect of the quota system has probably been to favor selected national firms with tariff-created rents. 54/

Yet another method of penetrating EEC tariff barriers is to use the EECs so-called "outward processing" regulations. These regulations (various national regulations were harmonized in 1975) 55/ basically impose the EEC tariff only on the value added overseas to EEC goods exported for fabrication or processing, and later re-imported, subject to three major conditions. First, the transaction must have the prior approval of the national customs authority, by general or special authorization, and must not cause serious damage to the essential interest of EEC processors. Second, the beneficiaries of the procedure must be national or legal persons established within the EEC who have the processing carried out. Third, duty relief is set equal to the duty that would have been levied on the untransformed component export.

This last condition can have peculiar effects if the component is subject to a different tariff rate than the final product. In semiconductors, for example, since parts and unfinished wafers are subject to only a 9 percent duty (as opposed to 17 percent on the finished product), an integrated circuit assembled overseas from an EEC-produced chip gets duty relief equal only to 9 percent of the value of the chip export; i. e. a duty of 17% is paid on value added overseas, and an 8 percent duty paid on the re-imported chip. Clearly, this is not a very attractive procedure when the component export has a duty rate very much lower than the duty rate on the final product, as is the case with semiconductors. As we shall see below, while SCDs are definitely being re-imported into the EEC after processing overseas, it is unlikely that this is a major factor in EEC semiconductor imports.

Finally, in addition to protecting their national SCD industries, most EEC countries have extended significant subsidies to their industries, especially in the funding of research and development. 56/ State funding for microcircuit research and development programs by national firms reportedly has amounted to $300 million over two years in West Germany, about the same figure for France, and $300 million over 3-5 years in the United Kingdom. In 1977, French government research grants reportedly amounted to one-third of research and development spending by electronics firms. The EEC had proposed a Community-wide program that would have cost $100 million per year over the five years ending in 1962, and has been assembling more proposals for joint R&D in microelectronics. Netherlands and Italy are also reported to provide important government monies for research and development of semiconductor technology.

EEC countries, perhaps focusing on the possible competitive advantage to be had from concentrating production experience, and subsequent learning economies, in a small number of firms, have also attempted to "rationalize" their industries by encouraging mergers or concentrating their aid on a single national "champion" firm. In France, Sescosem, a subsidiary of the French industrial giant Thomson-CSF, has received a disproportionate share of government aid in the past. In Germany, Siemens receives most support, while in the Netherlands, Philips is the only national producer. SGS-ATES, in Italy, is a government-controlled enterprise responsible for 60 percent of employment in the Italian industry. The British government is funding the development of a brand new firm, Inmos, in an effort to recapture its own market.

Japan

The tariff applied to most discrete SCDs was (before the Tokyo round cuts) six percent in Japan, while ICs, light-emitting diodes, and certain other products were levied a twelve percent rate. These rates, while not as steep as those prevailing in the European common market, offered significant protection to national producers. Although Texas Instruments is the only American producer to successfully sell on the

Japanese market with a large scale manufacturing facility, other U.S. manufacturers are quite openly eager to do so. 57/

Import quotas were also used to protect the Japanese market. At the end of the Kennedy Round tariff cuts, in 1972, the very high tariffs that protected Japanese markets in the 1960s were superseded by quotas on particularly sensitive items. These included integrated circuits and computer parts, but were discontinued in the mid-1970s. 58/ As in the EEC, government procurement policies are said to favor domestic suppliers. 59/

In fact, U.S. industry sources have claimed that Japanese government procurement of advanced design computers has subsidized the production of advanced semiconductor components in much the same way that military demand funded the U.S. industry in the late 1950s and early 1960s. In the U.S., by way of contrast, the typical computer used by the Federal government is six years behind the state of the art. 60/ The Japanese government, by subsidizing the lease of computers, has also acted to increase the use of recent vintage computers in the private sector. 61/

Japan also has a GSP system, much like the EEC's system. As with the EEC's system, overall quotas limit the use of these preferences for specific products, in addition to per country limits. In 1970, the annualized ceiling on GSP imports of integrated circuits was about $2 million (roughly 3.5 percent of all Japanese I.C imports in that year), with actual GSP imports from LDCs coming to $1.3 million. 62/ By 1978, the overall quota had risen to about $62 million (about 24 percent of 1978 I.C imports), and actual GSP imports from LDCs came to $44 million. 63/ In fact, all Japanese I.C imports from LDCs came to only

$44 million (all from Asia), implying that virtually all IC imports from Asia entered under GSP. 64/ U.S. affiliates in LDCs apparently used these provisions to export to Japan duty-free in the 1970s, 65/ but there is reason to believe that this may be of diminishing importance as a major factor in U.S. -controlled exports to Japan. For one thing, Japanese customs officials apparently treat imports from U.S. offshore production affiliates as U.S. imports if more than half of the value-added originated in the U.S. 66/ Since this treatment would leave these imports ineligible for GSP, and since (as shall be seen below) offshore-produced semiconductors entering the U.S. typically have a U.S. -made content in excess of half the customs value, it is likely that many such imports are ineligible for the Japanese GSP. 67/ With the use of increasingly complex (and costly) chips in integrated circuits, the recent trend has been to even higher relative values for U.S. content.

The Japanese also have a tariff provision much like the European "outward processing" regulations. Certain designated manufactured imports, with the prior authorization of customs authorities, can be granted duty relief on their Japanese component content. Various types of SCDs and computer parts are on the list of eligible products. 68/ American manufacturers have asserted that Japanese-produced semiconductors enter Japan from offshore under these provisions. 69/

Tariffs, however, will soon be a much less important influence on production for the Japanese market. In the Tokyo Rounds, both the U.S. and Japan agreed to cut their levies on semiconductor imports to 4.2 percent, and an agreement was reached in 1981 to accelerate the reduction so that it will take effect by mid-1982. 70/

Most importantly, state industrial policy has shaped the development of the electronics industries in Japan. Many argue that a general pattern of industrial development policy can be discerned, with Japanese planners "targetting" specific industries for promotion. The general characteristics of this pattern are said to have been the selection of industries with important learning or scale economies, protection of the Japanese national market for Japanese producers until scale and learning curve effects and relatively lower wages have made them competitive producers in national and world markets, and eventual penetration of world markets with even further efficiencies gained through increasing market share. 71/ This process is thought to have occured in the auto, steel, petrochemical, aircraft, industrial machinery and electronics industries.

In the electronics industries, at least, government promotion has played an indisputable role in shaping the growth of the industry. In 1957, the Japanese government enacted a "Temporary Measure for the Promotion of the Electronics Industry," with the main objective of inducing the private sector to focus "preferentially upon the electronics industry, by encouraging national consensus that the electronics industry was the perfect industry for Japan's socioeconomic state, and therefore, was the industry that should form the core of industrial Japan." 72/ The mandate was renewed by the 1978 Special Measures Law concerning Promotion of Specialized Machine and Information Industry.

This government-established consensus was given teeth by the extensive powers of the Ministry of Finance (MOF) and Ministry of Trade and Industry (MITI) to channel capital into favored industries.

Because a large amount of personal interest income is essentially untaxed in Japan (and interest payments deductible from corporate taxes) there would be, barring the risk of costly bankruptcy, a substantial incentive to finance corporate investment exclusively by the issue of debt. 73/ Since the MOF often exercises direct administrative controls over bank portfolios, it has considerable discretion to channel bank lending into areas consistent with its priorities. Banks, in turn, are effectively guaranteed the solvency of these "guided" loans and favored firms' risk of bankruptcy substantially reduced by the tacit promise of government intervention. This reduced risk of bankruptcy (which is also aided by a growth-oriented macroeconomic stabilization policy) reinforces the relative attractiveness of debt as a vehicle of financial intermediation, and the potency of administrative guidance of bank portfolios as a tool for influencing the composition of industrial investment. 74/

In addition, perhaps, to allocating supplies of capital to the electronics industry, MOF and MITI have also increased demand for investment with a variety of subsidies to capital investment in the favored industry. Subsidy policies used by Japanese authorities that are specifically geared to the electronics industry have included special industry depreciation allowances, 75/ special funding for technology development, 76/ and government underwriting of the operations of three laboratory groups developing VLSI technology. 77/ Other more general tax policies grant special tax write-offs for investment in export promotion activities. 78/ A new generation of programs to fund R&D in the electronics industry is currently being formulated by MITI, with the focus on developing advanced computers. 79/ Officially "coordinated" loans by the Japan Development Bank to the electronics industry (said to have signalled virtual guarantees on the loans of Japanese private banks to the industry) 80/ have recently increased in importance. While historically, over the 1951-1972 period, JDB loans for the "development of technology" (two of the three categories are in the electronics and computer industries) only accounted for about 6 1/2 percent of loans made, such loans accounted for between 10 1/2 and 13 percent of new JDB lending in the years 1975-79 (about $1.8 billion in loans outstanding in 1979). 81/

Prior to 1968, purchase of foreign technology was strictly controlled by the government. Electronics technologies were on the list of desired technology used as a guide by the government. 82/ Though most controls were lifted in 1968, the government retained the authority to apply controls. 83/ The controls, by denying access to foreign consumer goods technology to Japanese producers, may well have stimulated investment in basic industrial electronics technology.

Most recently, the chosen route to the acquisition of U.S. technology by Japanese firms has been acquisition of or investment in U.S. firms. 84/ The removal of all official controls on direct foreign investment in 1971 undoubtedly facilitated this process.

Although the control of direct foreign investment in Japan was substantially liberalized in the mid-1970s, U.S. firms still complain about obstacles to entering the Japanese market with a subsidiary. 85/ In the past, certainly, Japanese policy has been protective of the market shares of Japanese firms. Texas Instruments -- aside from the recent entry of IBM, the only successful U.S. SCD manufacturing subsidiary in Japan -- was allowed to invest only after agreeing to make its integrated circuit patents available to Japanese firms, and to limit its output so that Japanese firms were guaranteed 90 percent or more of the national market. 86/

United States

As a result of the Kennedy Round tariff negotiations, tariff rates on semiconductors were more than halved from the pre-1968 rate of 12.5 percent to the 6 percent rate effective in 1972. This left the U.S., in the 1970s, with probably the lowest rates on SCDs in the industrialized West. By mid-1982, the rate will drop to 4. 2 percent (as will the Japanese tariff).

Even more importantly, legislation establishing U.S. tariff item 806.30 and 807.00 (henceforth, "806/807") was passed in 1963. 87/ This arrangement differs from the European "outward processing" procedures in that the duty relief on the value of the reimported component is granted at the tariff rate on the assembled article (and not using the rate applicable to the unassembled component); the arrangement may be used by foreign concerns as well as U.S. concerns; the types of assembly operations that can be performed -- although constantly increasing in number as the result of Customs Court decisions -- are somewhat limited; and the U.S. Customs does not have any broad authority to limit the use of the tariff item other than by setting administrative procedures and by challenging the particulars of customs declarations.

The 806/807 tariff provisions are in widespread use throughout the U.S. semiconductor industry. Fully 84 percent of U.S. semiconductor imports were brought in under tariff items 806.30 or 807.00 in 1978; that percentage was even higher -- 90 percent -- for the integrated circuits that made up the overwhelming (79%) bulk of U.S. SCD imports. 88/ In fact, SCD 806/807 imports alone account for some 15 percent of the total value of all U.S. 806/807 imports, and 34 percent of the value of the duty-free U.S. components used in all such imports. 89/

The U.S. Generalized System of Preferences, on the other hand, is not used by the industry because SCDs are not eligible. The possibility of adding it to the list has been under study, however. 90/ Since, in 1976 (the first year of the U.S. GSP), U.S. importers rapidly switched from the use of 806/807 to the use of GSP for eligible items, 91/ the historical record would suggest that great use of GSP will be made if SCDs become eligible. The country-specific limitations of the U.S. GSP -- no more than a slow-rising ceiling (a little over $30 million in 1978) on GSP trade per country, or 50 percent of all U.S. imports of a specific product -- would also suggest potential for creating greater diversification in the sourcing of SCD imports from low-wage exporters.

The U.S. has not protected its domestic market against foreign entry through restrictions on direct investment. Major foreign investments in U.S. SCD producers were a prominent feature of the U.S. industry's evolution in the late 1970s. 92/ Such purchases served not only to allow foreign firms to sell directly in the U.S. market, but also as an important conduit for the acquisition of U.S. technology by Western European and Japanese producers.

While the U.S. has no explicit government-sanctioned restrictive procurement practices, the situation is not strictly comparable to that in Western Europe and Japan. Telecommunications are under the control of state-affiliated concerns in most foreign countries, while the U.S. Bell System is a publicly-regulated monopoly. Bell's equipment manufacturing subsidiary, Western Electric, along with IBM, is among the largest SCD producers in the world; all of their output is used internally. 93/

Furthermore, because defense applications account for a significant volume of U.S. demand, procurement restrictions on the manufacture of classified items limit foreign sales in this market. Industrial security regulations of the U.S. Department of Defense also prohibit the manufacture of classified products in offshore facilities. 94/

The importance of the defense market in the U.S. also obscures the issue of whether or not public subsidies are given to the U.S. industry. Since military users are generally willing pay premium prices for new standards of reliability and performance, as well as the research and development costs of new devices with military applications, it was argued in Section 3 that the U.S. government has, in fact, funded a major portion of the development costs for U.S. technology.

In Japan, by way of contrast, military SCD procurement expenditure is virtually nil, while European military sales accounted for 14 percent of consumption in 1972. 95/ In the U.S. , even after the dramatic decline in the importance of the military market in the 1970s, military expenditure still accounted for 14 percent of SCD sales in 1979 (See Table 3.1).

Most recently, the U.S. Department of Defense has started another major research effort. The Very High Speed Integrated Circuit (VHSIC) program is budgeted at $201 million over the 5 years ending in 1984. 96/ There are, however, widely divergent opinions over the commercial potential of the research. 97/ Clearly, dollar-for-dollar, civilian market-oriented research is likely to yield a greater return than research specifically tailored to military applications. This, in fact, has been a continuing source of criticism within the U.S. SCD industry. Also, to quote Robert Noyce, "there are very few research directors anywhere in the world who are really adequate to the job. . . and they are not often career officers in the Army." 98/

Finally, the absence of public funded and disseminated research on new semiconductor technologies has led to proposals within the industry for the formation of joint research ventures, to avoid the duplication of costly basic research. Research programs financed by major firms have already been set up with the sponsorship of leading American universities. 99/

Summary

A variety of government policies have affected the structure of the semiconductor industries in the U.S. , Western Europe, and Japan. Public subsidies to research and development, whether through explicit industry grants, or disguised as military procurement and loan guarantees, have played a major role in all three markets. The significance of government grants to research and development expenditure may have had some effect on the pattern of international specialization to be described below. It is difficult to conceive of large-scale government support for research facilities located outside its national boundaries.

Government funding of research, and subsidization and promotion of capital expenditure, in explicitly commercial applications, has been particularly important in Japan. As mentioned before, the long-run goal of Japanese planners is probably to create a strong national computer industry. The low rates of return implicit in a highly subsidized investment are presumably balanced by the tecnnological externalities that an advanced electronics industry transmits to other sectors of the economy.

Barriers to trade have also been an important determinant of global product flows. The United States has certainly been the least protected market, as might, perhaps, be predicted given its past dominance of world markets. The European market is the most protected at the moment, with Japan somewhat more open (at least formally) to imports. All major markets grant various sorts of preferences to LDC imports; the U. S. 806/807 tariff items are probably by far the most important such arrangement.

Barriers to direct investment, together with trade restrictions determine whether a foreign firm chooses to export, or to invest, behind a tariff wall. Again, the U.S. has the fewest barriers to such investment. The policies of most EEC countries have probably favored direct investment in a manufacturing subsidiary, undoubtedly with the explicit intention of acquiring foreign technology. Japanese policy toward direct foreign investment-formal and informal- has probably been the most restrictive. Historically, successful U.S. investment was permitted only in exchange for a closely-held technology, and after some limits to penetration of the national market were established.

6. The Internationalization of Semiconductor Production: The United States

The political and economic constraints on semiconductor firms, outlined in the last section, have shown considerable variation from country to country. Not surprisingly, these differences have resulted in strikingly different systems for the organization of production, with firms operating from different national bases taking radically different approaches to the location of production facilities. We next outline a brief history of the internationalization of production by U.S., Japanese, and Western European producers.

Offshore assembly of semiconductors by U.S. manufacturers can be traced back to 1961, when Fairchild, one of the major U.S. producers, set up a manufacturing affiliate in Hong Kong, exporting to the U.S. market. 122/ Other companies quickly imitated Fairchild.

In many ways the circumstances of Fairchild's move offshore were a preview of events that were to repeat themselves in the late 1970's. Fairchild began its offshore operations with the manufacture of transistors, a product whose technology had become well known by the late 1950's, sparking considerable competition, and pressure on prices, from Japanese producers.

Table 6.1 shows how quickly Japanese producers mounted a formidable threat to U.S. companies. Japanese transistor production literally almost quintupled between 1957 and 1956, with two thirds

Table 6.1

U.S. and Japanese Transistor Production

	U.S.	Japan	%of Japanese transistors used in radios	%of Transistor radios exported
	(millions of units)			
1957	29	6	67	n.a
1958	47	27	67	n.a.
1959	82	87	55	77
1960	128	140	48	70
1961	191	180	41	67
1962	240	232	34	76
1963	300	268	35	81
1964	407	416	33	69
1965	608	454	30	75
1966	856	617	26	85
1967	760	766	23	83
1968	883	939	20	90

Source: For U.S., Electronic Industries Association, Electronic Market Data Book 1977 (Washington, 1977).
For Japan, Table 6-5 in Tilton (1971).

of production slated for eventual use in the ubiquitous transistor radio. 101/ The Japanese were able to mount this successful offensive because wages in the Japanese industry -- at that time -- were considerably below U.S. levels. The basic technology for transistor production was at that time being widely propagated by ATT's Bell Labs, which had a very liberal licensing policy that made no significant discrimination between American and foreign firms. 102/ The year of the big push in production (1957) coincided with the major Japanese decision to promote the electronic industries, embodied in the Special Measures law described in the last section.

Confronted with low-cost foreign competition, American producers chose two paths. One path was to invest heavily in capital equipment, and automate the production of transistors. This was the road taken by Philco, and it led to disaster, due to the rapid pace at which existing transistor types became obsolescent with continuing technological advance. 103/ The other trail, pioneered by Fairchild, was to beat the Japanese at their own game by taking the labor-intensive stages of production to Far Eastern locations where wages were even lower than in Japan. This was a successful strategy, and one that was quickly copied by other U.S. producers.

Still, the Japanese, having acquired large volumes of sales concentrated in a relatively small number of firms, were able to ride down the learning curve and maintain fierce competition in established product lines. In 1967, for example, shipments of radios by U.S. producers amounted to $362 million, compared to $201 million in U.S. imports, of which $141 million were Japanese. 104/ The lesson learned was a bitter one: a competitive advantage, once lost, is exceedingly difficult to regain. The importance of maintaining a position at the cutting edge of technology, and responding quickly to potential competitive threats, was crystal clear. Henceforth U.S. producers were to move production to low cost locations just as quickly as the development of the product and its manufacturing technology were sufficiently stable as to make the establishment of assembly lines offshore feasible.

The general pattern of investment in offshore SCD assembly facilities that developed in the subsequent twenty or so years can be seen as a series of waves of activity. As information about the costs and risks of setting up assembly operations in a particular region was accumulated, the entire industry tended to follow the successful pioneers who had experimented with operations in a specific country. 105/

The rush by semiconductor firms into offshore production quickly spread outside of Hong Kong. In 1964 and 1965, significant investments were made in Korea and Taiwan. After 1967, producers moved into Mexico; from 1968 on, important facilities were also located in Singapore. Starting in 1972, Malaysia became a key area for export production, while Indonesia, Thailand, and the Philippines became popular offshore locations in the mid to late 1970's.

The sequential nature of offshore investment in the semiconductor industry can be seen, to some extent, by looking at the years in which offshore subsidiaries were established. Tables 6.2a and 6.2b, which report the date of establishment of U.S. overseas operations present in different samples of U.S. SCD firms in 1971, and 1974, respectively, support the general chronology outlined above. 106/

Table 6.2a

Date of Establishment of Overseas Operations in LDC's, 1971

Year	Hong Kong	Taiwan	Korea	Singapore	Other S.E. Asia	Mexico	Other America
Unknown	1	1	3	2		3	2
1961	1						
1962							
1963							
1964		1	1				
1965		2	2				
1966							
1967		1					
1968				1		1	
1969				3		3	
1970		1	1	2	1	4	
1971			1	1			
Total, 1971	2	6	8	9	1	11	2

Data is for a sample of 21 U.S. SCD firms in 1971.
Source: Chang (1971), p. 19

Table [illegible]

Data of Establishment of Offshore Assembly in LDC's, 1974

Year	Hong Kong	Korea	Taiwan	Singapore	Malaysia	Other S.E. Asia	Mexico	Other Latin America
Unknown	3					1	1	1
1961								
1962								
1963	1							
1964		1						
1965		1						
1966								
1967			1				2	1
1968		1	1	2				
1969	1		1	2		1	7	1
1970	2	5		2		1	2	
1971		1		3				
1972-74	1				11	3	3	5
Total, 1974	8	9	3	9	11	6	15	8

Data is for a sample of 32 U.S. SCD firms in 1974.
Source: Finan (1975), p. 57.

The continuing search for new offshore production locations can also be documented by examining U.S. import statistics. Table 6.3 breaks down U.S. SCD imports by country of origin, from 1964 (when SCD imports first received a separate statistical classification) until 1969. While they are somewhat imprecise (country detail for small volumes of export went unreported in published statistics), they tell the same basic story. In 1964, Hong Kong was the only major LDC supplier of SCD's to the U.S. ($2 million out of a total of $8.4 million in imports). Taiwan joined it as a volume exporter in 1966, followed by Mexico and Korea in 1967, the Netherlands Antilles and Portugal in 1968, and Singapore and Malaysia in 1969.

The behavior of the import shares in Table 6.3 suggests the importance of certain economic and political factors. Both Mexico and Taiwan established export processing zones, permitting the duty free importation of materials used in manufacture for export, in 1966; 127/ sizeable exports of SCD's to the U.S. followed in 1967. Korea undertook a major liberalization of its trade policy in 1965-66, permitting the drawback of duties paid on imported inputs used in exports, setting up in-bond processing arrangements, and establishing additional export incentives; again, significant SCD export began in 1967. Hong Kong, the original low wage source of U.S. assembly semiconductor imports, was a free port, it should also be remembered.

Coincident with this sudden 1967 increase in imports from new low-wage suppliers (and sharp drops in the growth rate of exports from the developed industrial countries) was the 1966-67 U.S. economic slowdown, which greatly reduced the growth of SCD import demand. It was a premonition of the sharp reactions to the 1970 and 1974-75

Table 6.3

STRUCTURE OF U.S. IMPORTS OF SEMICONDUCTORS, 1964-1969*

	1964	1965	1966	1967	1968	1969
W. Hemisphere						
Canada	2	1 (40)	1 (61)	1 (8)	1 (117)	2 (83)
Mexico				3	21 (1226)	18 (25)
North Antilles					2	2 (24)
Europe						
U.K.		z	1 (107)	1 (8)	1 (83)	z (-21)
France	8	12 (317)	4 (-38)	2 (-50)	1 (16)	z (-7)
W.Germany			z	2 (74)	3 (166)	2 (-17)
Ireland		9	19 (267)	18 (2)	15 (38)	12 (14)
Netherlands	24	12 (40)	8 (26)	4 (-51)	3 (8)	2 (-10)
Portugal					z	2 (1247)
Italy	4	4	3	1	1	1
Asia						
Singapore						7
Malaysia						z
Korea				2	3 (119)	5 (175)
Hong Kong	24	35 (329)	43 (106)	42 (.9)	28 (12)	30 (55)
Taiwan			z	7 (646)	10 (156)	9 (26)
Japan	36	28 (82)	17 (33)	14 (-17)	10 (18)	8 (12)
Total	98	101	96	97	99	100
Value of all SCD imports (million $)	8.4	24	42	43	72	104
Nominal growth rate, SCD imports	n.a	186	75	2	67	44

---

*(as a percent of total imports; nominal growth rates beneath)

z indicates less than one percent

Calculated from U.S. Dept. of Commerce, Bureau of the Census, FT246, various years.

recessions which were to later trouble the industry. The almost static behavior of imports in 1967 suggests that a "shake-out" in the industry occurred, with low-wage LDC suppliers displacing higher cost European exports.

The almost unchanged level of exports from Hong Kong in 1967, and the precipitous drop in its share of the import market in 1968, probably are linked to the major riots and political disturbances that shook that British colony in 1967. Increasing concerns about diversifying the country-specific political risk inherent to overseas assembly operations are likely to have played a role in the establishment of subsidiaries in Singapore in 1969.

These data do not, unfortunately, distinguish imports assembled offshore from wholly foreign imports. Information on U.S. imports under the 806/807 tariff classifications, which presumably capture offshore production returning to the U.S. reasonably well, <u>108</u>/ is first available for the year 1966. Table 6.4 details the total value of U.S. SCD imports, as well as the values for imports entering under tariff items 806.30 and 807.00. Estimates of 806.30 SCD imports from LDC's are not available until 1969, but cannot have amounted to more than a couple of hundred thousand dollars before 1968. <u>109</u>/ By 1966, it is clear, offshore assembly already dominated U.S. imports (62 percent of U.S. imports entered under 807 alone). By 1969, estimates indicate that U.S. 806/807 imports accounted for over ninety percent of SCD's entering the country. <u>110</u>/

When current dollar imports are adjusted for inflation with an SCD producer price index, as is done in Table 6.4, the particular sensitivity of the SCD industry to the effect of general economic

U.S. SEMICONDUCTOR IMPORTS

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
807 imports (mil.$)	31	36	67	106	127	130	162	223	346	312	556	864	1329
806/807 imports (mil.$)	n.a.	n.a.	n.a.	126	160	178	254	413	684	617	879	1120	1478
All U.S. imports (mil.$)	50	50	86	134	168	187	329	611	953	802	1098	1352	1768
(806/807)/All (%)	62	72	78	94	95	95	77	68	72	77	80	83	84
806/807 (mil.1967$)	n.a.	n.a.	n.a.	130	167	190	277	447	688	605	909	1231	1733
Rate of increase (%) 806/807 (1967$)	n.a.	n.a.	n.a.	-	28	14	46	61	54	-12	50	36	41
SCD Price Index	n.a.	100	96.5	96.6	95.7	93.6	91.8	92.4	99.4	102.0	96.7	91.0	85.3

Figures reflect revisions to original published trade statistics.

Sources:

Trade Data	1966-69 all data from USITC (1970), Appendix tables.
1970-76	1970-76 806/807 data are USITC estimates, from USITC (1976), Appendices B,C. All imports from U.S. Dept. of Commerce, Bureau of the Census (1979b), Table 3B.
	1977-78 806/807 data from USITC (1980), Appendix B. All imports from unpublished Census Bureau tabulations.
SCD Price Index	U.S. Dept. of Labor, Bureau of Labor Statistics, producer price index for 'semiconductors and related devices'.

recession stands revealed. The growth of constant-dollar assembly (and other) imports slowed considerably in 1971, and dropped 12 percent in 1975, compared with 30 to 60 percent growth rates in the fatter years of the 1970's.

The serious impact of general economic conditions on the industry, as well as the more recent changes in production location that occurred as the U.S. industry grew through the 1970's, are clearly defined when the country sourcing of 806/807 imports is examined, as in Table 6.5. Note that data prior to 1972 do not include 806.30 imports; hence, growth rates in 1972 are overstated and some discontinuity in the distribution of offshore imports across countries occurs in 1972 because of the definitional changes in the statistics.

The sensitivity of offshore production to the U.S. business cycle can be observed in the growth of 806/807 imports after the 1970 and 1974-75 U.S. recessions. Generally, slowdowns and even reductions in 806/807 imports took place in 1971, and even more pronouncedly, in 1975.

Dramatic changes in the geographic origin of offshore imports into the U.S. also took place in the 1970's. Before 1976, some 20 to 30 percent of U.S. 806/807 imports came in from Western Hemisphere sources, mainly Mexico. From 1976 on, that figure dropped precipitously into the 10 to 15 percent range.

That smaller level of Western Hemisphere imports masks even more dramatic shifts within the hemisphere. Prior to 1976, Mexico's share of offshore SCD imports hovered around 20 percent and accounted for almost all Western Hemisphere imports. After 1976, Mexico dropped to only 5 percent, while El Salvador and Barbados each jumped to three

Table 6.5

806/807 SCD Market Shares for Major Exporters (12of market)

(Figures are percentage shares: nominal growth rates below in parentheses)
(807 only 1969-1971; 806/807 combined for 1972-1978)

	1969	1970	1971	1972*	1973	1974	1975	1976	1977	1978
W. Hemisphere (total)	25	26	30	22	20	24	20	15	12	13
Canada	2	1	2	z	1	2	z	z	z	z
		(4)	(35)	(65)	(410)	(152)	(71)	(84)	(6)	(11)
Mexico	22	26	28	21	19	20	18	11	6	5
Mexic		(42)	(8)	(47)	(46)	(78)	(12)	(13)	(24)	(8)
El Salvador	0	00	0	0	0	z	1	3	3	3
							(274)	(303)	(30)	(5)
Haiti	0	0	0	z	z	1	z	z	1	1
					(1275)	(745)	(79)	(-66)	(108)	(12)
Barbados	z	0	z	0	z	z	z	z	1	3
						(6775)	(1)	(75)	(135)	(334)
Netherlands Antilles	1	z	z	1	z	1	z	z	0	0
		(73)	(81)	(3352)	(14))	(413)	(60)	(83)		
Brazil	0	z	z	0	0	z	1	1	1	1
							(57)	(60)	(57)	(57)
W. Europe (total)	14	15	15	11	7	4	2	2	1	z
United Kingdom	z	2	6	2	0	0	0	0	z	0
		(317)	(1275)	(-99)						
Ireland	12	11	4	7	4	3	2	2	1	z
		(16)	(62)	(210)	(0)	(32)	(38)	(48)	(26)	(26)
Portugal	2	4	5	4	3	1	z	z	z	z
		(102)	(23)	(72)	(5)	(23)	(96)	(83)	(932)	(57)
Asia (total)	61	56	55	67	72	71	77	82	87	88
Hong Kong	30	25	18	17	15	12	9	9	7	6
		(1)	(28)	(83)	(49)	(32)	(33)	(36)	(0)	(12)
Korea	14	13	17	18	17	16	13	17	19	15
		(11)	(36)	(101)	(54)	(59)	(27)	(85)	(43)	(1)
Taiwan	9	5	7	7	9	9	6	6	8	5
		(-28)	(31)	(97)	(123)	(58)	(-34)	(34)	(63)	(-7)
Singapore	6	10	13	25	24	16	20	23	21	20
		(104)	(33)	(276)	(61)	(11)	(12)	(60)	(19)	(24)
Malaysia	2	z	2	z	6	16	24	21	24	30
		(91)	(61)	(37)	(22,227)	(347)	(36)	(29)	(45)	(67)
Japan	2	3	2	z	z	z	1	z	2	2
		(27)	(81)	(1)	(6)	(51)	(457)	(65)	(74)	(63)
Thailand	0	0	0	0	0	z	0	z	1	3
									(314)	(219)
Indonesia	0	z	z	0	0	z	2	2	1	1
			(432)				(22)	(66)	(2341)	(22)
Phillipines	0	0	0	0	1	2	4	6	6	8
						(229)	(134)	(109)	(23)	(89)

Key:

* Series definition changes.
2 Less than 1 percent.

Source: Calculated from data furnished on magnetic tape by USITC.

percent, and Haiti and Brazil garnered one percent of the market.

Geographical diversification also played a major role in the evolution of Asian SCD exports to the U.S. . The Asian share of U.S. 806/807 imports zoomed from a 50 to 60 percent market share in the early '70's, to an 80 to 90 percent share by 1978. While 10 to 12 percent out of that 30 or so percent increases was at the expense of Western Hemisphere exporters, another 15 percent was added as Western European offshore exports practically disappeared.

Within Asia, diversification of supply also played a major role. Hong Kong offshore exports continued to decline precipitously, while Singapore and Malaysia seemed to have greatly benefitted from the drop in Hong Kong's importance. In the mid to late 1970's, Thailand, Indonesia, and the Philippines were major beneficiaries from the increased sourcing of production in Asia.

Again, the details of Table 6.5 point to the possible importance of political and institutional changes in producers' location decisions. Political difficulties and instability gripped Mexico in 1976, the same year that a huge drop in Mexico's relative importance occured. Inference of causality is made difficult, however, because labor difficulties (strikes, work stoppages) and a peso devaluation occured in the same year, while major wage increases had been decreed the previous year.

In Haiti, 806/807 SCD exports to the U.S. began in 1972, the year after the death of dictator Francois Duvalier, an event which coincided with what has been delicately described as a shift in "the government's general disposition toward industrial expansion.". 111/ In Netherlands Antilles an outbreak of rioting occurred in 1969, followed by large drops in exports in 1970 and 1971; labor problems continued in the early 1970's, as did large fluctuations in export share. In Portugal, the military coup of April, 1974, was accompanied by a sharp drop in 806/807 exports, which continued until 1977.

Malaysian offshore SCD exports, which had really begun in 1969, did not reach significant levels until 1973, two years after the rioting which had troubled that country in 1969-70. In Taiwan, exports dropped in 1978, the year during which the U.S. made clear its intention to normalize its relations with China and break its ties to Taiwan (actually carried out in December). In Thailand, a military junta was installed in 1976, ending a period of turbulent but democratic rule; significant levels of 806/807 SCD production began the following year. In the Philippines, Marcos' martial law declaration of 1972 was followed by rapid growth in SCD exports to the United States.

The last few cases also emphasize the inherent futility of this sort of casual empiricism. Not only major political changes, but also major institutional shifts in economic policies,occurred just prior to large volumes of 806/807 exports in the Philippines, Malaysia, and Thailand. Malaysia opened the doors of its first export processing zone in 1972. Thailand simplified procedures to rebate duties and taxes on inputs used in the export production of promoted investments as of 1977, 112/ while the Philippines' Bataan export processing zone started its operations in 1973. Similarly, substantial 806/807 exports began from El Salvador after an export processing zone opened its doors in 1975. Table 6.6 which shows the spread of export processing zone arrangements among the major SCD producers, emphasizes the coincidence of these policies with increasing exports in Tables 6.3 and 6.5.

Table 6.6

Export Processing Zone Start-ups, Major SCD Producers

Country	Date Established	First Year of Operation
Ireland	1958	
Mexico		1966 (Border Industrialization Program)
El Salvador	1974	1975
Haiti	1974	1974 (industrial park)
Netherlands Antilles		Free port
Brazil	1968	1968
Hong Kong		Free port
Korea		1966[1] (export industrial estates)
Taiwan	1966	1966
Singapore	1968[2]	Free port
Malaysia	1972	1972
Philippines	1972	1973

Notes:

1. Drawback system also begun in 1965-66.
2. Jurong Town Corporation established.

Sources:

'Data Established' from Currie (1979), UNCTAD (1973).

'First Year of operation' from Froebel, Heinrichs, and Kreye (1980).

It is, in fact, impossible to attribute rises and declines in exports to specific political events and economic policy changes without controlling for the effects of other economic variables, of which the most important is the cost of labor. Important changes in the relative costs of assembly labor in different producing countries occurred during the 1969-1978 period. We defer a more sophisticated attempt to unravel the separate contributions of political events, economic policy, the international business cycle, and wage movements on the country sourcing of offshore production until after our overall view of the evolution of offshore production is complete.

For the moment, it is sufficient to observe that production shifted out of areas with increasingly higher relative wage levels (Mexico, Hong Kong), and into regions with relatively cheaper labor (El Salvador, Malaysia, Thailand, Indonesia, Philippines). Table 6.7 contains estimates of dollar-equivalent compensation to unskilled labor in the major offshore producing countries (relative to the U.S.) for 1969 through 1978.

In spite of the multiplicity of factors which may have contributed to the increasingly geographically diversified spread of SCD assembly exports to the United States, there is little doubt that political factors played an important role in this process. Semiconductor manufacturers have explicitly acknowledged the role that country-specific political risk plays in their sourcing decisions, in interviews with researchers, 113/ and in public testimony. 114/

Though it is clear that offshore production, in successive waves of investment, became a prominent feature of the operations of U.S. semiconductor firms, it is very difficult to establish the quantitative

Table 6.7

Total Hourly Compensation in the International Electronics Industry
Dollar Indices, Relative to the United States (=100)

	1969	1974	1975a	1975b	1976	1977a	1977b	1978	1979
Major Offshore SCD Producers									
United States	100	100	100	100	100	100	100	100	
Canada	77		94		100	93		85	
Mexico	21		26	28	24	20	15	21	
El Salvador		50							
Haiti									
Barbados									
Netherlands Antilles	22								
Brazil				11			10		
United Kingdom	44		50	47	44	43	48	49	
Ireland									
Portugal								26	
Hong Kong	9.6	12	11	12	12	13	17	14	
Korea	10	80	6.0	6.8	7.1	8.4	9.1	10	
Taiwan	7.9		8.2	6.7	8.1	8.9	10	10	
Singapore	8.8	11	11	12	11		10		
Malaysia		7.4		8.6-10			9.4		
Japan	40		47	49	46	51	59	65	
Thailand				5.4			7.7		
Indonesia				4.8			4.4		
Philippines		4.0		5.8			6.0		
Other LDC's									
Jamaica	13								

Notes to Table

National currencies converted to dollars at prevailing exchange rates
Sources are:

1969 - U.S. Tariff Commission (1970), p. 170. Firm-level ratios for 'office machinery; consumer electronics', and 'semiconductor' have been averaged together together.

1974 - Foreign compensation data from UNCTAD (1975), Table 10. U.S. compensation based on average hourly earnings in semiconductors from U.S. Department of Labor, Bureau of Labor Statistics (1979) and unpublished BLS estimates of supplementary compensation. (Aug. hourly earnings in U.S., 1974 = $3.82 X 1.30 = $4.97)

1975(a), 1976, 1977(a), 1978 are unpublished estimates of U.S. Dept. of Labor, Bureau of Labor Statistics Office of Productivity and Technology.

1975(b), 1977(b) are estimates for unskilled labor, total monthly compensation, made by A.D. Little, Inc. for use in comparisons of international cost of manufacture of electronic products.

importance of these arrangements. To some extent, the lack of available information is symptomatic of the deficiencies of national statistical procedures, which are ill-suited to the task of documenting production flows within an international firm. In the United States, for example, Census bureau estimates of the value of shipments by U.S. establishments include devices assembled from U.S. components overseas and entered as 806/807 imports, but exclude devices assembled, tested, and finished overseas (even if they were made from U.S. components and entered under 806/807 and eventually shipped within the U.S. by a U.S. firm. 115/

Another problem is that - since the vast majority of 806/07 transactions represent the transfer of semi-finished product between related firms (and thus has no observable market value) - offshore production is given a constructed value as it passes through U.S. customs. 116/ By statute 117/ the constructed value was defined to be the cost of materials and fabrication overseas, plus a markup for general expenses and profit equal to that usual (not actual!) in sales of merchandise of that particular kind, exported from that particular country. 118/ Essentially customs value is then defined as variable production costs, plus a markup particular to the country and product. The effect of the valuation procedure is to effectively price the article at its declared cost of manufacture overseas, plus, possibly, a markup for general expenses and profit. No imputation for U.S.-based research and development expenditure, administrative overhead, or [illegible] was generally made. 119/

Since the latter charges account for a large portion of the price of the finished SCD, the customs value of an 806/807 import significantly understates the eventual market value of devices imported under tariff items 806/07. Cost data reported by Finan in 1975, for example, show corporate overhead (excluding direct manufacturing overhead) and profit equal to about 35 percent of sales price, or 54 percent of manufacturing cost. 120/ Detailed statistics from the 1977 Census of Manufactures show that SCD producers marked up purchased devices by about two-thirds, before reselling them. 121/ A recent study of I.C. manufacturing costs concluded that market prices ranged from 2 to 3.5 times production cost. 122/ Such figures suggest that 806/807 import customs values, for SCDs, may greatly understate the market value of these devices after they are tested, shipped, and sold to final consumers. A conservative estimate, in line with the lowest values mentioned above, would mark up the value of 806/807 imports by (at the very least) 50 percent when calculating the eventual market value of offshore production. 123/ Estimates described below indicate that in 1978, for example, some 70 to 80% of U.S. SCD consumption was produced offshore, yet the value of 806/807 imports accounted for $1.5 billion out of an estimated $4.0 billion in U.S. consumption (see Table 8.1).

Nevertheless, using 806/807 import statistics, we can devise a rough index of offshore production as a fraction of all U.S. shipments (including U.S. production that is exported). The basis for our calculations is the assumption that-since the price (in the U.S. market) for a semiconductor is the same whether or not it is assembled offshore, and the cost of the materials used is also roughly the same onshore or offshore (the materials used offshore are generally shipped from the U.S.) the total value added per unit shipped will be the same for units manufactured onshore and offshore, at any given moment. Thus, if we have an index of value added offshore, and another index of value added onshore and offshore, their ratio will be proportional to the fraction of U.S.-based shipments (including finished 806/807 imports) from U.S. producers that are actually assembled offshore. The constant of proportionality will be the ratio of value added per unit assembled offshore to total value added per unit (everywhere).124/ If the ratio of offshore assembly value added to total value added per unit is roughly constant over time, movements in this index will reflect changes in the proportion of finished units moving through U.S. domestic facilities which are assembled offshore.

Such an index has been constructed in Table 6.8. It shows the proportion of the total value of U.S. -based shipments added offshore almost doubled between 1971 and the late 1970's. The recessions of 1970-71 and 1974-75 were accompanied by particularly large increases in the relative share of offshore assembly facilities in total value added.

Note that this index probably understates the true increase in the relative fraction of U.S. based shipments assembled offshore. 125/ First, with increasing chip complexity, the proportion of total value added associated with offshore production, per chip assembled offshore, has probably declined, and our index of offshore valued added relative to total global value added per chip therefore does not fully reflect the increased reliance on offshore assembly in U.S.-based shipments. Second, our index of offshore value added is the dutiable content of

Table 6.8

Offshore Value Added in Relation to Total Value Added in Domestic and Export Shipments Passing Through U.S. Facilities*, Semiconductor Industry

All value in mil. U.S.$	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1. 806/807 Dutiable value	58	69	84	125	226	373	326	477	503	592
2. Value Added in U.S. Establishments	1,061	972	1,076	1,735	2,373	2,738	2,182	2,859	3,407	4,203
3. U.S.'Industry Value Added' (1+2)	1,119	1,041	1,160	1,860	2,599	3,111	2,508	3,336	3,910	4,795
4. Offshore Value Added/'Industry Value Added' (1/3, as %)	5.18	6.63	7.24	6.72	8.70	12.0	13.0	14.3	12.9	12.3
5. Index of Offshore Value Added/ 'Industry Value Added' (1971=100)	72	92	100	93	120	166	180	198	178	170

Sources:

1. Official U.S. trade statistics, as compiled by U.S.I.T.C., various publications.
2. 1969-77, U.S. Census of Manufactures; 1978 Annual Survey of Manufactures

*I.e., SCD's shipped in the U.S. (to the domestic and foreign markets) assembled from U.S.-made chips; also referred to in the text as 'U.S.-based shipments'.

U.S. 806/807 imports, which includes some U.S-made materials and freight charges, 126/ and, therefore exceeds the actual value added offshore. As chip complexity has increased, and offshore assembly costs have risen, our measured index of offshore value added has probably dropped closer to true offshore value added. 127/ This would also lead to our index understating the increase in offshore operations. It would, therefore, seem safe to assert that the proportion of semiconductors passing through U.S. facilities that were assembled offshore probably roughly doubled between 1971 and 1978.

To assess the magnitude of these flows, then, we need some base-year estimate of the proportion of U.S. semiconductor output that was assembled offshore. First, a 1970 survey by the U.S. Tariff Commission established that most firms operating in that year started their foreign assembly operations in 1967 or 1968 (excluding, of course, the earliest pioneers) 128/ Furthermore, in 1969, all 806.30 semiconductors and 'most' 807.000 assembly imports underwent further processing in the U.S., 129/ so that figures on quantities of 806/807 imports can be used as a measure of what fraction of U.S. SCD shipments underwent offshore processing. This exercise is undertaken in Table 6.9, for the period 1969-1971.

The results show an increase in the share of U.S. semiconductor shipments processed offshore, from about 40 percent in 1969, to about 46 percent in 1971, during the depths of the 1970-71 version. If we assume that the share of offshore assembly in U.S. -based shipments increased 1.7 to 2 times between 1971 and 1978, in line with our discussion of Table 6.8, the implication is that between 78 and 92 percent of U.S. semiconductors were assembled offshore in 1978.

Table 6.9

Offshore Production in Relation to U.S. Shipments

	1969	1970	1971
All Semiconductors			
No. shipped in U.S. (Mil units)	3387	3126	2273
No. Imported under 806/807	1365	1319	1275
% Imported under 806/807	40	42	46
Of which:			
Integrated Circuits			
No. shipped in U.S.	278	292	406
No. Imported under 806/807	n.a.	241	275
% Imported under 806/807		83	68

	1969	1970	1971	1972
Transistors				
No. Shipped in U.S.	1192	1064	997	1259
No. Imported under 806/807	646	548	482	1223
% Imported under 806/807	54	52	48	97

Sources: Shipments are official U.S. Department of Commerce estimates; 806/807 imports are official trade statistics; both found in U.S.I.T.C, Transistors and Diodes (1975), Tables 2, 4, 6, 8.

Unfortunately, we cannot reasonably extend this procedure into the mid and late 1970's, because the Department of Commerce ended its practice of estimating quantities of semiconductors shipped, and because during this period, U.S. manufacturers increasingly began to test and finish their semiconductors in overseas facilities. 130/ In the latter case, the finished semiconductors imported under 806/807 are no longer counted in the value of U.S. semiconductor shipments, as defined by the U.S. Census Bureau.

We can, however, estimate what proportion of U.S. -based integrated circuit shipments, in the mid to late 1970's, were processed offshore. Table 6.10 documents these estimates, which are based on the results of a 1979 U.S.I.T.C. survey of most U.S. producers. They indicate that between 1974 and 1978, the percentage of U.S. shipments that were processed offshore increased from about 79 to 82 percent. The proportion of U.S.-shipped IC's finished offshore increased from about 45 to 54 percent over that period.

One final scrap of information suggests that between seventy and eighty percent of all U.S. -based semiconductor shipments were assembled offshore. According to a 1979 market report by the Frost and Sullivan consulting firm (and whose methodology is unknown), 71 percent of U.S. semiconductor consumption was then assembled offshore.

Finally, note that we have been talking about U.S. 806/807 imports as if they are equivalent to what we have been describing as "offshore production" by U.S. firms. Strictly speaking, they are not, since some output is sold locally or exported to other countries. However, (as is shown in section 8), about 85 percent of the output of U.S. electronic components affiliates in Asia in 1977 was exported to the U.S., and

Table 6.10
Importance of Offshore Assembly in U.S. IC Shipments
(quantities are millions of units)

	1974	1975	1976	1977	1978
1. No units assembled in U.S.	250	176	245	314	372
2. No units imported under 806/807	935	670	1,011	1,325	1,666
3. Total U.S. units assembled (1+2)	1,185	846	1,256	1,639	2,038
4. No. units finished in U.S.	648	441	611	773	944
5. Assembled and finished in U.S., as % of Total (1/3)	21	21	20	19	18
6. Assembled offshore, Finished in U.S., as % of Total ((4-1)/3)	34	31	29	28	28
7. Assembled and Finished Offshore as % of Total ((3-4)/3)	45	48	51	53	54

Sources and methodology:

(1), (4) are from U.S.I.T.C. (1979), Table A-2.

(2) was calculated by dividing value of 806/807 imports reported by U.S. firms /U.S.I.T.C. (1979), Table A-25/ by average unit value of U.S. 806/807 IC. imports for 1974-78, making the assumption that the composition and value of reported 806/807 imports in survey was identical to official trade statistics for that year Unit values used (per IC) were ($)

1974	75	76	77	78
.43	.60	.47	.48	.53

and are based on tabulation by the U.S.I.T.C. (*Integrated Circuits and their Use in Computers*, May 1979)). The relation between official trade statistics and the 1979 ITC dollar figures was

	74	75	76	77	78
official (mil $)	446	476	690	910	1,245
U.S.I.T.C. (1979) survey	402	402	475	636	883

The discrepancies probaly arise because

(1) Not all U.S. IC producers were covered by the survey
(2) Not all 806/807 imports are made by U.S. producers
(3) The fiscal year to which company figures may refer may be different from the calender year to which trade statistics refer.

roughly the same situation appears to have existed in the early 1970s. 131/

Offshore assembly, then, grew mightily in the U.S. during the late 1960's and 1970's, and now dominates production shipped in the U.S. This offers a marked contrast to production arrangements in Europe and Japan.

7. Offshore Production of Semiconductors in Western Europe and Japan

While information is much more difficult to obtain on offshore production by European and Japanese firms, it is clear that it is a much less important part of their operations than is the case for U. S. firms. Table 7.1 makes this point very clearly. As on upper bound on offshore IC imports, the fraction of IC production accounted for by imports from the Asian "offshore" countries has been calculated. Less than 5 percent of Japanese IC production, and less than 16 percent of EEC IC production, could have been accounted for by offshore imports in 1976.

Furthermore, these numbers ought to be considered upper bounds 132/ on possible offshore imports by national firms, since they may include exports from offshore Asian affiliates of U. S. firms, and even indigenous Asian producers or assemblers. In 1976, it was estimated that about $33 million in IC imports from offshore subsidiaries of U. S. SCD producers entered Japan, though these flows did not necessarily come from Asian affiliates. 133/

These bounds also do not take into account as "offshore production" the output of Japanese affiliates in place behind the U. S. and Common Market tariff walls. With the broader definition of "offshore production" including output that never reenters Japan, the following figures are available for 1977: 134/

Table 7.1

Imports and Production in the Japanese and European I.C. Markets

	Imports	Imports from Offshore Countries*	Shipments or Production	% Imports to Shipments	% Offshore Country Imports to Shipments
	(Million US $)				
Japan					
1974	179	27	439	41	6.2
1975	134	25	395	34	6.3
1976	199	45	664	30	6.7
1977	187	27	761	25	3.5
1978	255	44	1330	19	3.3
EEC**					
1974	226	41	330	68	12
1975	184	30	313	59	9.6
1976	380	90	378	101	24
1977	329	74	465	71	16

Source: Calculated from data in U.S.I.T.C., Competitive Factors Influencing World Trade in Integrated Circuits, Washington, D.C. (November, 1979), Table A56, A59, A67, A70.

* Defined as all of Asia less Japan.

** Less Luxembourg, Ireland, Denmark.

1977

	Qty. (1000)	Value (mil U.S. $)
Discrete Production	9892	1015
Discrete Offshore Production	1186	47
% Total Production	12%	5%
I.C. Production	828	774
I.C. Offshore Production	67	22
% Total Production	8%	3%

By 1980, it was estimated that some 10 percent of ICs were made in overseas plants 135/ and all indications are that this upward trend will continue as Japanese producers accelerate their move into the European and U.S. markets with local production facilities.

Relatively little of the Japanese offshore output is re-exported into Japan. This can be seen by examining figures recently compiled by the U. S. I. T. C. on the operations of the 10 largest Japanese IC producers, who in 1978 accounted for some 85 percent of IC production within Japan (See Table 7.2). According to the ITC, these large Japanese IC producers had offshore IC facilities located in Ireland, Korea, and Taiwan. All of the facilities exported output only to related parties, hence the related party imports in Table 7.2 place an upper bound on Japanese imports from offshore locations for the top 10. While the importance of such related party IC imports has grown rapidly, it is still miniscule in relation to Japanese domestic production.

The offshore IC operations of the Japanese top 10 in Korea and Ireland also sold output locally in those countries; in Korea, some of those local sales were to other affiliates of the Japanese parent firm who presumably used the purchases in equipment being assembled in Korea. The top 10 firms also had much more extensive offshore operations in discrete semiconductor devices, with only a small portion of their offshore employment in integrated circuits. Their total offshore semiconductor employment grew very rapidly from 1974 to 1978, but still remained small relative to Japanese employment. 136/

Table 7.2

I.C. Shipments by 10 Largest Japanese I.C. Producers *

	1974	1975	1976	1977	1978
Total Japanese Production of Top 10 (million U.S. $)	268	331	516	643	1135
Exports as % of Japanese Production of Top 10	1.3	4.0	5.3	12.8	18.0
Related Party Imports as % of Top 10 Japanese Production	.6	1.1	1.8	3.7	1.8
I.C. Production by Top 10 as % All Japanese Production	62	84	78	83	85

* Top 10 producers are NEC, Hitachi, Toshiba, Matsushita, Mitsubishi, Sharp, Sanyo, Sony, Fujitsu, Oki.

Source: U.S.I.T.C., (November, 1979), Tables A41, A49, A55, A58, U.S.-Japan Trade Council (December 7, 1979).

Partially because of trade friction with U. S. and European producers, and partially because of other purely economic factors (see Section 8), Japanese producers increasingly began to invest in production and assembly facilities in U. S. and European markets in 1980 and 1981. 137/ It is doubtful that much of their "offshore" production of sophisticated ICs will be coming from the less developed Asian countries typically linked to such production.

On the other hand, offshore production in Asia, by Japanese firms, of simpler ICs and discrete semiconductors, while still fairly small portions of global output, has been increasing rapidly. 138/

The apparently meager use of offshore production facilities by Japanese semiconductor firms warrants further examination. Until the early 1970s, imports were discouraged by trade barriers and foreign investments were tightly controlled, and it might therefore be argued that these historical restraints account for the small levels of offshore production by Japanese SCD producers.

As far back as 1963, Japanese investments were permitted in the production of passive electronic components (simple devices like resistors, capacitors, etc.) in Hong Kong. 139/ The stimulus to this policy was undoubtedly international competition, since by then Japanese wages had started to move above the levels prevailing in the less-developed Asian economies, and U. S. producers were beginning to assemble their most labor-intensive products in those low cost Asian locations.

Foreign investments in active components (which include, along with semiconductors, various types of electronic tubes) were not approved until 1969, in Korea and Taiwan. 140/ After the 1970-71 recession, a whole rash of approvals followed in the 1972-74 period, and a number of firms moved into Malaysia as well, to produce active components. Table 7.3 documents this movement offshore. Few of these investments involved IC production; most were oriented toward simpler discrete devices. 141/

By 1979, Japanese semiconductor producers had literally spread themselves all over Asia. Table 7.4 shows Japanese semiconductor firms in most of the same locations where U. S. firms have established offshore affiliates. It is also clear that these affiliates, in increasing numbers, were producing more sophisticated devices, including simpler types of integrated circuits. Nevertheless, as the previous discussion has made clear, Japanese offshore production -- at the end of the 1970s -- was a very much less significant (albeit, growing) part of global production than was the case for U. S. firms.

A more detailed examination of the circumstances of Japanese foreign investments in semiconductor production sheds farther light on the motivation for and growth of such operations. Table 7A.1, appended to this section, summarizes the details of such investments by members of the Japan Electrical Machinery Industry Association (JEMIA); the data, while not exhaustive is suggestive. Table 7.5 highlights some of the information found there.

It is clear, for example, that penetration of foreign markets is the major aim of such investment. Only three countries -- Korea, Taiwan, and Malaysia -- had investments reporting exports to Japan. Also, the establishment of these offshore operations accelerated in the late 1970s. Of the 24 such investments made by JEMIA members, one

Table 7.3

Japanese Direct Foreign Investment in Active Components (SCD and Tubes) by Year of Approval, as of 3/74

	No. Investments			
Year	Taiwan	Korea	Malaysia	TOTAL (per year)
1969	1	1		2
1970		1		1
1971		1		1
1972	1	3		4
1973	1	3	3	7
1974 (1st quarter)	2	1	1	4
TOTAL (per country)	5	10	4	19

Source: Yoshihara, Japanese Investment in Southeast Asia (Kyoto, 1978), Table A7.

Table 7.4

Foreign SCD Investments by Japanese Firms
1979

	No. of Cases of Investment in	
	Discrete SCD	Integrated Circuits
Country		
U.S.A.		2
Mexico	1	
Argentina	2	
Korea	4	4
Taiwan	2	1
Hong Kong		2
Thailand	1	1
Singapore	3	2
Malaysia	3	4
Other	—	1
	16	17

Source: Japan Electronic Machinery Industry Association, Internationalization and its Impact on the Electronic Industry of Japan (1980, in Japanese), p. 51.

Investments listed here correspond to those of firms answering a survey carried out by the JEMIA.

TABLE 7.5

Japanese Offshore Semiconductor Investments*

Main Reasons Cited for Investment:

Country:	# Investments in SCD Production	Dates of Investment: (# cases) 1965-70	1971-74	1975-77	1978-79	Reexport to Japan	Production for Foreign Markets a/	Labor Supply b/	Financial Incentives c/	Other Related Producers There
U.S.	2				2		2			
Mexico	1	1					1		1	
Brazil	2	2					2		1	
Korea	5	2	2	1		1	2	5	4	
Taiwan	4	1	1	1	1	2		3	2	
Hong Kong	2			1	1		1		1	
Philippines	2			1	1			2	1	
Singapore	2			1	1		2		2	2
Malaysia	4	—	3	1	—	1	1	3	4	—
TOTAL	24	6	6	6	6	4	11	13	16	2

* List is not exhaustive, refers only to investments by members of Japan Electrical Machinery Industry Association (JEMIA).

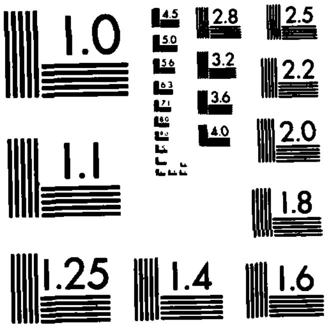
a. "increase 3rd country markets" or "increase domestic markets" or "difficult to export from Japan."

b. "stable labor supply" or "good quality labor" or "cheap labor."

c. "subsidy from host" or "easy access to domestic capital" or "cheap capital."

Source: Appendix Table 7A.1.

AD-A123 325 THE INTERNATIONALIZATION OF INDUSTRY ANNEX B OFFSHORE 2/4
PRODUCTION IN THE I..(U) DEPARTMENT OF STATE WASHINGTON
DC OFFICE OF EXTERNAL RESEARCH.. J GRUNWALD ET AL.
UNCLASSIFIED NOV 81 FAR-284-GP-ANNEX-B F/G 5/3 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

quarter were made since 1978, and half since 1975.

Patterns in the establishment of subsidiaries by country are also visible. Cheap or stable labor supplies were cited as a reason for offshore investment in the low-wage Asian countries like Korea, Taiwan, Philippines, and Malaysia. Access to export markets appears to have been more important in Hong Kong and Singapore, with nearness to user equipment industries especially important in Singapore. In 17 of the 24 investments, there was some sort of financial incentive to making the investment.

By the end of 1979, however, the production of such offshore facilities in Asia must still have been relatively small. While some of the investments shown in Table 7A.1 have no employment figures available, and thus, no complete figure on employment can be given, we can use the information to calculate some general orders of magnitude. Of 19 Asian operations, 12 reported employment. Of those 12, the 7 establishments producing only semiconductors employed about 9300 workers, while including the other establishments with a broader product mix raised employment to about 13,700. It seems safe to suppose that Japanese offshore semiconductor employment in Asia probably lay between 10,000 and 20,000 workers in 1979. Since the 10 major Japanese IC producers who accounted for the great bulk of Japanese SCD output employed roughly 33,000 workers in 1978 (See Section 8), this is significant in relation to Japanese domestic employment.

One salient feature of Japanese offshore electronic production is that it is mainly used to supply local and third country export markets, in contradistinction to U. S.-based operations. This point is made especially clear if we examine the trade statistics of Korea, Singapore, and Hong Kong. Japanese producers are using operations located in those countries to make significant exports using SCD parts produced in Japan. In those three countries, as a whole, the ratio of SCD parts imports to SCD exports ranged from about .7 to .8 (See Table 7.6). The ratio was much lower for most European countries' parts and product trade, and much higher for Japanese exports of parts and imports of product. Japan seems to have been a net exporter of parts to the European countries, via assembly operations in other Asian countries. 142/

Also, since all Asian IC imports in 1978 entered under GSP (see Section 5), and most Japanese offshore affiliates are in Asia, it is almost certainly true that the offshore production of Japanese producers entering Japan must have made significant use of Japan's generalized tariff preference scheme. Given the reasonably high tariff barriers protecting the Japanese market over this period, the existence of these preferences may have played an important role in making some offshore production economical.

In the EEC, by way of contrast, tough protective measures against SCD imports were so numerous 143/ that even the much lower wages available in Asia apparently did not spark a movement offshore. Since available GSP quotas were quite limited, such tariff relief was available to only a minor quantity of Asian imports produced by EEC and foreign nationals.

While no disaggregated statistics on EEC outward processing trade are published it can be established that the outward processing provisions were used for at least some SCD imports. In the

Table 7.6

Major Exporters of SCD Parts to Korea, Singapore, and Hong Kong 1978 (million $ U.S.)

	Parts Importers and Value of Parts Imports			Ratio of parts imports to SCD exports from:		
Country from which parts are exported	Korea	Singapore	Hong Kong	K	S	H.K.
France	11.8		1.8	.66	-	.60
Germany	.2	14.4	2.1	.20	.26	.12
Italy	-	12.2	-	-	.56	-
Japan	47.1	39.6	39.6	1.1	2.0	5.6
U.K.	.7	2.3	1.3	3.5	.19	.16
U.S.	165.7	325.2	68.8	.86	.84	.72
Netherlands	4.3	-	5.4	.52	-	.42
Korea	X	-	3.2	X	-	.64
Singapore	5.3	X	10.2	.48	X	.65
Hong Kong	7.6	3.6	X	.12	.14	X
Malaysia	.6	22.2	3.1	3	1.5	.8
Taiwan	-	-	8.7	-	-	.67
Philippines	-	1.6	1.2	-	.4	.19
Thailand	.2	.8	6.4	.4	.62	-
All Countries	245.2	424.3	155.3	.69	.75	.79

Source: Official trade statistics of Korea, Singapore, Hong Kong, 1978.

Philippines, at least, European firms are using the outward processing provisions to escape the EEC tariff in much the same way U. S. imports are entered under tariff items 806/807. 144/ As pointed out in Section 5, however, the EEC system is much less advantageous to producers than the U.S. 806/807 system.

We conclude, then, that offshore production, in the 1970s, had been a less important aspect of the global operations of European and Japanese firms than was the case for U.S.-based firms. Japanese firms, however, have been rapidly increasing the number of offshore affiliates in both industrialized and developing areas, and seem to be transferring increasing amounts of the manufacture of less complex semiconductor devices to their LDC affiliates. The Japanese operations seem to be primarily geared toward exporting to foreign markets, and the affiliates in low-wage Asian countries seem especially prone to export to Europe. By 1979, Japanese offshore employment in semiconductor production had become a reasonably important share of worldwide semiconductor employment.

APPENDIX TABLE 7A.1

List of Foreign Investments in Semiconductor Production by Members of Japan Electronic Machinery Industry Association

	Date of Invest.	Capital	Share of Capital		Employees		Output/Yr.		Type of Investment	Products	Reason for Investment
			Investor	Related Co.'s	Current	After Invest.	Latest	Original			
U.S.											
NEC	12/78	8.9mil/US$	100		286				(1)	IC	1,5
Hitachi	5/78	.1mil/US$	100	0					(6)	IC	5
MEXICO											
Toshiba	10/66	15 mil/p	49	-	215	5	75 mil/p		(3)	Discrete	5,6,9
BRAZIL											
Sanyo	4/70	112.2 mil/cr	99.98		540				(4)	Radio,TV, Hifi's, Calculators, Discrete	5,6
NEC	11/68	158 mil/cr	100		1806		1431 mil/cr		(6)	Telecom. Equipment, Discrete	1,5,6,8
KOREA											
Sanken Elec.	6/73	967.8 mil/w	100		400	100	3000 mil/w	66 mil/w	(8)	Subassemblies, Discrete	8,11,13
Sharp	9/73	100 mil/w	50	-	440	200	7800 mil/w	1400 mil/w	(2)	Calculators, Discrete	4,8,12,13
New Japan Radio	11/76		0	0					(7)	IC	9,13
Toshiba	1/70	1400 mil/w	35	0	1271	427	10100 mil/w	800 mil/w	(3)	Discrete, IC	3,9,11,13
NEC	3/70	300 mil/w	28		2424		17260 mil/w		(3)	B&W TV tubes Discrete	5,6,11,12,13

APPENDIX TABLE 7A.1

List of Foreign Investments in Semiconductor Production by Members of Japan Electronic Machinery Industry Association (con't)

	Date of Invest.	Capital	Share of Capital		Employees		Output/Yr.		Type of Investment	Products	Reason for Investment
			Investor	Related Co.'s	Current	1 Yr. After Invest.	Latest	Original			
TAIWAN											
Oki Elec.	7/79		0	0	800				(7)	IC	9
Sekiya Elec. Machinery	9/75	18 mil/NT$	19.3		225	80	48 mil/NT$	8 mil/NT$	(3)	Batteries, Discrete	3,13
Japan Inter. Rectifier	2/74	35.6mil/NT$	100		305		103.9mil/NT$		(6)	Discrete	3,8,11,13
Hitachi	5/67	9 mil/NT$	100	0					(6)	Discrete	8
HONG KONG											
New Japan Radio	6/77		0	0					(7)	IC	9
Hitachi	9/78	.8mil/HK$	70	30					(4)	IC	5
PHILIPPINES											
Oki Elec.	4/76		0	0	6000		———		(7)	IC	11,13
LMI	2/79			20	70		200 mil/pp		(3)	Discrete	9,11,12,13
SINGAPORE											
NEC	5/76	2.7 mil/S$		100	178		15.6 mil/S$	.8 mil/S$	(6)	Discrete	4,5,7,8
Matsushita	12/78	7 mil/S$		-	100				(6)	Discrete, IC	4,5,7,8

APPENDIX TABLE 7A.1

List of Foreign Investments in Semiconductor Production by Members of Japan Electronic Machinery Industry Association
(con't)

	Date of Invest.	Capital	Share of Capital		Employees		Output/Yr.		Type of Investment	Products	Reason for Investment
			Investor	Related Co.'s	Current	1 Yr. After Invest.	Latest	Original			
MALAYSIA											
New Japan Radio	8/76		0	0					(7)	Discrete, IC	9,11,13
Toshiba	3/74	9 mil/M$	100	-	850	1012	19 mil/M$	2.5 mil/M$	(6)	Resistors, Discrete, IC	3,9,11,13
NEC	7/74	6 mil/M$	100		697		.02 mil/M$		(6)	Discrete, IC	4,8,11,13
Hitachi	11/72	4 mil/M$	90	0					(3)	IC	8

Source: Internationalization and Its Impact on the Electronic Industry of Japan (1980)

Key to Codes

Type of Invest.:

(1) Takeover
(2) Foreign Direct Investment
(3) Joint Venture w/domestic co.
(4) " " w/Japanese co.
(5) " " w/other foreign co.
(6) 100% Japanese
(7) Contractor
(8) Other

Reasons for Invest.:

1. Other
2. Royalties
3. Reexport to Japan
4. Increase 3rd Country Markets
5. " domestic markets
6. Difficult to export from Japan
7. Other related producers there
8. Subsidy from host.
9. Easy access to domestic capital
10. Cheap capital
11. Stable labor supply
12. Good quality labor
13. Cheap labor
14. Good supply of materials
15. Good quality of materials
16. Cheap materials

8. International Competition and Offshore Production

Having established in the last two sections that Japanese and European producers (who ship perhaps 10 to 15 percent of their output from foreign locations) have organized their production flows in a very different manner from firms located inside the U.S. (perhaps 70 to 80 percent of their semiconductors are assembled offshore before returning to the U.S. for finishing or distribution), we turn to the task of explaining these differences. This will not be a simple task for the most interesting case--Japan-- since, as will be argued below, the choices made in organizing product flows are the outcome of a complex constellation of economic, political, strategic, historical, and structural factors.

European choices (including those of U.S.-owned SCD producers in the European market who have historically dominated Western European markets through the operations of their European affiliates) 145/ are, on the other hand, simple to explain. The very high levels of tariff protection make it uneconomical to import, except for the very simplest sorts of devices whose costs are mainly attributable to labor-intensive assembly and packaging operations. For such highly labor-intensive devices, the huge differential in labor cost between the Far East and Europe can even offset the very high tariff charges. For more complex devices, where the chip and other materials are a significantly larger portion of the cost of the finished device, even the use of the "outward-processing" tariff provisions (when permitted by the authorities) offers little relief, since the net effect of these provisions is to still impose a 9 percent tax on the material content of the chip upon reimportation.

The objective of this policy was probably to force foreign manufacturers to set up operations in Europe, as a means of encouraging joint ventures with European partners, the transfer of technology, and the creation of a strong indigenous European industry. The high tariff walls have been most effective in getting foreign-based manufacturers to set up affiliates in Europe. 146/ They have not been very effective in making European firms internationally competitive, and, perhaps belatedly, European governments are turning increasingly to subsidy policies as a means of increasing the competitiveness and technological competence of national producers.

The situation is quite different in Japan. The technological sophistication of Japanese firms has advanced at a steady and rapid rate, after a strategic national decision was made in the late 1950s that electronics technology was critical to the future economic growth of Japan. The advance of Japan can be seen in the rapidly increasing share of world semiconductor production that is reflected in Japanese damand (see Table 8.1). The Japanese share of world consumption has risen especially fast during periods of economic recession where a national policy of encouraging steady and stable growth in SCD producton have insulated Japanese producers, to some extent, from the business cycle fluctuations which are, normally, especially pronounced in the electronics business.

The success of Japan in arriving at the cutting edge of technology can also be seen in the rapid increase in the portion of Japanese output made up of technologically sophisticated integrated circuits. As Table 8.2 shows Japanese SCD shipments are swiftly approaching U.S. shipments in their composition, in terms of the importance of ICs.

Table 8.1 Estimates of SCD Consumption in Major Markets

	Share of Total Market of			Total
Year*	U.S.	Western Europe	Japan	(Billion $)
1956	87	8	5	.09
1960	80	12	8	.69
1965	76	14	10	1.40
1972	57	18	25	3.00

Source: Finan (1975), Table 6-1.

* Includes only Britain, France, West Germany in Western Europe.

1970	49	25	26	2.55
1972	48	22	30	3.15
1974	48	27	24	4.85
1976	46	25	29	6.34
1978	45	29	27	8.80
1980	45	25	30	14.10

Source: Electronics, various issues: 1970: 1/3/'72, 11/22/71, 12/21/70;
1972: 1/10/74, 11/22,73, 12/18/72;
1974: 1/8/76;
1976: 1/5/78;
1978: 1/3/80;
1980: 1/13/81

This should not obscure the fact that the Japanese industry continues to focus its efforts on staying up with technological developments in the U.S. The last major technological push by the Japanese and the government-funded VLSI labs, 147/ was intended to match technology already on the drawing boards at U.S. research labs. The next set of major semiconductor projects that will be supported by government-funded programs--a push to increase the speed of Japanese circuits-- 148/ will attack problems under study for years at [illegible] and Bell research labs, and funded elsewhere by the U.S. Defense Department's VHSIC program since 1979. 149/ The extensive research labs funded and run by the state-owned telecommunications company, Nippon Telephone and Telegraph, are modelled after the U.S.'s Bell labs which play a similar role in researching basic technology and providing it to private firms. 150/

In short, Japanese technological development efforts have been concentrated on catching up to the U.S. Unfortunately, in the semiconductor business, playing catch-up is not a successful business strategy (unless you have some sort of cost advantage) because of the importance of learning economies, the effects of cumulative production in reducing unit costs over time. To succeed in becoming internationally competitive, the Japanese industry needed to innovate, to ride down the learning curve on some innovation of its own.

In the early 1970s, then, the Japanese faced three fundamental problems in their semiconductor industry. As just remarked, innovations seem to be required to stay competitive, and greater resources therefore had to be channeled into research and development. Second, reliability problems were being experienced in the more sophisticated products manufactured, and quality improvements needed. Thirdly, the rising cost of labor in Japan was eroding Japanese competitiveness. 151/ Because, at the time, significant barriers to offshore semiconductor imports still existed, that strategic option could not be exercised by Japanese producers, even if institutional and political constraints would have permitted it.

The Japanese response to these difficulties attacked all three trouble spots. The subsidy and capital allocation policies described earlier were put into place, and channeled large sums into semiconductor R&D. The particular areas of research selected also attacked the quality problem directly, and the labor cost problem indirectly, by focusing on production technology using highly automated equipment.

The innovation selected for development by the Japanese -- and, in fact, an innovation which had worked successfully in other electronic products Japan came to dominate -- was quality. As was argued before, high levels of product quality require uniformity in production, and that meant the replacement of manual assembly and packaging techniques with automated procedures. It was also an innovation that relied on particularly Japanese industrial strengths, the development and improvement of manufacturing process technology (as opposed to research on basic technical principles), and an improvement whose time had come for economic reasons to be discussed below.

Automation, to be economic, generally requires large volumes of output. It was no coincidence that the particular product which Japanese firms began to aggressively export in the late 1970s, and in which they created a reputation for outstanding quality, was computer

Table 8.2 Relative Importance of ICs in Semiconductor Shipments

Year	Percentage of SCD Shipments Made Up of ICs (Measured by Value)	
	U.S.	Japan
1965	11	...
1970	38	22
1974	57	36
1975	57	43
1976	61	43
1977	60	44
1978	63*	53

Sources: Japan: Japan Statistical Yearbook, 1980

U.S.: 1967-1977, Census of Manufactures;

1978, Current Industrial Report, Selected Electronic and Associated Products... 1978; and Annual Survey of Manufactures, 1978;

1965, Electronic Industries Association, Electronic Market Data Book 1977

* Estimate, based on assumption that shipments of devices not separately classified have same distribution as classified devices.

memory chips. Memory chips are the largest volume product line in the semiconductor industry, have the highest growth rate, and promise to continue their leading role because of their central importance in the manufacture of computers. Computers, in addition to being an extraordinarily fast-growing product in demand, are also the technological focus of Japanese policies to promote the electronic industry.

The key role that computer chips have played in the expansion of Japanese semiconductor output in the late 1970s is quite striking. Table 8.3 shows the increased role of ICs in Japanese shipments and exports, and to some extent, the growing role of computer chips (the principle application of digital MOS chips is in computer logic). It does not capture the central role that computer chips played in export increases in 1979 and 1980, when Japanese chips first captured a significant share of the U.S. and European memory chip markets. Currently the largest Japanese firm, Nippon Electric, is the largest producer internationally in the important market for dynamic random access memory (RAM) chips, holding almost 50 percent of the global market. 152/

It shall be argued that there are at least seven possible historical and structural reasons why quality innovations were introduced by the Japanese, and not, say, by their U.S. competitors in semiconductors. 153/ The first was a matter of past experience. When Japanese firms pushed their way into the international transistor, and transistor radio market in the late 1950s and early 1960s (and it should be remembered that this probably stimulated the first offshore movements in the U.S. semiconductor industry), the Japanese had quality

Table 8.3 Recent Role of ICs in Expansion of Japanese SCD Industry.

	1974	1975	1976	1977	1978
	(All figures are percentages)				
1. (Japanese SCD Shipments) / (U.S. SCD Shipments)	33	31	36	39	39
2. (IC Shipments) / (All SCD Shipments), Japan	36	43	43	44	53
3. (Digital MOS Shipments) / (All SCD Shipments), Japan	14	20	19	18	25
4. (IC Exports*) / (All IC Shipments), Japan	5.3	11	12	15	19
5. (IC Exports*) / (All SCD Exports), Japan	17	32	32	38	52

Sources: 1. U.S. Census of Manufactures, Annual Survey of Manufactures; U.S.-Japan Trade Council, Council Report No. 41; U.S. Japan Competiton in Semi-Conductors: Part I (December 7, 1979).

2.-5. U.S.-Japan Trade Council, op cit.

problems that hindered their expansion. Removing the stigma from the "Made in Japan" label was made a matter of priority, and a deliberate and well-studied program of quality improvements carried out for electronic and other products. A considerable body of experience and expertise in quality control was accumulated. The success of this program is obvious today, and American electronics firms frankly acknowledge their imitation of Japanese techniques. 154/

Secondly, the history of semiconductor demand in the two markets also played a role. As was shown earlier, military demand for semiconductors played the central role in the development of the U.S. industry in the 1950s and early 1960s. Military users have very special requirements for quality and reliability; 155/ every device must work properly everytime. Commercial users, on the other hand, face a tradeoff between cost and quality, and can select the profit-maximizing combination. Every part supplied to military specifications was required to be inspected, tested, and "burned in" by equipment manufacturers. These "brute force" methods of quality control, required by the military, became standard in the American electronics industry. The Japanese producers, on the other hand, who were completely dependent on the commercial electronics market, were free to adopt entirely statistical approaches to quality control, which concentrated on improving processes of manufacture to the point where the defect rate was low enough to eliminate the need for costly and time-consuming testing and "burn in" procedures. 156/

Third, the changing nature of semiconductor technology made the Japanese approach to quality control-- reducing the manufacturing defect rate so that testing by the user was unnecessary -- much more attractive. With highly complex VLSI chips, very expensive computerized test equipment is required. While this fixed cost may be a necessary cost to a producer of chips, it becomes increasingly burdensome to users. With simple components requiring simple testing procedures, an equipment manufacturer could (with a relatively small investment) guarantee the quality of the parts used in his equipment; with the fixed costs of testing complex chips, however, it is much more cost-effective to have testing done by a centralized facility operated by the manufacturer, or better yet, to improve manufacturing processes so that testing is unnecessary. The increasingly costly test equipment required by complex VLSI integrated circuits is likely to have made this latter Japanese approach, eliminating the need for costly testing, more and more economically advantageous.

The attractiveness to equipment manufacturers of high quality parts is central to the fourth reason why quality improvements were a particularly Japanese innovation in semiconductors. In the U.S., many major semiconductor manufacturers (and there were over 108 firms manufacturing ICs alone in 1977) 157/ only produce semiconductors. In Japan, integrated circuit manufacture is carried out by perhaps 18 firms, 158/ with all of the major producers integrated into much larger electronic equipment producing firms. 159/ There was, therefore, probably a much greater tendency among the Japanese firms to tailor their products to the cost economics of complex equipment manufacture than existed in the United States.

Finally, an investment in quality control may partly be an investment in very "lumpy" and highly-specialized automated machinery, and partly a fixed investment in information and technology, in optimizing designs and studying and perfecting manufacturing processes. It may well be that the Japanese government's willingness to actively subsidize research and development in these areas corrects for the well known potential of a laissez-faire market economy to underinvest in these activities.

The apparent relationship between uniform and high-quality output and the use of very expensive automated machinery (which may also require customized design) provides a sixth reason why the Japanese may have been willing to make these heavy investments in automated manufacture. As was argued earlier, a large portion of the capital supply in Japan is rationed through the use of a sophisticated guidance machinery coordinated by various government agencies. There is a strong case to be made that government policies aimed at funneling capital into the Japanese semiconductor industry have had a significant effect, lowering the cost of such capital flows, and making (as was pointed out in our earlier discussion of semiconductor economics) more capital-intensive techniques much more attractive. 160/

Finally, there is much more to quality control than the mere functioning of hardware (much of the production equipment used by Japanese firms is actually purchased from U.S. producers, 161/ except in assembly, where the equipment is overwhelmingly of Japanese origin). 162/ Japanese quality control methods particularly stress cooperation between production workers, managers, and engineers; so-called "quality circles" in which workers and supervisors discuss their work, are an important part of the formula. 163/ Japan's unique system of labor relations, in which workers' and managers' relationships are more cooperative and less adversarial than in the

U.S. and Europe, with workers expected to show loyalty to the company in exchange for job security, probably was essential to the development of this participatory aspect of its quality control methods. [164]

Japanese-type quality innovations, it should be stressed, have limitations. There is a tradeoff between quality and cost from the point of view of an equipment manufacturer, with the parameters of that tradeoff sensitive to the complexity and cost of the equipment in which the semiconductor is to be installed and the difficulty and cost of testing the component. There is little reason, for example, to insist that defects in shipments of calculators chips to be installed in $7-dollar calculators be dropped from 1000 to 100-200 parts per million, when the cost of the equipment and processes necessary to achieve those levels might double the price of a one dollar chip; the $5,600 in defective calculators saved on a production run of a million would be lost in the million dollar cost of the improvement.

The increasing sophistication of the applications in which semiconductors were used, and especially the increasingly large share of the market going to computer chip applications, are the root cause for the recent stress on quality by semiconductor consumers (repeating the arithmetic exercise above with a half-million dollar minicomputer substituted for the cheap calculator makes clear why manufacturers of sophisticated equipment should even be willing to pay more for a higher quality chip). Japanese semiconductor merchants should get full credit for grasping the economic significance of quality, and investing in their quality-related innovations. [165]

Our reasoning, thus far, suggests only that Japanese producers had good economic reasons, the historical experience, and an industrial structure that supported their move into the high volume computer chip market, with their perfection of high quality processes of manufacture being their principle marketing tool and competitive advantage. Other reasons must be found for the location of these facilities, for the most part, in the developed countries, since offshore labor costs are still one-sixth to one-eighth their level in Japan (see Table 6.7). All other things equal, it still would have been cheaper to produce offshore. Furthermore, since the Japanese tax system exempts foreign investments in many developing countries with tax treaties with Japan from the payment of Japanese income taxes, it would also seem that the return to capital investment using funds raised in Japan might also be greater offshore (since most "offshore" countries tax export-oriented investments at low rates, or offer tax holidays). 166/

One explanation for the paucity of Japanese offshore semiconductor investment is that all other things were not equal. Certainly the industrial infrastructure offshore cannot have been as developed as in Japan, and capital intensive techniques may require expenditures on skilled technicians to supervise and maintain production equipment that are significantly more expensive offshore. This is not a very convincing explanation, however, because these factors did not seem to prevent American producers from setting up very sophisticated testing and packaging operations in these offshore locations. Also, the Japanese electronic component industry has not been particularly reluctant to go offshore. In 1979, for example, foreign employment by the Japanese industry was about 90,000 workers, of which 89,000 were in the so-called "offshore" Asian countries. 167/ Foreign affiliates of U.S. firms manufacturing electronic components in the less developed areas of Asia and the Pacific have roughly similar levels of employment, amounting to some 101,000 workers in 1977. 168/

The fact that Japanese firms have set up very significant offshore operations in developing areas, in electronic components, also casts doubt on another possible explanation, that Japanese investors are considerably more averse to the political risks of offshore production than U.S. investors. 169/ On the other hand, it may well be that the much greater capital intensity of automated bonding and packaging processes would require a very much larger stock of capital invested in a portfolio of production locations, and that firms are reluctant to shift the much larger fraction of their capital to riskier locations that would be required if high quality automated methods were to be put in place offshore. As shall be noted below, analysts of the U.S. semiconductor industry predict that a moderate amount of U.S. production will shift back to the U.S. industry as U.S. producers shift into increasingly capital-intensive technology.

Another purely economic factor that may explain Japanese reluctance to source their production offshore is that -- because freight and insurance costs are roughly proportional to value for semiconductors -- freight and insurance costs will be a much greater barrier to trade for the complex computer chips that Japanese producers are exporting most aggressively. In absolute terms, then, the greater the value of the chip, the greater the transport costs on the round-trip between offshore location and market. With automated assembly, labor input per chip is reduced and hence the absolute magnitude of the cost savings on a circuit assembled offshore. The net result is that offshore assembly may no longer reduce overall costs for complex chips with high transport costs and reduced labor content due to automation in the assembly process. Also, Japanese-made chips would face a significant duty cost upon entry into the U.S. In fact, precisely this explanation is given by Japanese firms when explaining why their IC production for the U.S. market is increasingly being assembled and packaged in the U.S. 170/

The corollary to this point is that *less* complex semiconductor devices will be produced offshore by Japanese producers, even when assembly is automated. In the last section it was shown that Japanese use of offshore assembly facilities does seem more geared toward producing simpler discrete devices. As Table 8.4 shows, the responses of a sample of Japanese semiconductor producers, quieried about their plans for expansion of offshore facilities, supported this hypothesis. Of 12 planned future manufacturing operations in Asia, only one was to supply the more sophisticated MOS IC types (which includes less complex chips, as well as highly integrated computer chips), four were slated to produce simpler linear ICs, and seven scheduled to produce simple discrete devices.

Finally, three institutional and political factors may affect Japanese sourcing decisions. First, Japanese producers are clearly sensitive to the political pressure for protection that their increasing U.S. market share will be generating within the industries, 171/ and their decisions to produce for the U.S. market with U.S.-based plants undoubtedly takes these pressures into account. The recent experience of Japanese auto and television exporters with

Table 8.4 Plans for Future Foreign Operations in SCD Production

(Number of responses by Japanese firms.)

	North America		Asia	
Product	N	E	N	E
Transistor/diode			1	5
Power transistor				1
Linear IC				4
Bipolar IC	1			
MOS IC	1			1

N: Establish new production site

E: Expand existing facility

Source: Japan Electrical Machinery Industry Association (1980, in Japanese), p. 227.

U.S.-trade restrictions have made clear that setting up U.S.-based operations will deflect such protectionist pressures. 172/

Second, the distinctly Japanese system of labor relations (in large Japanese companies -- these considerations are not so important in smaller firms) adds another dimension to production decisions. Because workers are basically assured job tenure (in return for loyalty to the firm and very few strikes or labor problems) the permanent labor force is effectively a fixed factor of production. Maximizing the profitability of investment as demand grows, in this context would imply shifting production overseas of those items with the greatest labor/capital ratios, subject to the constraint that domestic employment be maintained.

This appears to be the strategy of Japanese electronic firms. The bulk of Japanese producers' offshore employment tends to be in more labor-intensive discrete devices. 173/ And as Table 8.5 makes clear, employment in semiconductor manufacture in the ten top Japanese SCD producers has been roughly constant over most of the 1970s, but with a greater and greater portion of the labor force shifted into production of integrated circuits. A recent report by the Japan Electrical Machinery Industry Association explicitly states that in order to maintain domestic employment, Japanese electronics producers will have to shift into products with greater value added in their home plants, and transfer items with low levels of value added to their offshore production base, a process that will need to be "coordinated carefully by each Japanese manufacturer." In short, maximizing returns while maintaining employment levels appears to be the objective of Japanese firms, an objective that necessarily dictates the wholesale transfer of

Table 8.5 Domestic Employment in the Japanese IC Industry

(Data refer to 10 largest IC producers)*

	1974	1975	1976	1977	1978
Persons employed in producing semiconductors (in thousands):	34	32	33	33	33
Employment in ICs as % of employment in semiconductors:	47	52	54	56	61
Employment in semiconductors as % of employment in all establishments of firms:	10	10	11	11	11

Source: U.S. ITC (Nobember, 1979), Table A60.

*NEC, Hitachi, Toshiba, Matsushita, Mitsubishi, Sharp, Sanyo, Sony, Fujzitsu, Oki.

production of much more labor intensive items offshore before large amounts of production of the more complex types of semiconductors leave Japan.

Thirdly, because Japanese semiconductor firms have benefitted from implicit or explicit government subsidies to investment, it seems unlikely that they could make use of these funds without paying attention to national priorities. It can be argued that part of the implicit social contract in Japanese industry, to which firms, workers, and government are parties, is that in exchange for labor's peace and cooperation, and government assistance, producers are committed to maintaining, wherever possible, Japanese employment.

To conclude this interpretation of Japanese use of offshore production facilities in the semiconductor industry, it may be useful to review our arguments. The puzzle we have attempted to explain is why Japanese producers have not made extensive use of the offshore production stragegy used by profit-maximizing U.S. producers. Our starting point was to note that the recent penetration of global semiconductor markets by Japanese producers was associated with important quality innovations that some U.S. firms are still in the process of adopting. The economic application of these innovations, which involves the use of automated assembly techniques, requires large production runs, and therefore is limited to high volume production items, which include the large and fast-growing computer chip market. A whole list of factors made the adoption of these techniques attractive to Japanese firms.

The reasons why automated techniques used by the Japanese for the high volume computer chip market are not being installed in offshore facilities are both economic and institutional. From a strictly economic point of view, labor content is a smaller and smaller portion of cost for more complex types of semiconductors, and the absolute cost savings realized from producing in low wage areas less and less important. Since transport and duty costs are roughly proportional to cost, on the other hand, the absolute magnitude of these costs has risen considerably for complex devices. For advanced devices imported into the U.S. or Japanese markets, in fact, the net impact on cost of producing offshore has become quite marginal, or even negative. Greater political risks that would necessarily be faced with heavy investment in offshore facilities may tip the final market balance even further toward producing within or exporting from Japan.

Coupled to these economic considerations are some distinctive institutional features of the Japanese economy which discourage offshore investment. Protectionist pressure that is generated by U.S. semiconductor firms points to production within the U.S. market as a strategy for avoiding import restrictions. The Japanese employment system requires that Japanese firms maintain domestic employment levels, and more labor-intensive products have mainly been those transferred to offshore production locations, to date. Finally, the great degree to which the Japanese semiconductor industry has been the recipient of government assistance argues for strict respect by SCD producers of the commitment to full employment that is an essential part of the social compact among labor, industry and government in Japan.

This is not to say that offshore production will not become an important feature of the Japanese semiconductor industry. As we have seen in this section and the last, Japanese semiconductor operations in the low cost offshore areas of Asia, while still small, have been growing rapidly. We would expect to see Japanese production of the simplest, most labor-intensive types of devices to be located, increasingly, in the low cost Asian countries, while the more expensive complex devices are produced in the market that is their final destination.

We turn next to a brief consideration of whether the offshore operations of U.S firms which account for most offshore activity in the global semiconductor industry, will fall into a similar pattern.

9. The Economics of Offshore Production

As the discussion of the previous sections has indicated, the decision to produce offshore is a fairly complex one. Recent changes in the technology of the integrated circuit, and its manufacture, and in the institutional environment which interposes certain barriers (especially tariffs) to trade, make it worthwhile to consider the economics of offshore assembly. For the moment, we shall ignore the riskiness of investment in some of the less stable low-wage areas, and consider only the various certain costs of investment in the offshore countries. Our analysis will focus on two key aspects of such investment: the importance of tariff and transport costs as barriers to trade, and the likely effects of increased automation in the assembly process on the location of assembly operations.

The most reliable, albeit limited, information on offshore production economics is that collected by the U. S. Customs Services when duty-free content is declared as tariffs are collected on U. S. offshore imports. Table 9.1 summarizes available information on the percentage of offshore (806 and 807) imports coming in under item 807, and the U. S. content of 806/807 imports as a percent of total value.

The information on the percentage of imports coming in under 806/807 is significant because it tells us something about how quickly producers respond to their economic environment. Item 806.30 is generally much more costly to use than tariff item 807.00, since the item must be certified and loaded under the supervision of a Customs officer, and the nature and cost of processes of manufacture carried out overseas registered. 174/ On the other hand, prior to about 1975,

Table 9.1
Structure of U.S. 806/807 Imports of Semiconductors

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
As a % of 806/807 Imports:														
807 Imports	n.a.	n.a.	n.a.	84	79	73	64	54	51	51	63	77	90	97
U.S. Content*	37	56	57	59	59	53	51	45	45	47	46	55	60	62

* 807 Imports only prior to 1969
n.a.: not available

Source: Same as in Table 5.4, and U.S.I.T.C.

the operations qualifying as "processing" were much less restrictive than those permitted under 807. An important court case in 1976 (U. S. vs. Texas Instruments, Inc.), however, established that silicon wafers could be scribed and broken within the definition of "assembly," which could only have been done previously under the 806.30 provisions. 175/ As can be observed in Table 9.1, while 807 had been declining in importance prior to 1975, it grew rapidly in importance after that court case, accounting for 97 percent of offshore imports by 1979. Producers responded rapidly to take advantage of the more advantageous processing requirements.

The U. S. content of assembly imports showed a general tendency to increase over the 1966-69 period, a decline over the 1971-74 period, and an increase over the 1976-79 period. The International Trade Commission attributed the decline in U. S. content over the 1970-75 period to substitution of foreign-made components for U. S.-made components and to technological improvements in manufacturing processes (which presumably would lower the price of U. S.-made components). 176/ The increase in U. S. content over the 1975-78 period was also attributed to technological advances by the U. S. I. T. C. (which involved more "efficient and capital-intensive methods of production") 177/

It does, in fact, seem reasonable to attribute both the increases and decreases in U. S. content to technological factors. Over 1970 to 1975, as process technology for medium-scale integration of circuits on a silicon chip was improved, the cost of producing a functioning silicon chip did decline. And with the commercialization of a new generation of devices over the 1975-78 period, using much more complex and expensive chips, it is not surprising that U. S. content rose in relative value.

The objection might be made that aggregation over countries and products may cause spurious trends in U. S. content, resulting from changes in the geographical and product distribution of offshore production. Appendix Table 9.A.1 breaks down U. S. 806/807 SCD content by country, and Appendix Table 9.A.2 breaks down U. S. content by 7-digit product, at available levels of product detail for ICs, by country. The same basic trends noted above persist with much greater levels of disaggregation.

The increased complexity, and value, of the silicon chips from which integrated circuits are assembled, has potentially important effects on the pattern of international trade in chips. This is because the chief barriers to trade, tariff and transport costs, are basically proportional to the value of the chip. Let t be the tariff rate coming into an industrialized country market, and let be freight and insurance costs (going and coming) for a chip shipped overseas for assembly, and then re-imported. We can then express the cost savings from offshore assembly and packaging as a fraction of the cost of assembly if done entirely domestically, Δ_{for}, as

$$(9.1) \qquad \Delta_{for} = 1 - \ell\,(1 + t + f) - m\,(t + f)$$

with ℓ the ratio of foreign to domestic assembly and packaging costs, m the ratio of chip cost to domestic assembly cost. <u>17a</u>/ Clearly the greater ℓ (the smaller the saving from foreign assembly) or m (the less the importance of assembly in overall production cost), or t or f (the greater the barriers to trade), the less attractive offshore assembly becomes. Increased chip complexity makes for a larger value of m ; for m sufficiently large, it is quite possible that the tariff and transport costs on sending the chip offshore for assembly and packaging more than offset the cost savings in the actual assembly, so that expression (9.1) is negative.

If the offshore assembly U. S. tariff provisions are used, no U. S. duties are charged on the value of the U.S.-made chip upon reentry, and (9.1) becomes (denoting cost savings with 806/807 as a fraction of U.S. assembly costs by Δ_{807})

$$(9.2) \qquad \Delta_{807} = 1 - \ell\,(1 + t + f) - mf$$

While it is theoretically possible that the 806/807 tariff provisions made offshore assembly operations economically viable that might not otherwise have been cost effective, it is clear that this, historically, was not the case. 179/

This latter point is made quite effectively using cost data for the early 1970s, summarized in Table 9.2. It might be argued that since the tariff rate in the early 1960s was 12.5 percent, declining to 6% in 1972 after the Kennedy cuts, the use of 806/807 provisions may have been more economically important in the early 1960s. The calculations of Table 9.2 reveal this to be an insignificant factor, however. Offshore assembly probably lowered assembly costs for simple devices some 50 to 60 percent in the early 1970s, with the use of 806/807 tariff provisions shaving off perhaps another 1% of U. S. assembly costs. The same cost structure, with the 1960's tariff rate of 12%, yields basically identical results.

Table 9.2

Cost Reductions Due to Offshore Assembly, 1973
(as % of U.S. Assembly Cost)

		Simple Devices (discrete SCDs or simple ICs)	Complex Devices (LSI and complex ICs)
		$\ell = .4$ $m = .06$	$\ell = .6$ $m = .9$
Δ_{for}	with 12% tariff	53%	17%
	with 6% tariff	56%	27%
Δ_{807}	with 12% tariff	54% 54%	28%
	with 6% tariff	56%	32%

Source: f, t, ℓ, m, Δ_{for} , Δ_{807}, defined in text.

$\underline{f} = .03$ assumed, in line with Table 4.1.

ℓ, m calculations based on data in Appendix Table 9.A.3

and assumption that U.S./offshore labor cost ratio is 4.

With more complex devices, the arithmetic is somewhat different, but still implies that the existence of the 806/807 tariff provisions was only a marginal factor affecting the decision to assemble offshore. With more complex devices, the cost of the chip relative to U.S. assembly costs (m) increased drastically, while the ratio of offshore to U.S. assembly costs (ℓ) increased slightly, due to the greater relative expense of the more elaborate packaging materials used. Still, offshore assembly with 806/807 saved about one-third of U. S. assembly costs, with 806/807 responsible for a 5 percent saving over U. S. assembly costs. Even with the old 12% tariff rate, and no 806/807 tariff rate, a substantial saving would have been realized by packaging chips offshore.

With the even greater complexity of new generations of sophisticated integrated circuits, however, this situation may have changed. As Table 9.3 shows, a simple device (a linear op amp IC) would cost about 28% more to manufacture in the U.S. than offshore, using 806/807, or about 24% more if 806/807 were not used (or a non-U.S. chip were assembled). With a complex computer memory chip (16K RAM) however, this situation changes dramatically. U.S. assembly would now raise manufacturing cost about 6%, using 806/807, and leave cost almost unchanged if 806/807 were unavailable (or if the chip were fabricated overseas). The situation is basically the same for the even more complex 64K RAM, except that offshore manufacture is actually <u>more</u> expensive when 806/807 cannot be used.

Table 9.3

Cost Data, Selected ICs, 1979

	64K RAM* (16 pins)	16K RAM (16 pins)	Linear Op AMP (14 pins)
		(U.S. $)	
Assembly & Package Cost/Chip (plastic package, off shore assembly)	.10	.10	.06
Assembly Yield	90%	90%	75%
Final Test Yield	65%	70%	70%
Assembly Cost/ Yielded Chip	.17	.16	.11
Total Manufacturing Cost/ Yielded Chip	4.11	2.57	.37
		As Percent of Offshore Manufacturing Cost	
Assembly Cost/ Manufacturing Cost	4.1%	6.2%	30%
Cost Changes if Assembled in U.S. (as % offshore total manufacturing cost):			
Δ Assembly Cost (assumed doubled)	4.1%	6.2%	30%
Δ duties paid			
a. If U.S. chip 806/807 used (6% X Assembly Cost)	-.25%	-.37%	-1.8%
b. If 806/807 <u>not</u> used (6% X Total Manufacturing Cost)	-6%	-6%	-6%
Net Change: a.	+3.85%	+5.83%	+28.2%
b.	-1.9%	+ .2%	+24%

*64K RAM data is estimated, for 1981. Other figures are actual costs for 1979.

Source: Based on data in Dicken (1980), pp. 79-83.

The implications of increasing chip costs, then are quite striking. For complex ICs, the availability of the offshore assembly tariff-sparing arrangements can be the decisive factor in the decision to locate assembly facilities overseas. If they are unavailable (as is the case for Japanese affiliates assembling Japanese-made computer chips for sale in the U.S. market), it is actually more economic to assemble in the U. S. 180/

Also, because increasing chip complexity means that assembly costs are a smaller and smaller fraction of total manufacturing costs, the cost savings realized from offshore assembly of complex devices becomes a smaller and smaller part of the overall cost of production. 181/ It may well be that the more important fabrication costs will increasingly determine the location of production. 182/

The increasing importance of quality in complex chips, and the use of automated techniques associated with higher quality levels, promises to accentuate this trend. With automation, the cost differential between domestic and offshore assembly will continue to narrow, and the relative importance of chip cost in overall manufacturing cost will continue to rise with more complex chips (as will the costs of tariffs and transport). The result will be that offshore assembly will be less and less attractive for the more advanced chips.

While there is substantial evidence that U. S. firms have recently begun to automate their offshore operations in response to the Japanese quality challenge, 183/ the overall prognosis for the future must certainly be that, as the most complex, high quality chips become a larger and larger fraction of the market, offshore assembly will tend to shift back to the domestic market where the chip is sold. To some extent this may be offset by the forthcoming tariff cuts (to 4 percent) in the U. S. and Japanese markets. Also, learning economies will eventually decrease chip cost for the more recently introduced complex chips. Still, a recent market research study predicted that U. S. -assembled semiconductors will rise from 29 to 39 percent of U. S. consumption by the end of the 1980s, 184/ and these cost considerations certainly back this prediction.

It might also be thought that use of automated techniques, in and of itself, would tend to shift assembly back to the industrial country markets. The argument would be that use of sophisticated machinery requires a more skilled labor force than is available in most developing countries. While the maintenance and engineering staff required must certainly increase in more mechanized operations, however, the available evidence suggests that a *less* skilled production work force is actually required with automated bonding and packaging lines. While it takes about 3 months for a worker to learn manual bonding, and two months to become skilled at manual die attachment, about two *weeks* of experience are required to train the operator of machinery performing either operation. 185/

We conclude, then, that while savings on offshore assembly costs have for decades made it worthwhile to go offshore, with or without the use of 806/807-type tariff provisions, that situation is rapidly changing for the most complex devices. For those complex ICs (like computer memory chips), the use of 806/807 is important to the decision to assemble offshore. As chip complexity (and value) continues to increase, and automation continues to reduce onshore/offshore assembly cost differentials, we expect that assembly of the most complex types of chips will shift back to the final market where the chip is used. Automation, however, in and of itself will probably not force this to occur because of changing skill requirements, since less skilled workers are probably used on an automated packaging line.

Automation, since it increases capital intensity, will increase the need to invest much larger volumes of assets in offshore operations that are upgraded. As this occurs, manufacturers of semiconductors will give even greater attention to the possible political risks associated with large-scale investments. We next turn to the more elaborate analysis needed to take into account the effects of such risks on producers' production location decisions.

Table 9.A.1

U.S. Content of 806/807 SCD Imports (%)

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Mexico	79	74	70	64	57	64	68	59	66	65
El Salvador	-	-	-	-	-	18	15	17	47	51
Haiti	-	-	-	[79]	71	95	86	86	85	88
Barbados	-	-	-	-	-	[79	76	72]	59	59
Brazil	-	[57	47]	-	-	7	14	7	51	48
Thailand	-	-	[62	-	-	56	-]	54	60	63
Malaysia	[59	72	69	26]	53	45	44	47	56	63
Singapore	38	58	43	50	42	40	39	42	54	60
Indonesia		[68	61	-	-	33	23]	21	20	38
Philippines	-	-	-	-	76	57	61	57	66	69
S. Korea	66	74	63	63	59	50	57	59	61	63
Hong Kong	62	57	48	45	38	34	38	34	46	53
Taiwan	54	48	39	37	28	33	39	32	43	44

Source: Data furnished on magnetic tape by U.S.I.T.C.

[ ] : less than .5 million US $ in imports.

Table 9.A.2

U.S. Content of ICs Entered Under 806/807 (%)

	All ICs						Bipolar TTL ICs		
	1970	1971	1972	1973	1974	1975	1976	1977	1978
Mexico	78	71	69	57	73	76	48	66	62
Malaysia	73	69	41	53	46	44	44	54	58
Singapore	63	46	50	44	40	39	31	43	42
Korea	85	70	63	38	53	58	55	54	62
Hong Kong	64	52	56	44	38	47	64	57	64

	MOS IC's			Bipolar ECL ICs		
	1976	1977	1978	1976	1977	1978
Mexico	79	83	77	53	79	62
Malaysia	49	57	67	67	53	57
Singapore	52	56	64	41	54	57
Korea	70	74	72	45	33	45
Hong Kong	49	64	77	51	48	52

Source: Data furnished on magnetic tape by U.S.I.T.C.

Table 9.A.3

Manufacturing Costs, 1973
(Dollars)

	Discrete or Simple ICs	LSI & Complex Chips
Cost per Yielded Chip	.015	1.00
Packaging Cost	.05	.50
Labor (Assembly, Offshore)	.05	.15
TOTAL COST	.15	3.40

Source: E.F. Hutton and Co., cited in Office of Producer Goods, U.S. Department of Commerce (1979), p. 73.

10. The Impact of Country Risk

Various sorts of evidence, from the statements of the managers of multinational semiconductor firms, to the observed changes in the patterns of 806/807 SCD imports, suggest that the diversification of country-specific risk in production is an important objective of firms engaged in offshore production. If one reads the 1978 annual report of Motorola, a major SCD producer, for example, one finds a list of semiconductor manufacturing facilities scattered around the globe. As if to reassure stockholders, however, the report states that no single facility or country located outside the U. S. accounts for more than 10% of sales, revenues, assets.

Taking account of the riskiness of offshore production adds considerable complexity to a realistic analysis of the production location decisions of firms. Clearly, finding the 'least cost' location will no longer be the _sine qua non_ of selecting an offshore production site. Rather, a risk-averse producer should logically diversify production among a portfolio of sites, with considerable variation among average costs in these locations a distinct possibility.

The analysis of this section will focus on constructing the simplest possible model of offshore production that captures in a reasonably realistic way the problem of diversifying production location to reduce the political risks of offshore investment. This model will then be used with actual data on the offshore operations of the U. S. semiconductor industry. The empirical parameters to be estimated will be useful in assessing the impact of wage changes, and shifts in investors' perceptions of political risk, on the sourcing of offshore imports, and on the use of foreign-produced inputs.

Models of Diversification in Offshore Production

Modelling the decision process leading to a manufacturer scattering his production among a number of risky locations, rather than a single risky location which might have the lowest average cost, requires an explicit specification of how a manager trades off the expected return in a location against the country-specific risk he incurs when investing in that location. It should be stressed that -- because semiconductor assembly by U. S. offshore affiliates has not, historically, been a particularly capital intensive process, requiring huge investments in production equipment 186/ -- the risk that is run is as much from unexpected disruptions to production in a highly competitive business, as the risk of confiscation, expropriation, nationalization, or vandalization. Strikes, wars, unforeseen exchange rate fluctuations, revolutions, hyperinflations, political turmoil, and other potential disruptions to production are probably as costly or costlier than a mere threat to capital. In fact, the relatively simple production equipment required in the past for assembly is probably fairly mobile in the strictly physical sense.

We shall treat the diversification of assembly operations across countries as a special case of the classic analysis of portfolios of risky assets that goes back to the seminal work of Tobin (1959) and Sharpe (1964). A complete exposition of the results we shall cite is contained in the technical appendix to this section.

results are discussed.

The Model

Given these assumptions, it can be shown (see the technical appendix to this section) that the optimal strategy for a production manager allocating production among the risky locations is so select an optimal value of capital investment in country i, Ki*, as

$$(10.1) \quad K_i{}^* = \left[\frac{\pi_i - r_o}{\phi} - \sum_{\ell} C_{i\ell} \quad \Delta_\ell \right] \frac{W}{\sigma^2_{\varepsilon_i}} .$$

where π_i is the average (or equivalently, marginal, with constant returns to scale) return to a dollar invested in producing in location i; r_o is the riskless return; ϕ and the Δ_ℓ's are portfolio constants reflecting the market price of risk, and the covariances of the market portfolio of assets with the ℓ underlying factors affecting offshore returns, respectively; the Ci_ℓ's are location specific constants reflecting the influence on returns in location i of the ℓ underlying factors; 189/ and $\sigma^2_{\varepsilon_i}$ is the variance of that component of return in location i that is independent of the underlying factors, and hence, from the return on all other assets. Return on SCD assembly in location i, π_i, is a function of a vector of input prices, faced in location i and of output price, the value of an assembled semiconductor device, P'. There are j input and output prices.

We can write the part of (10.1) in brackets as a function g

$$(10.2) \quad K_i{}^* = g \; (\pi_i \;\; (P_i'), r_o \;, \phi \;, C_{i\ell}', \Delta_\ell') \frac{W}{\sigma^2_{\varepsilon_i}} .$$

Our basic assumption is that the manager of production scheduling in a multinational semiconductor firm acts as a portfolio manager, with some fixed allocation of investible resources to be distributed among assets. A semiconductor investment in every production location is treated as a unique asset, with some country risk of its own, so that a dollar of investment in SCD assembly in country i is expected to yield some average return π_i, a function of production costs in country i, and have some variance around that average return σ_i^2, as a consequence of country-specific risk. Industry production managers act in the interest of risk-averse investors, and are assumed to select portfolios of production investments that, in the aggregate, are efficient. [187]

We make three other simplifying assumptions:

1. There are constant returns to scale in assembly;
2. The returns to producing in different offshore locations are related to each other (and to the returns on all other assets) only through common relationships with a number of basic underlying factors; [188]
3. A riskless asset paying return r_0 exists (government bonds are usually cited in this role in the finance literature).

The model we construct in this section also makes a number of assumptions about producers' adjustment behavior. In particular, we assume that price expectations are formed adaptively, and that actual capital stock adjusts partially in response to changes in its optimal desired level. The reader uninterested in the technical details of this model is urged to skip to the end of this section, where the

(We use the ′ notation to denote a vector.) For our econometric work, we will express (10.2) in terms of natural logarithms, and represent ln g by a first-order approximation linear in the natural logs of its arguments, i. e. ,

$$(10.3) \qquad \ln K_i^* = \sum_j d_j \ln P_{ij} + H + J_i .$$

Barring structural change, intercept term H contains the effects of all variables constant for all locations (i.e. , for all i, including the loglinear terms in w, r_o , ϕ, the Δ_ℓ's), and takes on a different value in every time period as those variables and the market portfolio change. Country-specific shift-term J includes the effects of all the variables whose values are unique to country i, and do not shift over time (i.e. , $\sigma^2_{\varepsilon_i}$, the $C_{i\ell}$'s). A change in investors′ perceptions of country risk, by changing the $C_{i\ell}$'s and $\sigma^2_{\varepsilon_i}$, will alter the value of Ji. Technical change will shift H if it is of the output-augmenting type, which will be assumed, and leave the d_j unchanged. 120/

To make (10.3) useful for empirical purposes, we must recognize that optimal capital stock, K_i*, depends on capital investments that may have important transaction costs, and that reallocating existing investments among countries may involve significant costs of adjustment (for one thing, production flows will be disrupted as capital is shuffled among countries). We therefore operationalize (10.1) by assuming a so-called "partial adjustment" model, i. e. , that

$$(10.4) \qquad \ln K_{it} - \ln K_{it-1} = \delta(\ln K_{it}^* - \ln K_{it-1})$$

where the t subscripts refer to time periods and the K_i without asterisk denotes *actual* output as opposed to *optimal* K_i^*. Parameter δ is interpreted as reflecting the speed of adjustment of actual to optimal levels; with $\delta = 1$, adjustment is instantaneous, while with $\delta = 0$, there is no adjustment. If there are costs to adjusting the allocation of investment among countries, producers will not want to respond fully and instantaneously to changes in returns among countries, and δ will be less than one.

Also, since capital investment generally requires time to be carried out, it is reasonable to suppose that the prices affecting the returns in (10.3) ought to be expected prices (i.e. , P in K* is based on next period expectations of price at time t-1). We specify price expectations at the momemt optimal capital stock is determined, to be generated by the simple model

$$(10.5a) \quad (\dot{P})^e_t - (\dot{P})^e_{t-1} = \lambda \left[(\dot{P})_{t-1} - (\dot{P})^e_{t-1} \right]$$

with superscript e denoting an expectation, the subscripts referring to time period, and the rate of price change, $\dot{p}$, defined as

$$(10.5b) \quad (\dot{P})_t = \ln P_t - \ln P_{t-1}$$

and

$$(10.5c) \quad (\dot{P})^e_t = \ln P^e_t - \ln P_{t-1}$$

This is an "adaptive" model of producers' expectations of the rate of price change, $\dot{p}$. When parameter λ takes on value 0, expectations of the rate of price change in the next period are unaffected by the error in last period's expectation; when parameter λ takes on value 1, next period's forecast is increased or decreased by exactly the error in last period's expectation. If we think of the change in the rate of price increase as a random variable having transitory and permanent components, then the optimal forecast of the rate of change will use a λ close to zero if variation in the transitory component of change is much greater than variation in the permanent component, and optimal λ will be close to 1 if the opposite is true. 121/ Solving (10.5) for the expected price level, we have 122/

$$(10.6) \quad \ln P^e_t = (\ln P_{t-1} - \ln P_{t-2}) + \lambda \ln P_{t-1} + (1-\lambda) \ln P^e_{t-1}$$

Actual output in location i, Y_i, is given by

$$(10.7) \quad \ln Y_i = \ln K_i - \ln k\,(P_i')$$

The value of capital\output ratio in location i, k, is a function of the vector of input and output prices in location i, P_i (unless the technology is of the fixed coefficient type, in which case it is constant) 123/ K_i is the actual value of capital stock in place in location i.

Using a loglinear approximation to K as our functional form, we then have

$$(10.8) \quad \ln Y_i = \ln K_i + (e_o + \sum_j e_j \ln P_{ij})$$

with the e's the coefficients in the approximation. Again, because we assume technical progress to be output-augmenting, the e's will remain constant across countries and over time , while e_o will vary over time with technological advance. 124/

There is one last substitution that must be made before we can use our specification on actual data. The only input price whose movements can actually be reasonably well observed over time and across countries is the wage rate (P_{ilt}, in country i, year t). All other location specific prices will be assumed to be proportional to some common index which changes over time and is constant across countries (i.e., $P_{ilt} = q_{ij} I_{jt}$, for $j \neq L$). Thus, we assume that while the prices of inputs and outputs other than labor change over time, they are fixed in relative terms across countries. This is not terribly unrealistic, since the major inputs other than labor are U.S.-made components and material (whose effective cost is adjusted using the U.S.tariff rate), 125/ transport cost, infrastructural service costs, and to a minor extent, foreign material costs. Output price is necessarily uniform across countries. 126/

Most of the stupefying algebra in our functional forms is in the coefficients to be estimated, in brackets (in the last couple of footnotes), and (10.10) becomes much less fearsome when the coefficients are symbolized by α, β, and γ:

$$\text{(10.11)} \quad \ell n\ Y_{it} - \ell n\ Y_{it-2} = \beta_1(\ell n\ Y_{it-1} - \ell n\ Y_{it-2}) + \beta_2\ \ell n\ Y_{it-2}$$

$$\beta_3(\ell n\ P_{iLt} - \ell n\ P_{iLt-2}) + \beta_4\ (\ell n\ P_{iLt-1} - \ell n\ P_{iLt-2}) + \beta_5\ \ell n\ P_{iLt-2}$$

$$+ \gamma_t + \gamma_i + \alpha_1\ (J^e_{it} - J^e_{it-1}) + \alpha_2\ J^e_{it} + \hat{V}_{it}$$

($\hat{V}_{it}$ a redefined random disturbance).

The β's refer to the coefficients of lagged combinations of previous output levels, and wages, the γ's refer to country and time intercepts, and (since the J^e's only change value after shifts in perceived country risk) the α's are the coefficients of two variables taking on non-zero values when changes in country risk occur. However, the full specification given in (10.10) is useful because it allows us to derive restrictions on the coefficients of (10.11) when we impose various hypotheses on the parameters of our underlying model.

In effect the only influences on offshore production in different countries which we can really identify in (10.11) are those of the local wage and shifts in country-specific risk; all other influences cost differentials, we expect that assembly of the most complex types

are incorporated into intercept terms, expressed as dummy variables which are constant across countries but change from year to year, and dummy variables which are constant over time, but change across countries. Fortunately, from the point of view of individual producing countries, the local wage is the variable over which maximum control is exercised, and whose effects are therefore of greatest interest.

Equation (10.11) is the form actually estimated. To estimate the parameters of (10.11) more precisely, and because the determinants of U.S. component use are of intrinsic interest, we can use additional information on the use of duty-free U.S. components in offshore semiconductor assembly that is available. This is because (letting U_i be demand for duty-free U. S. components to be used in assembly in location i, year t),

$$(10.12) \quad U_i = \mu \; (P'_i) \, K_i$$

with μ_i the value of U. S. -components used per unit of capital installed in location i. 197/ Taking a loglinear approximation to μ we have

$$(10.13) \quad \ln U_i = \ln K_i + (f_o + \sum_j f_j \ln P_{ij})$$

Using exactly the reasoning described before, we derive an equation exactly like (10.10), with two minor modifications. All e's in coefficients in (10.9), which describe the capital\output ratio, must be replaced by the f's corresponding to the component\capital value share described in (10.13), and $\hat{v}_i$ may be replaced by a different random disturbance, $\hat{w}_i$. When this is done, we have a second relation

$$(10.14) \quad \ln U_{it} - \ln U_{it-2} = \beta_1 (\ln U_{it-1} - \ln U_{it-2}) + \beta_2 \ln U_{it-2}$$

$$+ \theta_3 (\ln P_{iLt} - \ln P_{iLt-2}) + \theta_4 (\ln P_{iLt-1} - \ln P_{iLt-2})$$

$$+ \theta_5 \ln P_{iLt-2} + \Omega_t + \Omega_i + \alpha_1 (J^e_{i_t} - J^e_{i_{t-1}}) + \alpha_2 J^e_{it} + \hat{W}_{it}$$

with all coefficients to be estimated, except for those of country i's wage (the θ's) and the time and country intercept terms (the Ω's), the same as coefficients in (10.11).

After studying (10.10), one can derive additional coefficient restrictions implied by the maintained hypotheses that:

(i) $\lambda = 0$, price change expectations are static over time;

(ii) $\lambda = 1$, price change expectations are corrected by last-period error in every time period;

(iii) $e_{P_L} = f_{P_L}$, the value of the U.S. component/output ratio is insensitive to changes in the wage rate.

(iv) $e_{P_L} = f_{P_L} = 0$, the values of the U.S. component/capital and output/capital ratios are insensitive to changes in the wage rate (i.e., fixed coefficients in U.S. input and capital use characterize the technology).

The implied restrictions on the coefficients of (10.11) and (10.14) are shown in Chart 10.1.

Data

We will use the 806/807 SCD import data described in Section 6 to estimate the parameters of our model. 198/ Data for six countries -- Mexico, Taiwan, Korea, Hong Kong, Singapore, and Philippines -- were used because consistent and reasonably reliable series of wage data were available over the 1966-1979 period. 199/ Country risk in these countries was assumed to be constant over time, except for the 1975-76 period in Mexico, when the appearance of political instability is thought by some to have sharply increased investors' perception of risk, the years 1978-79 in Taiwan, when the rupture of formal diplomatic relations with the U.S. was a likely source of increased perception of risk, and the years from 1972 on in the Philippines, when martial law was imposed.

The assumption of constant risk, except for these identified qualitative shifts, results in risk 'shift' dummy variables that displace the country-specific intercepts, γ_i and Ω_i in these countries. We assume that expected J risk variable in period t is just the unweighted average of acutal J in the three previous years, so that we can express the terms

$$\alpha_1 (J^e_{i_t} - J^e_{i_{t-1}}) + \alpha_2 J^e_{i_t} \quad \text{in}$$

(10.11) and (10.14)

as $R_{i1} + R_{i2}$

Chart 10.1

Effects of Various Hypotheses on Coefficients of (10.11) and (10.14)

Hypothesis:		Restrictions:
(0)	Theoretical specification is correct	Coefficients of U's and Y's and J's in both (10.11) and (10.14) same values
(i)	$\lambda = 0$	$\beta_2 = 0$ $\beta_5 = 0$ $\theta_5 = 0$ $\gamma_1 = 0$ $\Omega_1 = 0$ $\alpha_2 = 0$
(ii)	$\lambda = 1$	$\beta_1 - \beta_2 = 1$ $\alpha_1 = 0$
(iii)	$e_{P_L} = f_{P_L}$ (i.e., U/y fixed as P_L varies)	$\beta_3 = \theta_3$ $\beta_4 = \theta_4$ $\beta_5 = \theta_5$
(iv)	$e_{P_L} = f_{P_L} = 0$ (i.e., U/K and y/K fixed as P_L varies)	$\beta_3 = \theta_3 = 0$ $\beta_4 = \theta_4$ $\beta_5 = \theta_5$

where R_{11} displaces the country-specific intercept in an equation only in the year when a change in expected country-risk occurs, and R_{12} displaces the country-specific intercept for all years subsequent to the change. 200/ In the form the equations were actually estimated, all intercepts were normalized to the value corresponding to Mexico, 1971, and country-specific or year-specific intercept terms for other countries and years are expressed as displacement from that value. 201/

Since all other country specific prices other than the wage rate are assumed constant relative to indices changing over time (i.e., freight and insurance costs, infrastructural services, foreign-produced components), the country dummies capture the effects of cross-country differences in these prices, as well as country-specific risk.

The γ_t and Ω_t in equations (10.14) and (10.11), the dummy variables having value 1 in a single year, zero elsewhere, capture the effects of prices which are constant across countries, but change from year to year (the price of output, U.S. materials, the U.S. tariff rate; the unobserved indices which determine transport costs, foreign-made component cost, infrastructural service costs), as well as shifts caused by changes in technology, and annual changes in the various portfolio constants (which are a function of wealth available for risky investment, the risks and returns for all assets, and the market price of risk).

The value of output from U.S. assets invested in offshore semiconductor assembly was measured by the customs value of U.S. 806/807 imports. 202/ The value of U.S.-made components (mainly unassembled chips) was measured by the duty-free U.S. value declared to customs authorities when 806/807 imports entered the U.S. 203/

Estimation

In view of the previous discussion, we shall estimate the two equation system:

$$\text{(10.15a)}\quad \ln Y_{it} - \ln Y_{it-2} = \beta_1 (\ln Y_{it-1} - \ln Y_{it-2}) + \beta_2 \ln Y_{it-2} + \beta_3(\ln P_{iLt} - \ln P_{iLt-2}) + \beta_4 (\ln P_{iLt-1} - \ln P_{iLt-2}) + \beta_5(\ln P_{iLt-2}) + \gamma_t + \gamma_i + R_{i1} + R_{i2} + \hat{V}_{it}$$

$$\text{(10.15b)}\quad \ln U_{it} - \ln U_{it-2} = \beta_1 (\ln U_{it-1} - \ln U_{it-2}) + \beta_2 \ln U_{it-2} + \theta_3 (\ln P_{iLt} - \ln P_{iLt-2}) + \theta_4 (\ln P_{iLt-1} - \ln P_{iLt-2}) + \theta_5 \ln P_{iLt-2} + \Omega_t + \Omega_i + R_{i1} + R_{i2} + \hat{W}_{it}$$

Because the error terms ($\hat{V}it$ and $\hat{W}it$) might well display serial autocorrelation over time 204/ estimation of (10.15A) or (10.15B), which contain lagged values of the dependent variables, using ordinary least squares might yield inconsistent coefficient estimates. Instead, (10.15A) and (10.15b) were estimated jointly using an instrumental variable procedure (three-stage least squares). 205/ The advantage of this method is that it produces consistent and asymptotically efficient estimates of coefficients, using an estimate of the variance-covariance matrix of V and W (the errors are assumed independent over time, but not of each other at any moment in time), and cross-equation restrictions on the values of coefficients, to produce more precise estimates than equivalent single-equation instrumental variable cedures.

The results of Table 10.1 confirm the advantages of a systems approach to estimation of equations (10.15A) and (10.15B). The first set of estimates does not impose any of the cross-equation restrictions our theoretical analysis implies, but does use an estimate of the between-equations variance-covariance matrix to produce the estimated coefficients. Because the disturbances in the two equations appear to be highly correlated (the estimated correlation coefficient is .86), the coefficients, while having rather large approximate standard errors, are estimated with substantially greater precision than is the case with a single-equation two-stage least squares procedure (not shown, but which produced basically similar numerical estimates, with much larger standard errors).

When the theoretical specification restrictions are imposed, as is done in the second set of estimates in Table 10.1, considerably more precise estimates are produced. Statistically significant (i.e., where the null hypothesis that they are equal to zero is rejected) estimates of β_1, β_4 and Θ_4 are in fact produced.

The signs of political risk 'shift' terms (negative for Mexico and Taiwan, positive for the Philippines) would seem to indicate an increasing perception of country risk in Mexico during 1975/76 and in Taiwan after the break in formal diplomatic relations with the U.S., and lessened perception of risk in the Philippines after the imposition of martial law (which is basically compatible with the tenor of accounts in the U.S. press in analyzing these events). Only in Taiwan, however, are these risk shifts statistically significant, so we are less convinced of the importance of these events in explaining investment in Mexico and the Philippines. The rather low values of

Table 10.1

Estimation of (10.15A) and (10.15B) With and Without Theoretical Restrictions of Specification

	Without Specification Restrictions		With Specification Restrictions ((0) in Chart 10.1)	
	(10.15A)	(10.15B)	(10.15A)	(10.15B)
Coefficient:				
β_1	.17 (1.4)	.39 (1.2)	1.41 (.51)**	same
β_2	-.40 (.63)	-.21 (.35)	.11 (.28)	same
β_3/θ_3	.76 (.33)	.61 (.50)	.55 (.47)	.67 (.31)
β_4/θ_4	-1.1 (1.3)	-1.5 (1.2)	-2.1 (.78)**	-2.2 (.86)**
β_5/θ_5	-.015 (.37)	-1.8 (.48)	.038 (.37)	.029 (.30)
Mexico, R_2	-1.1 (1.2)	-1.1 (1.3)	-.12 (.55)	same
Mexico, R_1	.0015 (.73)	.0098 (.90)	-.36 (.56)	same
Philippines, R_2	-.78 (1.1)	-.51 (.93)	.0042 (.61)	same
Philippines, R_1	2.7 (2.0)	2.5 (1.9)	1.2 (1.4)	same
Taiwan, $R_2 + R_1$	-.24 (.33)	-.27 (.40)	-.48 (.22)**	same
Intercept (Mexico 1971)	2.6 (4.1)	1.9 (4.3)	-.67 (2.1)	-.82 (2.1)
Taiwan, δ_i/Ω_i	-.36 (.87)	-.27 (1.1)	.36 (.38)	.43 (.53)
Korea, δ_i/Ω_i	-.052 (.24)	.011 (.26)	.15 (.16)	.15 (.18)
Hong Kong, δ_i/Ω_i	-.29 (.48)	-.28 (.66)	.10 (.22)	.15 (.32)
Singapore, δ_i/Ω_i	.21 (.16)	.085 (.20)	.11 (.13)	.18 (.16)
Philippines, δ_i/Ω_i	1.22 (.90)	.99 (.84)	.59 (.66)	.61 (.65)
1972, δ_t/Ω_t	.29 (.17)*	.36 (.23)	.20 (.14)	.46 (.17)
1973, δ_t/Ω_t	.55 (.53)	.41 (.38)	.11 (.25)	.17 (.21)
1974 δ_t/Ω_t	.67 (.77)	.57 (.44)	.039 (.34)	.30 (.25)
1975, δ_t/Ω_t	.24 (.83)	.28 (.62)	-.42 (.41)	-.008 (.33)
1976, δ_t/Ω_t	.45 (.61)	.51 (.57)	.090 (.41)	.23 (.38)
1977, δ_t/Ω_t	.74 (1.2)	.86 (.99)	-.24 (.58)	.21 (.50)
1978, δ_t/Ω_t	.67 (1.1)	.81 (1.2)	-.16 (.59)	.044 (.59)
1979, δ_t/Ω_t	.80 (1.1)	.88 (1.2)	.017 (.62)	.20 (.62)
$\hat{\sigma}^2$	.0392	.0493	.0762	.100
$\hat{\sigma}_{12}$		.0377		.0784
$\hat{\rho}_{12}$		.86		.90

Estimation Method: 3SLS

* Significant at 90% Confidence Level.
** Significant at 95% Confidence Level.

$\hat{\sigma}^2$ is estimated variance of equation random disturbance term.
$\hat{\sigma}_{12}$ is estimated between equation covariance of random disturbance terms ρ_{12} is correlation coefficient.
Approximate standard errors in parentheses next to coefficient estimates.

F-test for specification Restrictions:

$F_{(7,52)} = .202$

Cannot reject at 90% or 95% Confidence Levels.

, β_2, β_5 , and θ_5 , the R_2 shift terms, and the country dummies -- all quite close to zero - suggest that either parameter δ or λ equals zero (but not both). 206/ Since the R1 terms would also be zero if δ was close to zero, and they are not, and because the empirical evidence cited before *does* indicate that managers *do* respond to changes in the profitability of production in different locations, the results of Table 10.1 suggest that λ may be quite close to zero, and that long-run expectations of the rate of increase in real wages are little affected by transitory variations from period-to-period. 207/

Also, the striking similarity of the values of the β_3 ,β_4 and β_5 values to θ_3, θ_4 and θ_5 suggests that both output/capital and U.S.-component/capital ratios display an identical response to variation in labor costs from location to location (which includes, as a special case, the possibility that the U.S. component to output ratio is fixed at any moment in time). 208/

Table 10.2 displays the effects of imposing restrictions on price rate expectation adjustment parameter λ . The first set of estimates imposes restrictions implied by $\lambda = 0$; the second set of estimates is produced assuming $\lambda = 1$. While the data do not permit us to reject either set of restrictions, the estimates relying on the $\lambda = 0$ hypotheses are essentially identical to the estimates of Table 10.1 made without these restrictions. The same is *not* true for the $\lambda = 1$ estimates, suggesting that we may wish to impose the λ $= 0$ restriction, as consistent with our results, to produce more ise coefficient estimates.

A statistically significant estimate of δ of .45 is implied by the estimate of β_1, in the first part of Table 10.2. This suggests moderately rapid adjustment of actual to desired capital stock, with 45 percent of the adjustment made in the year a shift in desired capital stock occurs, 70 percent of the adjustment made after one year has passed, 84 percent after two years, 93 percent after three years, 97 percent after four years. 209/

With one exception, none of the political changes thought to be of possible importance in determining country risk is statistically significant in Table 10.2. The exception, as before, is Taiwan. With $\lambda = 0$ assumed, we cannot reject, for any of the three countries, the hypothesis that those changes had no effect on country risk. But the estimated effect was reasonably large in the cases of Mexico and Taiwan, dropping optimal investment by close to one-half its previous value, *ceteris paribus* (to calculate the effect on the log of optimal capital stock, R_1 must be multiplied by 1\ δ $(1 - \lambda)$; for δ = .45, $\lambda = 0$, this means R_1 ought to be multiplied by about 2.2). While there seems to be no good reason not to drop the Philippine risk shift intercept from the regression, since it is statistically insignificant and close to zero, the potential for committing a specification error argues against doing the same for Mexico and Taiwan, with their large effects on investment. The risk dummies were therefore not dropped in further regressions.

The coefficients β_3 and θ_3, β_4 and θ_4, and β_5 and θ_5 continue to have remarkably similar values, no matter which assumption about λ is used. Again, this suggests that U.S.-made components are used in fixed proportion to output (i.e., that the chip

Table 10.2

Estimation with Additional Restriction on Adaptive Expectations Parameter λ

	With Theoretical and λ=0 Restrictions (i.e. (0) and (i) on Chart 10.1)		With Theoretical and λ=1 Restrictions (i.e. (0) and (ii) on Chart 10.1)	
	(10.15A)	(10.15B)	(10.15A)	(10.15B)
Coefficient:				
β_1	1.55 (.17)**	same	.86 (.21)**	same
β_2	0	same	-.14 (.21)	same
β_3/Θ_3	.86 (.61)	.95 (.71)	.70 (.47)	.80 (.52)
β_4/Θ_4	-2.1 (.98)**	-2.3 (1.2)**	-1.7 (.71)**	-1.8 (.76)**
β_5/Θ_5	0	same	.052 (.36)	.051 (.38)
Mexico, R_2	0	same	-.54 (.38)	same
Mexico, R_1	-.29 (.62)	same	0	same
Philippines, R_2	0	same	.28 (.46)	same
Philippines, R_1	-.067 (.62)	same	0	same
Taiwan, R_2	-.31 (.24)	same	-.40 (.21)*	same
Intercept (Mexico, 1971)	.11 (.15)	-.10 (.18)	.72 (1.6)	.50 (1.6)
Taiwan, δ_i/Ω_i	0	same	.041 (.29)	-.026 (.40)
Korea, δ_i/Ω_i	0	same	.084 (.16)	.062 (.18)
Hong Kong, δ_i/Ω_i	0	same	-.072 (.18)	-.13 (.26)
Singapore, δ_i/Ω_i	0	same	.16 (.12)	.14 (.15)
Philippines, δ_i/Ω_i	0	same	.11 (.25)	.10 (.26)
1972, δ_t/Ω_t	.23	.53 (.23)	.24 (.14)	.39 (.15)**
1973, δ_t/Ω_t	.11 (.20)	.16 (.24)	.31 (.19)	.29 (.19)
1974, δ_t/Ω_t	.042 (.21)	.33 (.25)	.32 (.25)	.44 (.23)*
1975, δ_t/Ω_t	-.30 (.20)	.026 (.23)	-.098 (.31)	.11 (.28)
1976, δ_t/Ω_t	.37 (.19)**	.47 (.22)	.27 (.36)	.34 (.34)
1977, δ_t/Ω_t	-.11 (.19)	.34 (.22)	.14 (.43)	.47 (.41)
1978, δ_t/Ω_t	.0092 (.20)	.16 (.23)	.20 (.46)	.41 (.46)
1979, δ_t/Ω_t	.21 (.20)	.38 (.24)	.40 (.48)	.56 (.49)
$\hat{\sigma}^2$	.0882	.126	.0467	.0616
$\hat{\sigma}_{12}$		.0947		.0483
$\hat{\rho}_{12}$		.90		.90

F-test for all specification restrictions:

F (22,52) = .238

Cannot reject at 90% or 95% Confidence

F-test for all specification restrictions:

F (11,52) = .284

Cannot reject at 90% or 95% Confidence

to assembled semiconductor ratio is fixed irregardless of the cost of labor in different locations) at any moment in time, which seems totally reasonable.

This hypothesis is imposed in the estimates of the first column of Table 10.3. The estimates are very similar to those of Table 10.1 and suggest that the hypothesis seems to describe changes in observed output and U.S. duty-free content reasonably well.

The results in the first column of Table 10.3 do not yield statistically significant estimates for β_3 or θ_3. Since β_3 and θ_3 are an estimates of the labor price elasticity of the output\capital and duty-free U.S. content/capital ratios, this might indicate that they are zero, and thus, that these ratios are completely insensitive to the wage in location i.

Alternatively, if the positive estimate of β_3 is taken at face value (and its large standard error blamed on multicollinearity in the data), it would seem to imply that the existing capital stock is used more intensively as the wage rises (and thus output\capital rises), and that dutiable components and materials are substituted for assembly labor. 210/ This last interpretation may have some merit if less labor can be used with more wastage of materials. Still, the most parsimonious explanation is that these ratios, at any moment in time, are relatively insensitive to wage rates (i.e., $\beta_3 = 0$). 211/ This is borne out by the results in the second column of Table 10.3, which show that imposing this last constraint has no large effect on the values of the other coefficients, and cannot be rejected statistically.

Table 10.3

Estimation Under Hypothesis of Fixed u/y Ratio

Coefficient:	Along with Theoretical Restrictions		Along with Theoretical Restrictions <u>and</u> u/k, y/k Fixed	
	(10.15A)	(10.15B)	(10.15A)	(10.15B)
β_1	1.38 (.50)**	same	1.50 (.55)**	same
β_2	.099 (.27)	same	.18 (.30)	same
β_3	.56 (.47)	same	-0-	same
β_4/θ_4	-2.04 (.77)**	same	-1.57 (.77)**	same
β_5/θ_5	.036 (.37)	same	-.056 (.44)	same
Mexico, R_2	-.15 (.55)	same	-.14 (.64)	same
Mexico, R_1	-.35 (.56)	same	-.52 (.65)	same
Philippines, R_2	.022 (.61)	same	.17 (.70)	same
Philippines, R_1	1.21 (1.40)	same	1.19 (1.67)	same
Taiwan, $R_2 + R_1$	-.47 (.22)**	same	-.50 (.26)*	same
Intercept (Mexico, 1971)	-.59 (2.1)	-.77 (2.0)	-.69 (2.4)	-.85 (2.4)
Taiwan, δ_i / Ω_i	.34 (.38)	.41 (.52)	.46 (.42)	.58 (.57)
Korea, δ_i / Ω_i	.15 (.16)	.15 (.17)	.21 (.18)	.21 (.20)
Hong Kong δ_i/Ω_i	.093 (.22)	.14 (.32)	.15 (.24)	.23 (.35)
Singapore, δ_i/Ω_i	.12 (.13)	.16 (.16)	.11 (.15)	.17 (.19)
Philippines, δ_i / Ω_i	.61 (.66)	.62 (.63)	.54 (.79)	.56 (.78)
1972, δ_t / Ω_t	.20 (.14)	.46 (.17)**	.20 (.17)	.48 (.20)**
1973, δ_t / Ω_t	.12 (.25)	.18 (.21)	.14 (.28)	.22 (.24)
1974, δ_t / Ω_t	.054 (.34)	.32 (.25)	.061 (.39)	.37 (.29)
1975, δ_t / Ω_t	-.40 (.40)	-.082 (.33)	-.45 (.47)	-.095 (.38)
1976, δ_t / Ω_t	.10 (.41)	.23 (.37)	.099 (.48)	.25 (.44)
1977, δ_t / Ω_t	-.22 (.57)	.23 (.49)	-.25 (.66)	.23 (.57)
1978, δ_t / Ω_t	-.14 (.59)	.066 (.58)	-.14 (.68)	.076 (.67)
1979, δ_t / Ω_t	.036 (.61)	.22 (.60)	.42 (.72)	.23 (.71)
σ^2	.0738	.0969	.0892	.1151
σ_{12}		.0759		.0915
ρ_{12}		.90		.90

F - tests for restrictions on coefficients:

F (10,52) = .158 F (11,52) = .205

Cannot be rejected at 90% or 95% confidence levels.

Table 10.4 maintains the hypothesis that the U.S. chip to assembled SCD ratio is constant across countries in any year, and also imposes the constraints implied by adaptation parameter λ taking on its extremal values, 0 and 1. The results are virtually identical to those of Table 10.2. As before, the $\lambda = 0$ specification differs little from the unrestricted estimates of Table 10.1, and we conclude that a fixed U.S. component/output ratio and λ close to zero (relatively fixed forecasts of long-run real wage changes) are consistent with the available data.

Conclusions

Our analysis of the very simplest model of offshore investment decisions in the presence of country-specific risk has, when applied to U.S. offshore import data on semiconductors, yielded some interesting information on producer behavior. The econometric estimates imply that producers adjust investment portfolios rather rapidly in response to changes in production costs, with almost half of the adjustment made immediately, 70 percent after 1 year has elapsed, and over 90 percent by the end of the fourth year.

The estimated model coefficients also seem to indicate that U.S.-duty free component/output ratios are fixed. Since the preponderant ingredient of U.S.-duty free components value is unassembled semiconductor chip, this merely confirms that the chip content of an assembled semiconductor is effectively unaffected by the wage rate chaged to the producer. The data also indicate that, while there may be some moderate degree of substitution possible between other material inputs and labor, it is very likely that these ratios

Table 10.4

Estimation Under Hypotheses of Fixed u/y Ratio, Theoretical Restrictions, and Restrictions on Adaptation Parameter

	$\lambda = 0$		$\lambda = 1$	
Coefficient:	(10.15a)	(10.15b)	(10.15a)	(10.15b)
β_1	1.55 (.17)**	same	.86 (.21)**	same
β_2	-0-	same	-.14 (.21)	same
β_3 / θ_3	.83 (.60)	same	.69 (.47)	same
β_4 / θ_4	-2.10 (.98)**	same	-1.71 (.71)**	same
β_5 / θ_5	-0-	same	.052 (.36)	same
Mexico, R_2	-0-	same	-.54 (.38)	same
Mexico, R_1	-.29 (.62)	same	-0-	same
Philippines, R_2	-0-	same	.28 (.46)	same
Philippines, R_1	-.066 (.62)	same	-0-	same
Taiwan, $R_2 + R_1$	-.31 (.24)	same	-.40 (.21)*	same
Intercept (Mexico, 1971)	.11 (.15)	-.097 (.18)	.73 (1.59)	.51 (1.57)
Taiwan, δ_i / Ω_i	-0-	same	.04 (.29)	-.019 (.40)
Korea, δ_i / Ω_i	-0-	same	.084 (.16)	.017 (.17)
Hong Kong, δ_i / Ω_i	-0-	same	-.073 (.18)	-.13 (.25)
Singapore, δ_i / Ω_i	-0-	same	.16 (.12)	.15 (.15)
Philippines, δ_i / Ω_i	-0-	same	.11 (.25)	.095 (.26)
1972, δ_t / Ω_t	.23 (.19)	.53 (.23)**	.24 (.14)*	.39 (.15)**
1973, δ_t / Ω_t	.11 (.20)	.17 (.24)	.31 (.19)	.30 (.19)
1974, δ_t / Ω_t	.043 (.21)	.33 (.24)	.33 (.25)	.45 (.22)**
1975, δ_t / Ω_t	-.30 (.20)	.021 (.23)	-.096 (.31)	.12 (.27)
1976, δ_t / Ω_t	.37 (.19)**	.47 (.22)**	.27 (.36)	.35 (.33)
1977, δ_t / Ω_t	-.11 (.19)	.34 (.22)	.14 (.43)	.47 (.39)
1978, δ_t / Ω_t	.011 (.20)	.17 (.23)	.20 (.46)	.42 (.45)
1979, δ_t / Ω_t	.21 (.20)	.38 (.23)	.41 (.48)	.57 (.47)
σ^2	.0882	.1266	.0466	.0616
σ_{12}		.0948		.0482
ρ_{12}		.90		.90

F - tests for restrictions on coefficients:

$F(24,32) = .223$ $F(13,32) = .249$

Cannot be rejected at 90% or 95% confidence levels.

are fixed without regard to the wage rate in assembly.

Producers' wage rate expectations, on the ohter hand seem to have reacted quite sluggishly to year-to-year variation in the real wage. Our estimates suggest that changes in the year 1978 were associated with substantially less investment in Taiwan in the following years; we have identified this shift with the end of formal diplomatic ties to the U.S.

Estimated coefficient $\hat{\beta}_4$ (as well as θ_4 if the duty-free components to output ratio is not fixed as P_L varies) contains information which permits us to estimate d_{pL} in (10.3), the partial equilibrium elasticity of optimal capital invested in location i with respect to the wage in location i. It is a partial equilibrium estimate of the wage elasticity of investment because the various portfolio constants incorporated into our time and country intercepts will also be altered as the rate of return in location i is changed. If investment in location i is very small relative to the size of the entire market portfolio of risky assets, however, these effects on constants common to the entire portfolio will be very small, and therefore can be ignored if we are concerned with the first-order impacts of a marginal wage change on investment in one of many production locations.

To get a consistent estimate of the wage elasticity of capital invested in semiconductor assembly, dpl, note that adding the product of our estimates of β_3 and β_1 to β_4 leaves a point estimate of $\delta\ (1 + \lambda\ )\, d_{pL}$. Using the estimates of Tables 10.2 or 10.3, (and $\lambda = 0$, $\delta = .45$), a wage elasticity of investment of about -1.7 is calculated. Capital investment in location i is moderately (but not extremely) elastic with respect to the local wage.

On the other hand, if uncertainty and country risk were not a factor in producers' offshore location decisions, this elasticity would be infinite (since only the lowest cost location would receive any investment). The moderate elasticity estimated, then, supports a model of location with the presence of diversifiable country risk as an important ingredient.

Our analysis also indicated that the share of location i in all assets invested in semiconductor production was fairly (but not extraordinarily) sensitive to changes in wage rates, with an elasticity perhaps on the order of -2. This would imply that fairly large changes in investment and production might be expected from changes in tax or wage policies that alter the return to investment in a particular location.

Next, we turn to a brief consideration of the implications of the sensitivity of optimal output and investment to changes in returns, and the rapid adjustment of actual to optimal levels, for home and host country policy.

Technical Appendix to Section 10

General Framework

To examine the geographical sourcing of production within an industry, we shall assume production managers make decisions taking their objectives to be to maximize the value of their company's stock. Since any change in the characteristics of a firm's assets that improves the potential expected utility of investors holding that stock ought to increase the market value of the stock, we shall assume that managers therefore act to maximize the expected utility of investors.

We shall also assume that the utility function contains total return from all assets held by a "representative investor" as its only argument, and that it is concave (i.e., investors are risk averse). The returns on all assets will be assumed to have a joint normal distribution.

The concavity of the utility function, the normal distribution of returns, and the maximization of expected utility all imply that expected utility maximization will result in mean-variance (Markowitz) efficient portfolios, as Tobin first pointed out. 1/ That is, for any given average return, that distribution of total wealth among assets which minimizes the variance of return around its average will be preferred. This permits us to consider only mean-variance efficient portfolios of assets when considering how investors' utility can be maximized.

We shall also assume a riskless return, paying r_0, is available to investors (for example, government bonds). Under these conditions, it can then be shown that all investors will allocate their wealth between a fixed efficient portfolio of risky assets (with the allocation among the risky assets determined only by the characteristics of the assets), and the riskless asset (with the allocation between the fixed efficient market portfolio of risky assets and the riskless asset determined by the investor's wealth and preferences). Thus, we can make use of this "separation" property, that the optimal allocation of riskily invested wealth among risky assets is independent of investor preferences and wealth. The market portfolio of risky assets will reflect these optimal choices among the risky assets.

It can then be shown that the optimal portfolio of risky assets satisfies the relation [2]

$$E(r_i) - r_o = \frac{(E(r_m) - r_o)\,\sigma_{im}}{\sigma_m^2} \qquad \text{for all } i \tag{10.A.1}$$

with r_i the return on each of i risky assets, r_m the return on the optimal efficient portfolio of risky assets as a whole, σ_m^2 the variance of the return on a dollar invested in this market portfolio, E the expectation operator, and σ_{im} the covariance of the return on risky asset i with the optimal market portfolio of risky assets.

Investment in Production Locations

The investment required for the production of a given product in a specific location will be though of as a particular type of asset, with risk and return characteristics specific to the product and its production location. Firms, by making decisions to place capital into specific lines of business and production locations, construct portfolios of assets, which are purchased by stockholders. If there are at least as many different firms as there are types of assets, an investor can construct any portfolio of assets by judiciously purchasing stock in different firms.

If, in the aggregate, firms are guided toward constructing the efficient optimal market portfolio of risky assets through their attention to stock market prices, the aggregate market portfolio of risky assets will satisfy relation (10.A.1). Note, however, that since firms essentially form arbitrary combinations of investments (since firms only serve to translate a financial investment into claims on real capital assets in this simple model), the portfolio of any single firm is indeterminate. In the aggregate, though, stock market prices will guide marginal firm investments so as to construct the efficient market portfolio satisfying (10.A.1). (In much the same way, in competitive industry with constant returns to scale, while the size of any single firm is indeterminate, the size of the industry is not.)

Suppose we invest assets with value K_i in the production of semiconductors in location i. Such an investment yields an average return (and since we will also assume constant returns, a marginal return) of

$$r_i = \pi(P_i') \tag{10.A.2}$$

with r_i the return on a dollar of semiconductor capital invested in location i; π the so-called unit "variable" profit function, giving the maximum value of output less variable costs per dollar of capital, as a function of vector P_i', containing output and input prices as its elements. The function π has certain useful properties, notably that q_i^* (profit maximizing output per dollar of capital in location i) is equal to $\frac{\partial \pi}{\partial P_Q}$ (P_Q output price), and profit maximizing use of input j per dollar of capital in location i is given by

$-\frac{\partial \pi}{\partial P_{ij}}$, with P_{ij} the price of input j in location i.

(If we take into account maintenance and replacement costs for capital, which will be assumed proportional to the value of capital, we would merely subtract a fixed constant from π defined gross of capital maintenance costs; therefore we define π in 10.A.2 as net of maintenance and replacement costs for capital. Note also that we are assuming that the price of capital goods is constant across locations, since the form of function π is <u>not</u> location-specific.)

Return r_i will be assumed to reflect a random disturbance ε_i, related to uncertainty about the costs of production, even when input and output prices and known with certainty. Wars, strikes, confiscation or expropriation of property, revolutions, hyperinflations, political turmoil and other country-specific risks are embodied in disturbance ε_i.

Thus, taking into account the location-specific risk of producing in location i, we have

$$r_i = \pi(P_i') + \varepsilon_i . \tag{10.A.3}$$

By definition,

$$E(\varepsilon_i \varepsilon_j) = \sigma_{ij} \qquad \text{all } i, j \qquad (\sigma_{ii} = \sigma_i^2) \tag{10.A.4}$$

$$E(\varepsilon_i) = M_i \qquad \text{for each } i.$$

Note that, without loss of generality, ε_j refers to the uncertainty in return of <u>any</u> other asset, not just those invested in semiconductor production.

The Optimal Portfolio

Let us assume that there are a total of N different assets, containing as a subset investments in semiconductor production in various locations. The average return to SCD investment in location i, $E(\pi_i)$, is just defined by

$$E(\pi_i) = \pi(P_i') + M_i \tag{10.A.5}$$

We shall assume that the disturbance to return on semiconductor production in location i can be expressed as the sum of the effects of underlying factors common to returns on other assets, and a unique (mean zero) country-specific disturbance δ_i that is independent of all disturbances affecting the return on all other assets. That is,

$$\varepsilon_i = \sum_{\ell=1}^{L} C_{i\ell} I_\ell + \delta_i + M_i \tag{10.A.6}$$

with the L (mean zero) indices I_ℓ of factors affecting other assets related to disturbance ε_i through fixed location-specific constants, the $C_{i\ell}$.

Then,

$$E(\varepsilon_i \varepsilon_j) = \sum_{\ell=1}^{L} \sum_{m=1}^{L} \sum_{j=1}^{N} C_{i\ell} C_{jm} E(I_\ell I_m) \quad \text{for } i \neq j \tag{10.A.7}$$

$$E(\varepsilon_i^2) = \sum_{\ell=1}^{L} \sum_{m=1}^{L} C_{i\ell} C_{im} E(I_\ell I_m) + \sigma_{\delta_i}^2$$

(with $\sigma_{\delta_i}^2 = E(\delta_i^2)$).

If we then return to relation (10.A.1), we can rewrite it as

$$(10.A.8) \qquad \pi_i - r_o = \frac{E(r_m) - r_o}{\sigma_m^2} \sum_{j=1}^{N} E\left[\varepsilon_i \; \varepsilon_j \; V_j\right]$$

with V_i and V_j the proportion of riskily invested wealth invested in assets i and j, respectively, in the market portfolio. Using relation (10.A.7) we then have

$$(10.A.9) \qquad \pi_i - r_o = \frac{E(r_m) - r_o}{\sigma_m^2}\left[\left(\sum_{\ell=1}^{L} \sum_{m=1}^{L} \sum_{j=1}^{N} C_{i\ell} \, C_{jm} \, E(I_\ell \, I_m) \, V_j\right) + V_i \, \sigma_{\delta_i}^2\right],$$

which can be rewritten as

$$(10.A.10) \qquad V_i \, \sigma_{\delta_i}^2 = \left[\frac{\pi_i - r_o}{\phi}\right] - \sum_{\ell=1}^{L} C_{i\ell} \, \Delta_\ell$$

with

$$\phi \equiv \frac{E(r_m - r_o)}{\sigma_m^2}, \text{ "the market price of risk" ;}$$

and

$$\Delta_\ell = \sum_{m=1}^{L} \sum_{j=1}^{N} V_j \, C_{jm} \, E(I_\ell \, I_m),$$ constants do not depend on the exact asset i we are examining at any moment in time.

Then, noting that total value of assets invested in location i, K_i^* is equal to $V_i W$, with W the total value of wealth invested riskily, we have

$$(10.A.11) \qquad K_i^* = \left[\frac{\pi_i - r_o}{\phi} - \sum_{\ell} C_{i\ell} \, \Delta_{\ell} \right] \frac{W}{\sigma^2_{\varepsilon_i}}$$

(with $\sigma^2_{\delta_i}$ rewritten as $\sigma^2_{\varepsilon_i}$, representing the unique and independent country-specific component of the variance of return in semiconductor production in location i)

which is just (10.1) in the text.

TECHNICAL APPENDIX TO SECTION 10

FOOTNOTES

1. See Tobin (1959), pp. 74-75. Ross (1978) provides more general necessary and sufficient conditions on the distribution of returns that allow us only to consider mean-variance efficient portfolios.

   Alternatively, restrictions on the utility function can yield similar results. See Cass and Stiglitz (1970).

2. This model is known as the Capital Asset Pricing Model (CAPM). See Fama and Miller (1972) for a more detailed exposition.

11. Implications of Diversification for Developed and Developing Countries

The framework for understanding offshore production decisions outlined in the last section, and applied to data for U.S. 806/807 semiconductor imports, raises important questions.

Some Theoretical Considerations

At the purely theoretical level, it is clear that diversification of country-specific risk by producers, when choosing production locations, will have profoundly different effects on the industrialized economy exporting components, and on the developing economy assembling them, than a decision to produce in the lowest average cost location. Instead of being a binary choice between onshore and offshore, country 1 or country 2, production at home and abroad will respond in a smooth and continuous fashion to changes in input prices in different locations. 212/

For the industrialized economy, any measure raising returns to production overseas no longer is guaranteed to increase the total value of production entering the market from offshore. First, although it is not a particularly probable outcome, it is theoretically possible for the supply of resources to be invested offshore to be "backward-bending" with respect to the return available offshore, if, as the average return on investable resources increases, the effect of increased income is to make an investor less willing to bear risk (i.e., an investor's preferences are such that his aversion to risk increases with wealth).

Second, even if the amount of resources invested offshore were to increase with return offshore, if the source of the increased return was accompanied by a shift in relative factor prices offshore, it is possible that substitution of capital for other factors of production could have the perverse effect of lowering the output produced with the increased stock of capital located overseas. For example, suppose a drop in wage rates offshore were the source of the increased return overseas. It is not impossible to imagine that, if capital and labor were complements (and the empirical work of the last section supported this as a possibility), substitution of capital and labor for material inputs could actually raise the capital/output ratio sufficiently as to cause a net drop in output, even as offshore investment was increasing.

These examples of perverse effects are probably unlikely, but nevertheless possible. If we were to assume the most likely case -- that resources invested and output produced offshore increase with offshore return -- then the supply of capital to be invested in the offshore location by home country producers will slope upwards with the rate of return in that location.

As is well-known, <u>213</u>/ an upward sloping supply of foreign capital means that an optimal host-country policy toward foreign investment will tax the returns on foreign capital, with a tax rate dependent on the elasticity of foreign capital supply. However, as a careful reading of the last section will confirm, this elasticity of supply will, in general, depend on a great many factors, including all the determinants of the market portfolio of assets, and the technology of the particular product being produced offshore. In particular, every product will have a potentially different optimal tax rate on foreign investments in its manufacture.

For many countries and products, an optimal tax policy would then require intersectoral tax rate discrimination, based on the characteristics of the product being produced and the nationality of the producer. Furthermore, taxes would have to be continuously adjusted as time passed, technology changed, and other determinants of the market portfolio of investments evolved.

If such adjustments are possible, it is easily shown that an optimal host country policy would tax foreign investments at rate t given by

(11.2) $t = 1 - \dfrac{\eta_{kr}}{1 + \eta_{kr}}$, η_{kr} the elasticity of capital supply with respect to the net rate of return. Foreign firms would pay a wage equal to the marginal social opportunity cost of withdrawing a worker from the domestic economy. 214/

Such constant change and variability in tax rates might, in fact, increase country risk. Taxes, after all, are a mechanism for the social expropriation of output, and frequent or discriminatory change increases the threat of expropriation as a business risk. The essence of a 'stable' investment climate is a guarantee that taxes on profits will be fixed at some known and stable level.

Also, for a variety of institutional reasons, it is generally very difficult to tax the manufacture of different products at different rates. 215/ Even if it were possible to do so, a great deal of risk would then be created for the investor, since, as the product mix produced inevitably evolved and changed, a revision of the industrial classification of output by the tax authorities would be necessary. Finally, since the elasticity of capital supply with respect to the rate of return to production in country i is an empirical magnitude that must be determined by authorities, it may be impossible to estimate with any precision without observing the operations of foreign manufacturers already in place, which generally will not exist until guarantees of a fixed tax rate and other rules of investment are made.

Thus, because information on the elasticity of the supply of capital with respect to return is only available through direct observation, because foreign capital generally required guarantees of fixed tax rates as a precondition for investment, because continuous adjustment of tax rates would create a perception of instability in the business 'climate' for foreign investment, and because it is institutionally impractical to create and administer a structure of product-specific tax rates on foreign investment, the implementors of a tax on foreign investment earnings probably must content themselves with setting a fixed tax rate on profits for all manufacturing with (perhaps) occasional marginal rate adjustments taking place over time. To some extent, investor-specific variation in effective tax rates can be achieved through the granting of tax concessions to individual projects, but such individual concessions create costs for the entire system by creating potential for abuse and corruption.

In practice, then, an optimal tax policy can probably only be approximated when a single tax rate structure for foreign investment is designed and administered. Given that a first-best tax policy using discriminatory tax rates cannot be achieved, a second-best wage policy [illegible] the gain to the host country from foreign investment. This follows from the fact that -- for some fixed tax rate -- the supply of capital (and the demand for labor) will be an upward (downward) sloping function of the wage rate, which is easily varied across industries and over time. Some offshore countries, for example, have an industry-specific minimum wage structure in place, and wages are continuously adjusted over time through the political economy of labor markets and government regulation.

The significance of a downward-sloping demand for labor in a developing economy is that it then has some element of monopoly power it can exercise. In the absence of taxes, it should set the wage charged to offshore producers such that the marginal revenues received from selling an additional laborer's services to the foreign-owned export platform are just equal to the marginal social cost of withdrawing that worker from the domestic economy. [215] Since marginal revenue will be less than the wage charged to exporters (because of the downward-sloping demand for labor), this clearly implies that the wage should be fixed above the opportunity cost of labor in the domestic economy, if an optimal policy is to be followed. In particular, when the investment is not subject to taxes (i.e., enjoys an unlimited tax holiday), the wage for any sector should be set such that

$$(11.2) \quad PL = C \left(-\eta_{LP_L} / 1 - \eta_{LP_L} \right)$$

with Pl the wage charged to foreign producers, C* the marginal social opportunity cost of labor, and η_{LP_L} the wage elasticity of sectoral labor demand faced by the country playing host to offshore investment.

If, on the other hand, tax rates were to be continuously adjusted in an optimal fashion, all profit greater than that actually required [illegible] influx of foreign investment would be taxed off, and the marginal net revenue from hiring out a marginal worker to the foreign assembly plant just equal to the wage received. The loss in the value of aggregate wages (and increase in gross profitability) due to the drop in the wage rate required to stimulate the hiring of an additional worker, would be exactly offset by an increase in the tax rate and tax collections (and would leave net profitability unchanged).

Empirical Implications

The results of the empirical models of the last two sections make a certain amount of sense, and have a reasonable policy content. First, recall that δ, the capital stock 'adjustment' parameter, was reasonably high (about .45). As remarked before, this means that about seventy percent of the adjustment to optimal capital investment levels will be achieved after a year, and better than ninety percent of the adjustment made after three years. This is entirely consistent with the relatively light and easily mobile capital investments traditionally used in labor-intensive assembly methods.

Our results also supported (and we were unable to reject) the hypothesis that duty-free U.S. content was essentially invariant to the wage charged for assembly labor. This suggests that manipulation of the wage, the main policy parameter available to authorities in the exporting country, cannot be an effective means of reducing the duty-free U.S. component content of production. On the other hand, there was some indirect evidence that raising wages may increase the use of dutiable materials, including perhaps those produced locally, as more material-intensive production materials may have been adopted. These effects, however, are rather hypothetical, and we cannot reject the presumption that the wage has no effect at all on material content.

At the same time, the long-run elasticity of production in country i, with respect to the wage was quite high, on the order of -2. (As before, note that this is a partial elasticity, valid at the margin for a small producing country, for whom changes in returns have virtually no impact on the aggregate market portfolio of investments.)

The long-run scope for action by a small country hosting offshore SCD production, then, may be quite limited. The one policy variable that is easily manipulated is likely to have little impact on the imported content of the product, and a very large impact on the market share of the country.

Still, there are positive aspects. The reasonably high elasticity of output with respect to the wage also may mean that a substantial monopoly rent can be extracted by correctly setting taxes or wages. Suppose, for example, that the underlying production technology displays a fixed capital/labor ratio, and that the country is a 'small' producer. Then, the coefficient of the log of the offshore wage in the output equation of section 10 is just the long-run elasticity of SCD assembly labor demand faced by that country; use of (12.2) suggests a hefty wage differential -- on the order of 50 to 100 percent over the opportunity cost of labor in the domestic economy -- ought to be charged, in the absence of taxes.

If a discriminatory tax rate can be charged, then the wage ought to be set at the domestic opportunity cost, and the tax rate set according to (11.2). While we do not have any direct information on Nkr, our estimates suggest that it is greater than 2;[21] at that value, the tax rate ought to be set at about one-third. Since that is above levels charged by most Asian offshore countries, a second-best policy would then charge higher (than social opportunity cost) wages to SCD assemblers to maximize national gain.

Since many offshore countries do, in fact, charge minimum wages that are higher than levels within the domestic economy, there is some evidence that the benefits of such policies may already have been evident to national planners. 218/

Appendix to Section 11

Optimal Tax and Wage Policy fo an Offshore Location

The total benefit to a host country is given by

$$B = \phi K + P_L \ell K - rK - C(\ell K)$$

with ϕ gross profit per unit of capital;

K capital stock, a function K(r) of r, net profit per unit capital;

P_L the wage in assembly production;

ℓ the labor to capital ratio;

C the domestic social opportunity costs of transferring labor out of the domestic economy and into the offshore production enclave; C' is marginal social cost;

r net profit per unit capital is just under $(1-t)\phi$, t the tax rate.

Differentiating B with respect to r, we have

(11.A.1) $$\frac{\partial B}{\partial r} = (\phi + (P_L - C')\ell - r)K' - K$$

$$\frac{\partial B}{\partial P_L} = (P_L - C')\frac{\partial \ell}{\partial P_L}K$$

Note that, with constant returns, ϕ and 1 are functions of input and output prices only; we have also made use of the fact that $1 = \frac{-\partial \phi}{\partial P_L}$ (this result is a variant of Shepherd's lemma).

As a necessary condition for an optimal policy, set both of the derivatives in (11.A.1) equal to zero. Clearly, we must have $P_L = C'$, the wage equal to social opportunity cost, and

$$(11.A.2) \qquad r = \phi \frac{\eta_{kr}}{1 + \eta_{kr}}, \quad \eta_{kr} \text{ the elasticity of } K$$

with respect to r.

Substituting for r we then have

$$(11.A.3) \qquad t = 1 - \frac{\eta_{kr}}{1 + \eta_{kr}} \quad \text{for the tax rate.}$$

Now suppose the tax rate is fixed. Net return r is then linked to the tax rate (since it equals $(1-t)\,\phi$), and

$$(11.A.4) \qquad \frac{dr}{dP_L} = -(1-t)\,\frac{\partial \phi}{\partial P_L} = -(1-t)\;1.$$

Differentiating B with respect to the only remaining policy instrument, P_L,

$$(11.A.5) \qquad \frac{dB}{dP_L} = \frac{\partial B}{\partial P_L} + \frac{\partial B}{\partial r}\,\frac{dr}{dP_L}$$

$$= (P_L - C')\,\frac{\partial \ell}{\partial P_L}\,K + \left[\frac{\partial B}{\partial r}\right](-(1-t)1)$$

using (11.A.1) and (11.A.4).

Setting (11.A.5) equal to zero, and solving for $(P_L - C')$, we have

$$(11.A.6) \qquad P_L - C = \frac{(1-t)\,\ell}{\left(\frac{\partial \ell}{\partial P_L}\right) K}\;\frac{\partial B}{\partial r}$$

This will have the same sign as $-\frac{\partial B}{\partial r}$ (since $\frac{\partial \ell}{\partial P_L}$ must be negative).

So when increasing the tax rate (and lowering r) would have resulted in a welfare gain, P_L will exceed C'. When the tax rate is above the optimum, P_L will be below marginal opportunity cost C'.

In the special case when $t = 0$ (and $\phi = r$), (11.A.6) becomes

$$(11.A.7) \qquad P_L = C' \frac{-\eta}{1-\eta}$$

where is the elasticity of labor demand with respect to the wage

$$= \frac{d(\ell K)}{d P_L} \frac{P_L}{\ell K} = \frac{\partial \ell}{\partial P_L} \frac{P_L}{\ell} - \frac{P_L \ell K'}{K} .$$

Finally, suppose wages charged to offshore foreign investors were fixed, by social and political constraints, at a level above marginal social opportunity cost C' (i.e., $P_L - C'$ is positive and fixed). Then, setting $\frac{\partial B}{\partial r}$ in (11.A.1) equal to zero, we have

$$(11.A.8) \qquad r = \frac{\eta_{kr}}{1 + \eta_{kr}} \left(\phi + (P_L - C')\, 1 \right)$$

Comparing this expression with (11.A.2), it is clear that the optimal tax rate will be set at a level below that which would prevail if both wages and taxes were set by policymakers.

12. Effects of Offshore Semiconductor Production on the Host Economy

In an idealized world of perfectly frictionless, competitive, and unregulated markets for economic resources, there would be little difficulty in evaluating the effects of offshore production activity on national welfare in the host economy. Since the prices of all national resources furnished to an offshore operation would, under those circumstances, fully reflect the marginal value of those resources in the national economy, the net gain to the host would be the increase in the productivity of national resources due to the inflow of foreign capital and/or technology plus whatever revenues would be secured through the application of taxes to the returns received by foreign capital and technology. The analysis of the last section focused on the optimal tax level to be set when the host faced an upward-sloping supply curve for foreign capital (or when the tax policy cannot be used in a discriminatory manner, the second-best optimal wage to be fixed).

Reality, however, requires that we consider the effects of such operations in a more complex framework. Because markets for capital and foreign exchange often tend to be thin and highly imperfect in developing economies, market prices for those resources often do not reflect marginal social costs. For political, structural, and institutional reasons, the wage paid in a particular sector of the economy may exceed, or fall short of, the social marginal return to an hour of labor. Because tariffs, controls, taxes, and subsidies alter the market prices of goods and services, those prices will no longer be accurate guides to the social costs of the resources they use. 219/

In evaluating the impacts of offshore manufacturing on the domestic economy, a host government is likely to focus on five major sets of socioeconomic effects. First, because most developing economies are faced with significant problems of open unemployment and underemployment, the effects of offshore operations in absorbing an excess supply of unskilled labor are bound to be of fundamental importance. Second, because foreign exchange is generally a scarce (and often, rationed) commodity in these host economies, the net impact on the balance of payments, and the availability of foreign exchange, will be of great importance. Third, many developing countries have selected industrialization as an explicit development strategy, and the contribution of offshore manufacture to this process will be of interest. Similarly, the possible importance of this type of foreign investment in transferring more advanced technology to the developing areas ought to be considered. Finally, the possible long-term implications of orienting the industrial economy to foreign markets and technical developments, over which the host has little or no control, raises the issue of the effects of this type of manufacture on the stability of the host economy, and its dependence on foreign markets.

Employment

While reliable and detailed information is difficult to obtain, available data do allow us to draw some conclusions. Table 12.1 summarizes available information on employment in the electronics industries of the major Asian "offshore" countries. It is clear that while employment in the electronics sector has grown very rapidly in all of these countries, it absorbed a fraction of the working age

Table 12.1

Significance of Employment in Asian Electronic Industries

	Employment in Asian Electronic Industries (1000 Employees)						Potential National Labor Force, 1977 * (1000s)	Percentage of Labor Force in Industry, 1977 (%)
	'70	'71	'72	'73	'75	'79		
Korea				86		180	21,600	33
Taiwan				98		230	10,700	27
Hong Kong	37		41			94	3,300	57
Singapore			27			60	1,300	32
Malaysia	6	7				55	7,000	20
Philippines					21	35	22,400	15

* Total population 15-64 years of age.

Sources: Potential National Labor Force and Percentage of Labor Force in Industry from World Bank, World Development Indicators, (June, 1979), Tables 17, 19.
Employment in Electronic Industries from Japan Electronic Machinery Industry Association (1980), p. 180; Electronics, December 7, 1970; December 4, 1972; Suh (1975), p. 117.

population ranging from about four-fifths of a percent (in Malaysia) to close to five percent (in Singapore). It was most important in Singapore and Hong Kong, followed by Taiwan and Korea, and still a relatively minor source of jobs in Malaysia and the Philippines. Since (except in Hong Kong) industrial employment amounted to from about 15 to 30 percent of employment, however, electronics was considerably more important (in relative terms) as a source of industrial employment.

Because electronic component production is only a (substantial) fraction of electronics output in most of these countries, and semiconductor output of offshore affiliates a smaller fraction, these figures overestimate the employment impact of offshore semiconductor employment in the major Asian producer economies. The only really solid figures on offshore employment (by U.S. semiconductor producers) appear in the 1977 Benchmark Survey of U.S. Direct Investment Abroad. 220/ That survey lists data for "electronic component" -- producing affiliates of U.S. firms in a number of regions. For Asia and the Pacific (excluding Japan, Australia, and New Zealand), however, exports to the United States accounted for some 83 percent of sales. When checking data on U.S. imports of electronic components from the Far East (excluding Japan) in 1977, one finds that some 92 percent of these imports consisted of semiconductors. 221/ Thus, electronic component production by U.S. affiliates in Asia in 1977 was almost exclusively devoted to the manufacture of semiconductors; we shall therefore use this data on the Asian operations of U.S. affiliates as a close proxy for those of U.S. offshore semiconductor facilities in 1977.

Table 12.2 summarizes this information on employment by U.S. electronic component affiliates in 1977, along with similar data on Japanese affiliates in 1979. The U.S. data are also broken out separately for majority-owned foreign affiliates (MOFAs). While the Japanese employment is almost entirely concentrated in Asia, substantial U.S. electronic component employment can also be found in Latin America and Europe. Little of this U.S. output is exported to the U.S. from Europe (less than 3%); in Latin America a substantial percentage (75 percent) is exported to the U.S., but little consists of semiconductors. In the Japanese firms, probably only 10,000 to 20,000 of the Asian component employment is related to semiconductors (see Section 8).

At any rate, Table 12.2 suggests an upper limit of about 100,000 on employment by U.S. Asian offshore semiconductor affiliates in 1977. To this must be added any employment by non-affiliated local contract assemblers working for U.S. firms; this was probably reasonably small in relation to the overall figure and 100,000 is probably a reasonable estimate of all U.S. -- related offshore semiconductor employment in Asia in that year.

It would be interesting to break down this employment by country, so as to make a comparison with Table 12.1 and guage the employment impact by country. The data, unfortunately, are not sufficiently disaggregated to do so. However, all U.S. electrical equipment employment in developing Asia and the Pacific in 1977 amounted to some 158,000 workers (of which 101,000 were in electronic components) which is given by country in Table 12.3. Again, these ought to be considered approximate upper limits on offshore employment in Asia by U.S. SCD

Table 12.2

Foreign Employment of Foreign Affiliates
(1000 Employees)

Electronic Component Producers (SIC 367)

	U.S. Firms, 1977		Japanese Firms, 1979
	MOFAs Only	All Affiliates	All Affiliates
All Foreign Employment	185	219	99
Europe	52	62	.1
Japan	3	NA	-
Other Asia and Pacific	95	101	89
Latin America	24	37	5
North America	-	-	1
Home ± Industry Employment, Electronic Components		374	228[1]

Source: For U.S., U.S. Department of Commerce, Bureau of Economic Analysis, U.S. Direct Investment Abroad, 1977 (Washington, April 1981)
For Japan, Japan Electrical Machinery Industry Association

Home Industry Employment from U.S. Census of Manufactures, 1977 and U.S. Dept of Commerce, Country Market Survey, Electronic Components - Japan, (Washington, 1979).

1. For 1978

Table 12.3

Employment of U.S. Affiliates Producing Electrical Equipment (1000 Employees)

Hong Kong	19
Indonesia	5.3
Malaysia	24
Philippines	8.9
Singapore	25
South Korea	8.5
Taiwan	48
Developing Asia and the Pacific	158

Source: U.S. Department of Commerce, Bureau of Economic Analysis, U.S. Direct Investment Abroad, 1977 (Washington, April 1981) producers. As can be seen, the great bulk of U.S. operations are located in Taiwan, Singapore, Malaysia, and Hong Kong. By comparing these figures to Table 12.1, it seems safe to argue that at least half of electronics employment in Singapore (most, probably, in semiconductors), and Malaysia was associated with U.S. subsidiaries and perhaps on the order of a quarter of electronics employment in Hong Kong and Taiwan owed to U.S. subsidiaries.

Two other, rather fragmentary, sets of information, give us some indication of how offshore semiconductor employment has grown overtime. First, Table 12.4 documents offshore employment by major semiconductor firms of all nationalities in 1971 and 1974. 222/ These figures also represent upper bounds on semiconductor employment, since they often refer to assembly operations which produced electronic output other than semiconductors. They suggest that developed-country semiconductor producers of all nationalities employed under twenty thousand workers in their offshore semiconductor assembly operations in 1971, and perhaps three to four times as many workers in 1974. Roughly three-quarters of the employment was by U.S. firms in 1971; roughly 85 percent was American in 1974. The greatest growth occurred in Singapore and Malaysia.

The other source of information on the growth of offshore employment is a 1979 study by the U.S. International Trade Commission of the U.S. integrated circuit industry. In it, U.S. IC firms responded to a questionnaire with information on their domestic and foreign employment, presented in Table 12.5. The numbers on foreign employment in semiconductor manufacture include European manufacturing facilities, as well as the "offshore" operations in Asia described

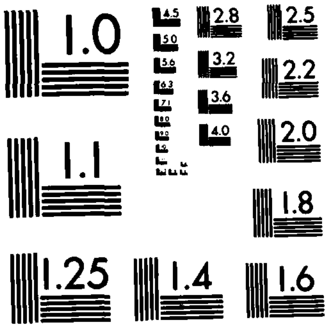
Table 12.4

Offshore Employment of Major SCD Producers
1971 and 1974
(1000 Employees)

	Nationality of Producer							
	U.S.		European		Japanese		All	
Location	1971	1974	1971	1974	1971	1974	1971	1974
Singapore	5.7	18	.75	3.0			6.5	21
Korea	4.8	13				4.3	4.8	13
Malaysia		14		1.8		1.2		16
Hong Kong	2.0	5.4	3.0	2.9			5.0	8.3
Mexico	2.2	NA						2.5
Indonesia		2.5						2.5
Taiwan	1.7	4.5	.85	1.0			2.6	5.5
Thailand		2.0						2.0
El Salvador		1.8					1.8	
Philippines				2.0				2.0
TOTAL	16	61	4.6	11		5.5	21	72

Source: UNCTAD (1975), pp. 17-18.
Data refer to employment in facilities producing semiconductors, but many also assemble other electronic products.

AD-A123 325 THE INTERNATIONALIZATION OF INDUSTRY ANNEX B OFFSHORE 3/4
PRODUCTION IN THE I..(U) DEPARTMENT OF STATE WASHINGTON
DC OFFICE OF EXTERNAL RESEARCH.. J GRUNWALD ET AL.
UNCLASSIFIED NOV 81 FAR-284-GP-ANNEX-B F/G 5/3 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Table 12.5

Foreign and U.S. Employment of U.S. IC Producers 1974-1978

	1974	1975	1976	1977	1978
1) Foreign SCD Employment (1000s):	70	59	78	81	89
2) % of (1) working in Manufacture of ICs:	63	64	68	69	73
3) As % of (2), Production Workers:	94	93	93	93	93
4) (1) as % of U.S. SCD Employment of Sample:	81	87	108	103	100
5) As % of U.S. Workers, % in Manufacture of ICs:	73	69	68	71	74
6) As % of U.S. IC Workers, Production Workers:	53	60	64	63	63

Source: U.S.I.T.C. (1979), PP. 100-101.

above, and exclude the employment of U.S. firms which manufacture semiconductors other than ICs.

The survey shows over 80,000 in foreign SCD employment in 1977, by U.S. IC producers, of which almost 70 percent was in the manufacture of ICs. Some 93 percent of the foreign employees in IC production were production workers. Roughly the same proportion of domestic SCD employment was in IC production, but a much smaller proportion (under 2/3) were actually on the production line. Since total U.S. SCD employment in 1977 was 114 thousand, 223/ the proportion of U.S. semiconductor employees covered in this sample was close to three-quarters. The figures of Table 12.5 also indicate a significant increase in the relative importance of overseas employment during and after the 1974-75 recession.

We conclude then, that all the statistical information examined indicates a very large increase in offshore employment in the production of semiconductors between, say, 1971 and the mid-1970s, and a much more moderate growth after the end of the 1974-75 recession. If we had to venture an educated guess on the size of the offshore labor force in semiconductors in Asia in 1977, it would be in the neighborhood of 100,000 workers, and certainly no more than 120,000 as an upper limit.

While this, in the aggregate, is a respectable number of jobs, it is at best a marginal contribution to employment absorption for most Asian countries. It might be argued that there are "multiplier" effects, since offshore assembly operations might stimulate the growth of industries using the assembled components in exports of other electronic goods. The low transport costs for semiconductors argue against this point, however; and even if we were to consider all electronics employment in those offshore countries, the absorption of employment is still marginal when compared to the size of the working age population.

The exceptions to this generalization seem to be Singapore and Malaysia, where semiconductor-related employment is the major component in electronics employment, which, in turn, is a major portion of the industrial work force. But, in general, offshore semiconductor assembly operations probably have a relatively minor impact on employment in most Asian economies.

Before turning to other possible impacts, we should also remark that offshore assembly of semiconductors, like the offshore manufacture of other products described elsewhere in this book, uses a predominantly young, female labor force. 224/ To a certain extent, such operations may exacerbate LDC employment problems by encouraging labor force participation by demographic groups not normally economically active. 225/

Balance of Payments and Industrialization

To evaluate the effect of offshore production on the host economy's foreign exchange position and balance of payments, a conceptually precise approach would calculate the domestic resource costs of the nationally-produced inputs used in assembly per dollar of foreign exchange produced, and compare the calculation with the domestic resource costs of earning a dollar of foreign exchange in alternative activities. 226/ If the only national input used were labor, then net inflow of foreign exchange would equal employee compensation, plus whatever taxes were collected by the host on the profits of offshore operations. The domestic resource costs of a dollar of foreign exchange would just be the wage bill, divided by this latter sum multiplied by the market exchange rate. If the price charged for labor services supplied to offshore producers differed from the opportunity cost of labor used in the national economy, the wage bill in the numerator would have to be corrected for the divergence of market price from marginal social cost. Effectively, the wages of workers and income taxes are paid in foreign exchange, at a social cost to the national economy of the value of the workers foregone services in the national economy. If workers are paid more than is the case in the national economy, costs per dollar of exchange will decline.

On the other hand, if national inputs other than labor are used, the calculation will have to take into account the social costs of directing those resources from the national economy into the export enclave. A calculation of the domestic resource costs of assembly for export, then, will be greatly affected by the amount and type of national resources used. In particular, an export-oriented assembly operation using capital drawn from local capital markets (for example, if a national entrepreneur sets up a factory that subcontracts assembly operations with foreign principals) may have much higher domestic resource costs, especially if capital is very dear, as is usually the case in a developing economy. Also, if the assembly operation (even if totally financed by foreign capital) requires infrastructural investment by the host country, the cost of those investments must be added into the domestic resource costs of the foreign exchange.

The little empirical evidence that exists suggests that foreign-owned semiconductor assembly operations use significant amounts of non-labor national inputs. This can be seen in Table 12.6, which breaks down the income and costs of U.S. electronic component affiliates in Asia into imported and national components. As remarked before, the output of these affiliates consists, overwhelmingly, of semiconductors. The table shows that imports from the U.S. account for over forty percent of sales, 227/ and net profits, fees and royalties another five percent. The remaining 54 percent of sales is paid out in employee compensation, taxes, utilities and overhead and purchases of inputs. This latter figure may have to be reduced (in calculating the net inflow of foreign exchange) if inputs are imported from other countries, which is not known from the available information.

To calculate domestic resource costs, the various components of the 54 percent of sales composed of national inputs would have to be identified and priced at the correct shadow prices for those inputs. Unfortunately, lack of information on the structure of these costs, and the correct shadow prices prevents us from doing so.

We can, however, gauge the importance of semiconductor exports in terms of gross flows of foreign exchange. Table 12.7 displays the value of semiconductor production and exports in a number of Asian countries in 1976, in comparison with manufactured exports and merchandise exports. For Singapore, Taiwan, and the Philippines, semiconductors are a large and significant portion of manufactured exports. The situation in the Philippines in recent years is even more dramatic, as exports of semiconductors zoomed to $289 million by 1979. 228/

Table 12.6

Income and Costs of U.S. Foreign Affiliates, Electronic Components, Less Developed Asia and Pacific 1977

	Million $	% Total Income
TOTAL INCOME	1622	100
- Imports of Inputs from U.S.	661	41
- Direct Investment Income	54	3.3
- Remittances of Fees and Royalties	22	1.4
= Net Inflow of Foreign Exchange	885	54.3
of which:		
Employee Compensation	195	12
Operating Expenses, Overhead, Taxes, Inputs	690	42.5

Source: For U.S., U.S. Department of Commerce, Bureau of Economic Analysis, U.S. Direct Investment Abroad, 1977 (Washington, April 1981)

(Note: Reinvested earnings are not subtracted from direct investment income, on the assumption that they would be close to zero for an investment with stable capacity.)

Table 12.7

Importance of Semiconductors in Manufactured Exports 1976

Country	SCD Production (Million $)	Active Component Exports to DCs* (Million $)	of which, % to		Manufactured Exports	
			U.S.	Japan	(Million $)	(as % of all exports of merchandise)
Hong Kong	168	113	80	5	7,882	97
Singapore	314	313	79	1	3,020	46
Taiwan	401				6,922	85
Philippines		81	73	17	608	24
Malaysia		252	82	7	824	16
Korea		261	64	25	6,770	88
Indonesia		13	90	7	130	2
Sri Lanka		1.3	0	100	76	14
Thailand		4.7	98	2	572	19
Brazil		11	85	0	2,500	25
Mexico		127	98	.2	1,010	31
El Salvador		35	85	.2	209	
Barbados		1.5	99	0		
Haiti		3.3	78	0	43	51

* Includes tubes, as well as SCDs, as reported in import statistics of 24 developed countries.

Source: For SCD production, U.S. Department of Commerce, Country Market Surveys - Electronic Components (Washington, 1979).
Active component exports are SITC 729.3 from U.N. Statistical Office, Supplement to World Trade Annual, 1976.
Manufactured Exports Data from World Bank, World Development Indicators (Washington, 1979).

While the precise contribution of offshore semiconductor exports to the foreign exchange position of the host economies is unclear, since the costs of securing foreign exchange cannot be calculated with precision and compared to alternative activities, it is clear that they are a substantial source of foreign exchange for those economies. They are also a major factor in the industrialization of those economies, as can be seen in the significant portion of manufactured exports they account for.

Transfer of Technology

Discussions of the transfer of technology through the offshore operations of multinational firms tend to focus on two distinct sets of issues. The first is whether or not workers in these firms gain valuable skills and industrial work discipline through their experiences. This issue is discussed in great detail 229/ elsewhere in this book. The only point to be added here is that, as remarked earlier, 230/ an assembler reaches peak efficiency after about two to three months of experience, which does not indicate a particularly difficult level of skill is attained.

The second issue, and by far the most intriguing from the viewpoint of the host, is that valuable process and product technology is transferred as nationals from the host country observe the technology of production, distribution, and sales. Semiconductor assembly using manual techniques is not a particularly difficult industrial process, and nationals from various "offshore" countries have set up contract assembly plants, relying upon subcontracting arrangements with developed country firms for their business volume.

Firms in the Philippines are particularly well known as independent subcontractors in semiconductor assembly. 231/

While it may be argued that the value of this sort of simple assembly technology is low, the increasing complexity of the operations performed and equipment used offshore are upping the technological ante. Discrete semiconductors were being manufactured by local producers in Asia by the early 1970s 232/ and more complex integrated circuits chips were being produced by the late 1970s. 233/ American firms increasingly began to locate complex testing equipment in Asia in the 1970s, and most recently, automated assembly equipment. 234/

On the other hand, it is not clear that the offshore assembly operations had any clear relationship to the technology used by local producers in chip manufacture. Gold Star Semiconductor, of Korea, which is one of the few (non-Japanese) Asian firms to produce its own chips, is a joint venture with ATT's Western Electric manufacturing arm. 235/ The three Hong Kong-based manufacturers who recently started installing IC capacity obtained their technology by sending engineers to the U.S. for training, and by importing production engineers. 236/

Thus, while it is true that local entrepreneurs have successfully started contract assembly plants for semiconductors, and that this may have been related to experience in and observation of the successful offshore operations of foreign firms, 237/ it is also clearly true that assembly experience is limited relevance to the manufacture of the heart of the device, the etched silicon chip. It is questionable just how much technology can be transferred without the educational and research infrastructure that is required for the successful application of technology. In fact, the experience of Japan would seem to indicate that technology can be acquired successfully without direct investment, as long as the skills and manpower resources that are needed to transmit it exist and access to proprietary knowledge can be negotiated. On the other hand, all the investment in the world will not transmit technology if the educated manpower required as a medium of transmission does not exist. 238/

Stability/Dependence

The final set of issues we ought mention when discussing impacts on a host economy of offshore assembly relate to the degree of stability of the level of economic activity, and the dependence on foreign markets, created when resources are transferred into an offshore assembly enclave. If the costs of shifting resources between activities were nil, this would not be an issue. But unemployed or displaced workers, for however long they remain in that state, and fixed infrastructural or industry-specific investments, are costs to the the economy when demand drops in the industry in which those resources are employed. Hence, variation in the level of output imposes costs on an economy, and the stability of demand is a factor with economic value when evaluating the return to committing resources to an industry.

This economic cost of instability also imposes a certain amount of economic and political dependence. If demand can be affected by the decisions of some group, that body has a degree of bargaining power in its relations with the economy facing that demand. Rather than consider the costs of shuffling resources about, it may be more worthwhile for host country policy-makers to make economic concessions of a lesser cost.

This latter sort of dependence does not seem an important feature of the international semiconductor industry, because of the fiercely competitive nature of the industry (as opposed, say to some of the natural resource industries). There have been few suggestions that foreign offshore assembly operations, acting in concert, have been able to exert influence over host country economic policy decisions by threatening to close or reduce their operations. 239/

On the other hand, cyclical instability is an important feature of electronics demand. An economy that places a major portion of its labor force, or its capital, in an export-oriented electronics industry may face a severe cost when the trough of the world business cycle hits. Also, the low transport costs and high mobility that led to the original overseas migration of the semiconductor industry will make local production levels exceedingly sensitive to changes in the costs and attractiveness of a particular host country, and therefore, somewhat unstable. Historically, variations in costs and political conditions have led to drastic and rapid changes in the international distribution of assembled output.

Thus, instability in demand -- for individual host economies as a consequence of their economic decisions and those of their competitors, and for the world economy as a whole -- is likely to be an important factor in determining the optimal amount of national resources (labor and capital) to commit to semiconductor assembly. When the cost of adjusting resources among sectors is reasonably low, however, as may be the case for the unskilled labor used in assembly, and when the overall level of employment (and potential unemployment) is small, as appears to be the case in the Asian countries we have examined, it will probably be of only marginal significance.

This reasoning implies that the less developed host economies may be playing a risk-sharing role in the world semiconductor economy, spreading among themselves the consequences of variations in world demand that would otherwise be felt by workers in the home semiconductor industries of the multinational firms that dominate the industry. This very naturally leads us to consider the effects of offshore production on the industrialized countries that serve as markets for this international trade.

13. Impacts on the Home Economy

The export of semiconductor assembly tasks to offshore plants has also had significant effects on the structure of the industry in the industrialized countries where it is based. In an idealized world of frictionless competitive markets, the benefits of that movement offshore to the home economy would be measured by the lower prices paid for assembled devices by producers, which in turn are reflected in lower prices to consumers for the final good which use them as inputs (and ignoring distributional questions) 240/

In a real world economy with rigidities, adjustment costs, and a host of structural and institutional imperfections, however, the question of the effects of this international transfer is not so easily resolved. 241/ Changing the number and mix of workers in an industry may impose social costs on distinct groups within the economy. If there are displaced workers, they will have to seek new employment, retrain, or perhaps even face involuntary unemployment. So it may be of interest to investigate what precisely, the effect of offshore assembly on the domestic labor force will be.

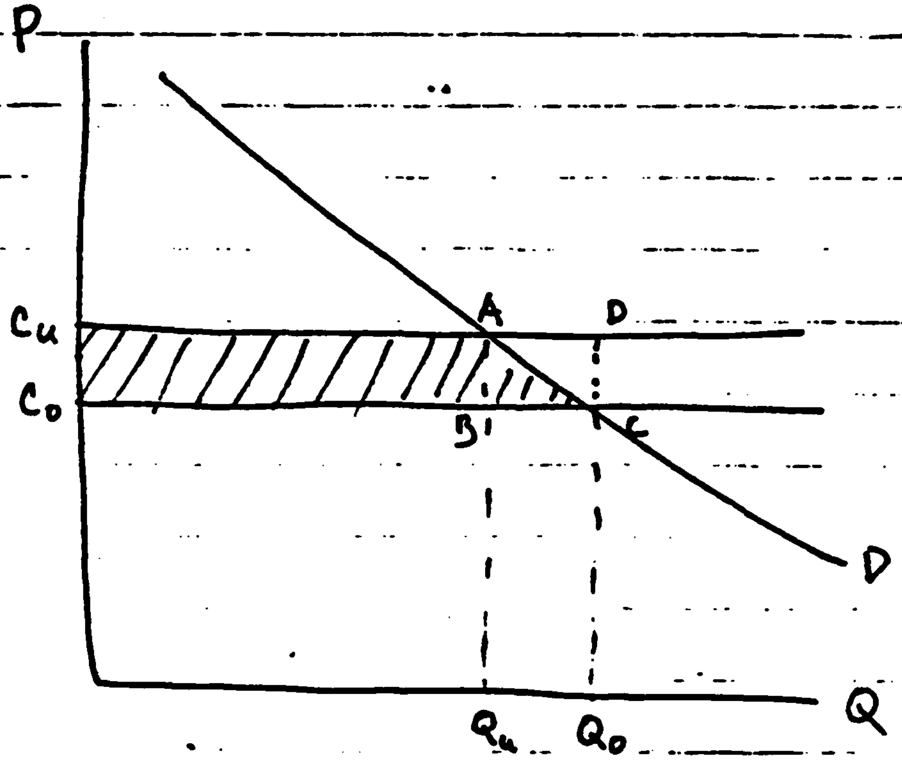
In this section, we will evaluate these effects. Because useful data are only available in detail for the United States, and because, as we have seen, the United States is the only national semiconductor market in which offshore production is the dominant feature of supplies to that market, we will only look at effects on the U. S. industry.

The Economic Benefits of Offshore Production

Figure 13.1 displays the theoretical framework we will use to construct some (mainly illustrative) social cost-benefit calculations. We assume all resources used in assembly (onshore and offshore) are available in perfectly electronic supply to a competitive semiconductor industry, and that there are constant returns to scale in assembly. D is the demand curve for semiconductors as an input to the consumer goods industry. 242/ Cu is cost of a finished semiconductor when manufactured in the U. S. , Co the cost with offshore assembly, Qu and Qo the demands for semiconductors with prices set equal to the respective costs.

With these assumptions, the benefit received by consumers, in the form of price reductions for goods using semiconductors, can be measured by the increase in consumers surplus in the final goods market, given by the shaded trapezoid C_u C_o B A in Figure 13.1. 243/ That is, suppose cost were to drop from C_u to C_o . Then a savings of C_u C_o B A on semiconductor inputs would be immediately passed on to consumers in the form of cost reductions. Because of the drop in price, furthermore, more semiconductors will be used (per unit of consumer goods, if this is substitution in production as well as in the greater volume of consumer output demanded at lower prices). Because some producers and indirectly, consumers, would have been willing to pay more than C_o for some of the semiconductors they used, triangle ABC must also be added to C_u C_o B A to get the net social benefit of reduced semiconductor costs.

Figure 23.1



Alternatively, if we consider the social cost of bringing home offshore production, we can calculate a welfare loss V having a value equal to the area of that trapezoid. Taking a second order approximation, we can express that change as a fraction of the original (offshore) value of semiconductor output 244/

$$\text{(13.1)} \qquad \frac{V}{C_o\, Q_o} = -\left(\frac{C_u}{C_o} - 1\right)\left(1 + \tfrac{1}{2}\left(\frac{C_u}{C_o} - 1\right)\eta_{QP}\right)$$

with η_{QP} the price elasticity of D at C_o.

We then approximate the social cost (in terms of a dollar value) of transferring resources out of other sectors of the economy and into domestic semiconductor assembly, instead of producing other goods and trading them 245/ for offshore assembly services, with (13.1). The resources required to assemble a semiconudctor domestically come at the expense of other output having value C_u, exceeding the value of the costs with a foreign assembler, C_o. To measure this loss, estimates of $\frac{C_u}{C_o} - 1$, additional U. S. assembly costs as a fraction of the cost of an offshore-assembled device, and η_{QP}, the price elasticity of demand for semiconductors as an input are needed.

To arrive at a crude estimate of the latter, we can use the information on SCD input per unit of output given in Table 3.3. To see this, first note that [246]

$$(13.2) \quad \eta_{Qp} = \eta_{qp} + \varepsilon \cdot S$$

with η_{qP} the price elasticity of semiconductor demand per unit of consumer good, ε the price elasticity of demand for the consumer good; S the cost share of semiconductor inputs in consumer good production.

Since S is quite small (See Table 3.2; it never exceeded .06 in the 1972 input/output table), to a close approximation we can ignore the second term of 13.2 as long as η_{qp} is reasonably large.

To estimate η_{qp}, we will make use of the fact that cost reductions in semiconductors, which have been extremely large, have almost certainly swamped all other relative price movements affecting semiconductor usage. If all input prices other than semiconductors have moved roughly proportionately to output price, we have

$$(13.3) \quad \eta_{qp} = d\ell nq \,/\, d\ell n\,(P/P_x) \,,$$

ℓn in the natural log, $\frac{P}{P_x}$ the price of semiconductor input relative to output. We have already tabulated data on q in Table 3.3. If we obtain data over time on the relative price of semiconductors, and approximate the differentials in 13.3 by the first difference over time of the natural logs of q and $\frac{P}{P_x}$, their ratio will be an estimate of η_{qp}. This is done in Table 13.1.

The estimated per unit SCD demand elasticities show a rather elastic demand, with estimates of about -5.4 for computers, and estimates in the neighborhood of -2.5 for various other types of electrical equipment. Since aggregate demand elasticity is a

Table 13.1

Estimated Elasticity of Demand for Semiconductor Input per Unit Electronic Output

Sector	Output Price Indices 1972 = 100 P_x 1967	Estimated SCD Demand Elasticity η_{qp} (1967-1972)
Computers & Calculators	98.6	-5.4
Radio & T.V. Receivers	103.6	-2.6
Telephone & Telegraph Equipment	83.8	-2.6
Radio & T.V. Communication Equipment	83.1	-2.5
Semiconductors	115.1	NA
1972 Sales Value Weighted Average, 4 Electronics Sectors	-	-3.5

Source: Same as in Table 3.3 calculation of demand elasticities described in text. No correction for technological advance in levels of integrated circuit component density has been made.

Table 13.2

Lower-Bound Estimates, Elasticity of Semiconductor Demand

Computers & Calculators	-1.6
Radio & T.V. Receivers	-1.2
Telephone & Telegraph Equipment	-1.4
Radio & T.V. Communication Equipment	-1.4
1972 Sales Value--Weighted Average, 4 Electronics Sectors	-1.5

Source and Methods: Same as in Table 13.1, as described in text. The 1967-valued indices of IC production and price were multiplied and divided by 4, respectively, and used to recompute the ratios of quantity and relative price changes.

value-weighted average of the elasticity of demand by sector, aggregate demand elasticity for semiconductors used in electronic output was about -3.5. We have not done the elasticity calculations for sectors other than electrical equipment, because their use of semiconductors is generally in electronic equipment used as internal consumption, and thus, the elasticities so calculated would also reflect the elasticity of demand for electronic equipment which contained the semiconductor content.

These elasticity estimates, to be sure, are crude, but are probably the best available. 248/ They may be affected, however, by a serious negative bias. The price data used to construct Table 13.1 are based on U. S. Bureau of Labor Statistics wholesale price series for various types of semiconductors, and probably accurately reflect price declines in existing types of semiconductors over the 1967-72 period. Around 1970, however, a major advance in IC production technology was made. The number of circuit elements on a single chip was increased about four times for most computer chips; 249/ this technological jump in levels of circuit integration is not reflected in the price series for existing types of chips. A 1972 IC computer memory chip was equivalent to four 1967-generation computer memory IC's. Other types of IC's were also subsequently produced at much greater levels of complexity using the same technology.

Thus, on average, a 1972 IC performed the functions of several 1967 ICs. Since IC's rose from 21 percent of the value of US SCD shipments in 1967 to 54 percent of the value of U.S. SCD shipments in 1972, [illegible]/ the Census semiconductor output measure must significantly understate the amount of 1967-equivalent output produce in 1972, and the price index must overstate the cost of performing 1967-equivalent functions. The net effect will be to overstate the magnitude of the true price elasticity of demand. 251/

The elasticity estimates of Table 13.1 support this conjecture. The sector which made use of the integrated circuits most affected by the great increase in component density, computers and calculators, has an estimated elasticity roughly double that of the other electronic equipment sectors whose SCD usage of relatively more discrete devices, and simple ICs, was less affected by the technological leap forward. Since 13.1 effectively places an upper limit on the magnitude of the price elasticity of demand, it would also be convenient to place a lower limit on that elasticity.

This is done in Table 13.2 by assuming that all 1972-generation ICs performed the functions of 4 1967-generation ICs. We are implicitly treating the demand for ICs as a demand for the electronic functions performed by the ICs, so that one 1972 IC and four 1967 ICs would be perfect substitutes in the manufacture of an item of electronic equipment. 252/

This rather radical upward revaluation of the quantity of 1967-equivalent ICs produced in 1972 almost certainly results in the elasticity estimates of Table 13.2 lying significantly below their true magnitudes since most ICs used outside of the computer sector were probably much less affected by the higher chips density levels, and even within the computer industry, not all chips quadrupled in density. Thus, the true per unit price elasticity of SCD input demand probably lies somewhere in the -1.5 to -3 range, with the clustering of values in Table 13.1 for non-computer uses suggesting the midpoint of that range, or around -2.3, as a decent point estimate.

Before we can return to our original objective, calculating the relative welfare loss that would be suffered if offshore assembly were transferred back onshore, as given in (13.1), we also need an estimate of $\frac{C_u}{C_o} - 1$, the relative price increase to users of semiconductors if assembly were to be relocated. This cost increase depends, in turn, on two key parameters: the increase in assembly costs onshore, as a percent of total manufacturing cost with offshore assembly (call it a), and total manufacturing cost as a fraction of SCD output price, with offshore assembly (call this ratio b). Then $\frac{C_u}{C_o} - 1$ will just equal ab, if the absolute difference between price and manufacturing cost remains roughly constant. 253/

To estimate how much more costly assembly in the U.S. would be is difficult, since only fragmentary information is available. The only real datum is a table in Finan (1975), which can be reworked to estimate the cost differential, as in Table 13.3. It indicates that in spite of the fact that labor cost increases in the U.S. raised total manufacturing cost by 60 percent of its Singapore value, substantial savings in material costs and manufacturing overhead leave the net U.S. cost increase at about one-third of Singapore cost. The evidence reviewed in Section 9 on manufacturing costs suggests that, since assembly costs have shrunk in relative importance with the more advanced complex chips, this cost differential may actually have declined somewhat by the late 1970s, in the aggregate, as demand for these chip types soared.

Table 13.3

Cost Breakdown, Assembly in U.S. and Singapore
U.S. Semiconductor Industry, Early 1970s

All Values Expressed as Percent Total Manufacturing Cost
with Assembly in Singapore

Cost:	Assembly in U.S.		Assembly in Singapore		Increase if Assembled in U.S.
Manufactured Overhead	40		50		-10
Direct Labor Cost, of which	80		20		
Wafer Fabrication		12		12	
Assembly		68		8	+60
Materials	13		30		-17
TOTAL COST	133		100		+33

Source: Finan (1975), P. 66. To rework his figures into this form, we used the fact that the absolute direct labor cost in wafer fabrication (which was done in the U.S.) is constant, whether or not assembly takes place offshore.

The other critical parameter, manufacturing cost as a fraction of sales price was also estimated by Finan to be about .65, in the early 1970s. More recently, Dickens (1979) puts the ratio at about .3 and .4 for a simple and complex IC, respectively, in the late 1970s. 254/ To some extent, the smaller ratios for 1979 may reflect demand pressures on prices in that year; they may also reflect the greater role of research and development costs in the production of newer and more advanced chips.

If we take Finan's estimates of .33 for a, and .65 for b, as appropriate to the early 1970s, the cost difference as a percent of sales price with offshore assembly, $\frac{C_u}{C_o} - 1$, was about 21 percent. If both ratios dropped by the late 1970s, say to .25 for a, and .40 for b, as lower bounds, the increase in sales price would not have been less than ten percent. Thus, we shall hypothezise that in the early 1970s, $\frac{C_u}{C_o} - 1$ was about .2, and in the late 1970s, somewhere between .1 and .2.

The above estimates refer to cost increases per unit when offshore production is transferred back to the U.S. What we are attempting to measure in equation (13.1), however, is what the aggregate welfare effect of transferring offshore assembly back to the U.S. is. Since not all assembly took place offshore, however, the effect on the aggregate price level for semiconductors will be a weighted average of the effect on offshore output and on output already assembled in the U.S. (i.e., no effect). To put it more precisely, we must replace $\frac{C_u}{C_c} - 1$ in (13.1) with $\frac{P_u}{P_o} - 1$ with $\frac{P_u}{P_o} - 1$ referring to the average price increase per SCD after the transferring back of offshore production, as a fraction of average price with the existing use of offshore assembly.

Using a range of .1 to .2 for $\frac{C_u}{C_o} - 1$, and an estimate of the fraction of output assembled offshore of 70 percent, the implied range for $\frac{P_u}{P_o} - 1$, the average price increase as a fraction of the average price before relocating offshore production, is from .07 to .13. 255/

Table 13.4 performs the welfare calculations of equation (13.1), using a variety of parameter values over the plausible range. Taking a price elasticity estimate of -2.3 as our preferred choice, the calculations suggest that transferring offshore assembly onshore would be roughly equivalent to a windfall loss in income to consumers of about eight percent of the value of their SCD consumption, give or take perhaps three percent. Since U.S. semiconductor consumption in 1979 is estimated to have been about $5 billion, 256/ this translates into a loss of roughly $400 million, plus or minus perhaps $150 million. This is a respectable but not overwhelmingly large sum.

Since, implicitly, we have assumed protectionist policies to prevent imports from displacing U.S. products as U.S. prices rise, the calculations of welfare loss overestimate the loss in the absence of protectionist policies. Prices for semiconductor output would then be, on average, lower, and the welfare loss smaller.

These calculations, of course, ignore the costs of retraining and relocating workers who were displaced by offshore production, as well as the costs of any unemployment they may have had. While they may give a useful approximation to the costs of relocating offshore assembly to the U.S., they must certainly underestimate the costs of the original movement offshore to some extent.

Table 13.4

Value of Welfare Loss as a Percent of SCD Consumption with Transfer of Offshore Assembly to U.S. Late 1970s

Parameter Values		Value of Welfare Loss as % of SCD Consumption
$\frac{P_u}{P_o} - 1$	η_{qp}	
.13	-1.5	12
.13	-2.3	11
.13	-3.0	10
.07	-1.5	7
.07	-2.3	6
.07	-3.0	6

Source: Equation (13.1); see text.

Effects of Offshore Production on the Structure of U.S. Employment

The export of labor-intensive assembly operations to offshore areas has had vastly different effects on different groups within the U.S. semiconductor labor force. In this section, we briefly spell out what some of those differences have been.

Table 13.5 displays basic information on employment in the U.S. industry. The first, and most obvious, feature of employment is that it has been growing quite slowly, relative to output. Between 1963 and 1978, it increased about 2.3 times. The value of shipments, over the same period, increased about 9.4 times; since prices for semiconductors were declining, real growth was even greater. Certainly, some large part of the divergence in growth rates must be due to the use of offshore assembly arrangements.

Second, recession and economic slowdown have had drastic effects on employment in the U.S. industry. Employment growth rates fell off sharply during th 1966-67 economic slowdown, and dropped steeply during and after the 1970 recession. During the 1974-75 recession, employment in the U.S. industry fell by over 27 percent in 1975 alone.

Third, the U.S. semiconductor industry is top-heavy witn non-production employment. In 1977, the average for all U.S. manufacturing was about 2.6 production workers per non-production employee, and about 1.9 production workers per non-production employee in electrical equipment; the corresponding figure for the SCD sector was 1.3; about half of the average for all manufacturing. Only the ordinance industry (with .8 production workers per non-production employee) fell below this level. 257/

Table 13.5

Structure of Employment in U.S. SCD Industry

	Total Employment (1,000s)	Annual Growth Rate		Production Workers per Non-Production Employee	Wage per Production Worker Hour ($)	Ratio (%) Wages per Prod. Work Hour SCDs/All Mfg.
		All Employment (%)	Production Workers			
1958	23.4	NA	NA	3.0	1.90	87
1963	56.3	5.6[1]	4.5[1]	2.0		
1964	55.3	-1.8	1.3	2.2	2.19	87
1965	67.4	21.9	28.2	2.6	2.27	87
1966	82.2	22.0	21.4	2.6	2.31	86
1967	85.4	3.9	-2.0	2.1	2.32	84
1968	87.4	2.3	4.5	2.2	2.60	89
1969	98.5	13.0	14.5	2.3	2.80	90
1970	88.5	-10.4	-13.0	2.1	2.83	87
1971	74.7	-15.6	-24.5	1.6	3.07	89
1972	97.6	30.7	28.4	1.5	3.33	90
1973	120.0	23.0	27.9	1.6	3.61	91
1974	133.1	10.9	9.2	1.6	3.73	86
1975	96.7	-27.3	-35.8	1.2	3.93	86
1976	102.5	6.0	10.5	1.3	4.34	86
1977	114.0	11.2	9.7	1.2	4.46	87
1978	130.8	14.7	15.9	1.3	5.57	90

Note:

1. Growth rate 1958-63/5

All data calculated from U.S. Department of Commerce, Bureau of the Census, Census of Manufactures, Annual Survey of Manufactures, various years, and refer to manufacturing establishments (excluding administrative offices and auxiliary operations).

Furthermore, recession seems to have been a catalyst for the restructuring of employment in the U.S. industry. Permanent declines in the ratio of production workers to non-production employees occurred during the 1970-71 and 1974-75 recessions, with the new and lower ratios of production employment persisting after the recession. In the aftermath of the most recent recession, that of 1980, worldwide semiconductor employment again dropped significantly, with U.S. employment taking the brunt of the cutbacks. 258/ Coupled with the information in Section 6, this seems to indicate that major restructuring of the industry has occurred during recessions, with higher-cost U.S. assembly operations shut down, and replaced with offshore assembly plants when demand again picked up.

Little pattern is evident in the relation of hourly wages in semiconductors to the wage for all manufacturing. The SCD wage has generally fluctuated between 80 and 90 percent of the manufacturing wage; some of this instability may reflect shifts in the sectoral pattern of manufacturing employment and overtime.

More insight into the impact of offshore assembly on the structure of U.S. semiconductor employment can be had by examining more detailed information on the structure of production employment in census years, displayed in Table 13.6. The data reveal that there was little change in the structure of production employment until the period from 1967 to 1972. Over that period, however, use of assembly laborers, per non-production employee, was roughly halved, while non-assembly production employee per non-production employee increased slightly. This radical shift suggests that the bulk of the movement toward offshore assembly took place over the 1967-72 period. The slight

Table [illegible].6

Structure of Production Employment
U.S. Semiconductor Industry

Year	Production Workers (1,000s)	Estimated Workers in "Assembly of Product"		Assembly Workers/ Non-production Employee	Non-assembly Production Workers/Non-production Employee
		(1,000s)	As % Total Production Workers		
1963	37.5	28.4	76	1.5	.48
1967	57.9	44.6	77	1.6	.48
1972	58.4	30.6	52	.78	.71
1977	63.5	28.7	46	.57	.69

Source: U.S. Bureau of the Census, *Census of Manufactures*, *Selected Metalworking Operations*, various years. Estimate of workers in "assembly of product" calculated with assumption that manufacturing establishments not covered by special metal working survey (which had roughly 10 to 30 percent of all employees, depending on year) were identical in composition of employment to establishments completing the special survey.

increase in other types of production employment may be due to the increasing complexity of chip fabrication operations, and to greater numbers of production workers required to handle materials handing, inspection, and testing operations servicing offshore-assembled output.

Between 1972 and 1977, relative use of assembly workers again dropped, though by a much smaller amount than was the case over 1967-1972. This is consistent with the continued more gradual expansion of the role of offshore assembly in production for the U.S. market noted in Section 6. Non-assembly production employment, per non-production employee, remained essentially constant over this period.

What little direct information exists supports the view that the transfer of U.S. production employment offshore coincided with major recessions. Table 13.7 gives a breakdown of U.S. and worldwide production employment in semiconductors of U.S. integrated circuit producers over the 1974-78 period. Since IC makers accounted for the bulk of U.S. SCD output and employment over this period, the table probably reflects the worldwide distribution of employment fairly accurately. It shows a marked increase in the relative share of foreign SCD employment following the 1974-75 recession; it also confirms that growth in foreign employment in the mid to late 1970s was rather gradual compared to what must have been explosive growth in the late 1960s and early 1970s.

The significance of the transfer of production employment offshore during and after major recessions is that it suggests that recessions may be considerably less harmful to foreign employment than to domestic U.S. production employment. Slackening demand may lead producers to

Table 13.7

Worldwide Employment of U.S. SCD Producers
(for U.S. IC Producers only)

Year	Production Workers in Integrated Circuit Production (1,000 workers)			All Employees Producing Semiconductors (1,000 workers)		
	Total	Foreign Subsidiaries	% Foreign	Total	Foreign Subsidiaries	% Foreign
1974	74	41	55	156	70	45
1975	63	35	56	127	59	46
1976	81	50	62	150	78	52
1977	88	52	59	161	81	50
1978	103	61	59	179	89	50

Source: U.S. International Trade Commission (1979), Tables A-33, A-34. Data are for a sample including all major U.S. producers.

close their least profitable operations, which are probably more often than not in the U.S., with its much higher costs for assembly labor.

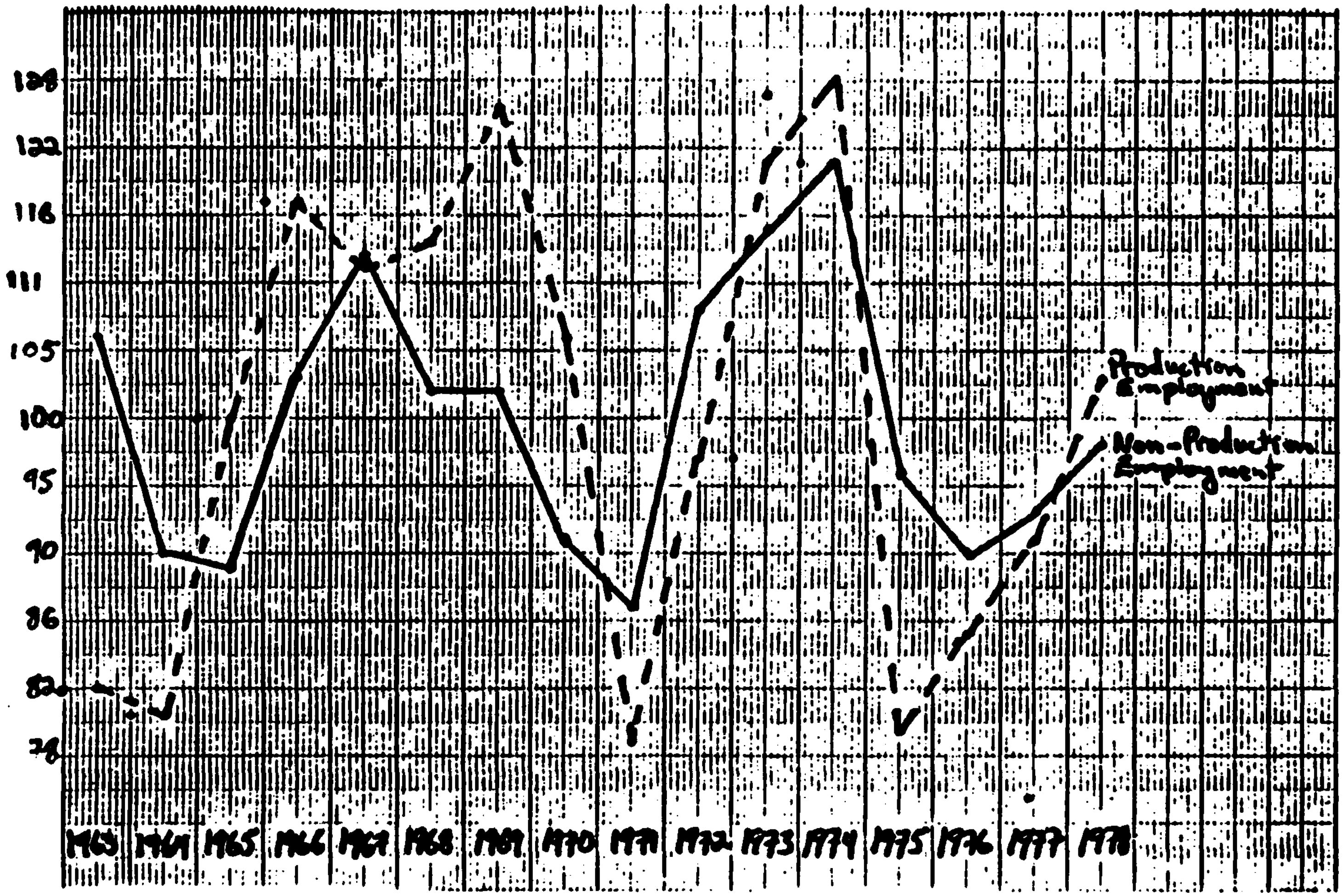
Since significant variation in output and employment over the business cycle seems to be a key characteristic of the semiconductor industry, it might be asked what effect the transfer of assembly operations offshore has had on the stability of employment within the U.S. industry. To examine this question, the deviations of production and non-production employment from their trend growth over the 1963-1978 period were examined. 259/ The results are plotted in Figure 13.2.

Over the 1963-1978 period, production employment grew at a trend rate of 3 percent annually, while non-production employment grew at 8 percent per year. As can be seen in Figure 13.2, deviations of actual employment from the levels predicted by this average growth rate were substantially more severe for production employment. The movement toward more offshore assembly, however, seems to have had little or no discernible effect on the instability of U.S. production employment, suggesting that assembly employment is not, or is only slightly more affected by business cycle fluctuations than other types of production employment. Prior to 1968 or so, there may have been slightly less fluctuation in production employment around its trend, but the difference seems slight and of little significance. The same may be said of non-production employment.

That is not to say, of course, that offshore production has had no effect on the stability of U.S. employment. Since the use of offshore assembly seems to have been associated with a shift toward relatively more U.S. non-production employment, which shows less variation around

Figure 13.2

Actual Employment as
% Trend Growth Employment



its trend, the changing composition of U.S. SCD employment served to stabiilize total U.S. employment. 262/

Before ending this discussion, it is useful to briefly describe the characteristics of production workers in the U.S. industry. A Labor Department survey, conducted in September of 1977, 261/ found about one-fifth of the production workers were unionized, with almost all unionized plants in the Northeast (defined to include the mid-Atlantic States). About half of production workers in the Northeast were unionized. The unionized workers held a 61 percent wage advantage over their counterparts in unorganized plants, nationwide, though the differential drops to 48 percent when only Northeastern plants are examined, and 31 percent when only large Northeastern plants are studied.

Most strikingly, the production labor force in semiconductors is overwhelmingly female. As Table 13.8 shows, this has been true historically, since at least the early 1960s, and shows little prospect of changing. The occupation most dominated by female workers, in fact, is assembly, where over 90 percent of workers are women.

The preponderance of women in this work force is in part attributable to an employee preference for women workers in close tolerance work, 262/ i.e., in routine and monotonous tasks where manual dexterity is required and great physical strength is not particularly useful. It may also be related to generally lower wage rates paid to women, and a lesser propensity to organize in unions. Many labor force analysts attribute the high labor force participation rates for women in areas with electronic industries to this demand, which draws into the labor force women not previously a formal part of it. 263/

Table 13.8 Women as Percentage of All Workers in the U.S. Semiconductor Industry by Occupation

	Women as Percentage of All Workers by Occupation	
	1962	1977
Assemblers	90-100	92
Inspectors and testers	90-99	88
Processing and fabrication	65-90	NA
Processing only	NA	73
Custodial and janitorial	5	14
All production workers	70-72	71

Source: U.S. Department of Labor, Bureau of Labor Statistics, Bulletins 2021 (April 1979), 1363 (October 1963).

Whatever the cause of the predominance of female workers, it carries with it the implication that the phenomenon of offshore assembly has imposed relatively more costs on female workers, as the U.S. assembly work force contracted. Female workers, as noted elsewhere in this book, also seem to suffer greater than average losses when displaced. Since, in many cases, it appears that formal female participation in the labor force was stimulated by an employer preference, the transfer of assembly to foreign locations may have exacerbated unemployment among women workers, and imposed upon the female labor pool a disproportionate share of the costs of adjusting to shifts in production location.

Net Employment Within the U.S. Semiconductor Industry

The price elasticity estimates constructed earlier in this section can be used to assess the net impact on employment within the U.S. industry of the trend to offshore assembly. The net effect will reflect a balance between two conflicting forces. On the one hand, offshore assembly leads to a decrease in the unit requirements for U.S. labor per semiconductor. On the other hand, a decline in the price of semiconductors leads to increased demand and greater employment.

We start by relating the elasticity of SCD demand with respect to α (the fraction of output assembled offshore), $\eta_{Q\alpha}$, to the price elasticity of semiconductor demand, (η_{QP}) 24/

$$\eta_{Q\alpha} = -\eta_{QP}\left(\frac{P_u}{P_o} - 1\right) \qquad (13.4)$$

where, as before, $\overline{\frac{P_u}{P_o} - 1}$ is the average percent increase in the price of a finished semiconductor to be expected when offshore assembly is entirely relocated back in the U.S. 265/

Next, note that production employment in the U.S., L_u, can be divided into non-assembly employment and assembly employment, with labor requirements per unit of assembled output of ℓ_{NA}, and ℓ_A, respectively, 266/ so that (with Q total units of U.S. output)

$$(13.5) \qquad L_u = (\ell_{NA} + (1-\alpha)\ell_A)\,Q$$

and its elasticity with respect to a change in α, the fraction of output assembled offshore is just

$$(13.6) \qquad \eta_{L_u\alpha} = \eta_{Q\alpha} - \frac{Q\ell_A\alpha}{L_u}$$

where $\frac{Q\,\ell_A\alpha}{L_u}$ is the U.S. assembly employment that would be created if all offshore assembly were transferred back to the U.S., as a fraction of current U.S.-semiconductor production employment.

Substituting (13.4) into (13.6), we have

$$(13.7) \qquad \eta_{L_u\alpha} = -\eta_{QP}\left(\frac{P_u}{P_o} - 1\right) - \frac{Q\ell_A\,\alpha}{L_u}$$

If as before, we work under the assumption that perhaps 70 percent of U.S. semiconductors were assembled offshore in the late 1970s, the roughly 29,000 workers shown in Table 13.6, who in 1977 worked in assembly occupations in the U.S. industry, would have been assembling perhaps 30 percent of U.S. output. If the additional 70 percent of output were brought back onshore, then, perhaps another 68,000 U.S. semiconductor assembly jobs would have been created, amounting to roughly 106 percent of 1977 U.S. industry production employment. If we take our range of estimates for the elasticity of demand, η_{qP} , 267/ to be from about -1.5 to -3, as before, and $\frac{P_u}{P_o}-1$ to be from about .07 to .13, as in Table 13.4, we produce the range of estimates for $\eta_{L_u\alpha}$ given in Table 13.9, from about -.7 to -1. There can be little doubt that the trend toward offshore production has resulted in the loss of moderate numbers of assembly jobs in the U.S. industry, with a 10 percent decline in the percentage of output assembled offshore (from 70 to 63) associated with the creation of perhaps 4500 to 6400 U.S. assembly jobs.

As before, we are assuming that protectionist policies prevent foreign imports from displacing U.S. product as U.S. SCD prices rise. To properly take into account these displacement effects, we would need an estimate of the degree to which foreign imports would be substituted for U.S. output as prices rose, which would be very difficult to obtain. Since the relative importance of assembly costs, and price increases, in output price are fairly small, however, these would probably reduce these job creation estimates by a small amount. Also, we have not considered the impact of price increases in semiconductors on other industries. Cheaper semiconductors displace other types of

Table [illegible] Estimates of the Elasticity of U.S. Semiconductor Production Employment with Respect to α, Fraction of U.S. Production Assembled Offshore.

$\frac{Pu}{Po} - 1$	η_{Qp}	$\eta_{Lu\alpha}$
.13	-1.5	-.9
.13	-2.3	-.8
.13	-3.0	-.7
.07	-1.5	-1.0
.07	-2.3	-.9
.07	-3.0	-.9

Sources: Equation (14.7), with $\frac{Q^{\ell} A \alpha}{Lu} = 1.06$ assumed.

See text.

components and the workers who produce them, and used as inputs in the electronic equipment industry, may reduce labor demand in the user industries (if the elimination of the need to wire many discrete components into equipment in lieu of a single integrated circuit more than compensates for the increase in demand for the product due to input costs savings passed onto the consumer as lower prices), and increases demand for workers in industries that supply the semiconductor sector with inputs. The net effects are hard to predict, but may be relatively small, since the cost savings due to offshore assembly are fairly small.

The Balance of Payments

Finally, we briefly summarize the impact of offshore production on the U.S. semiconductor industry balance of payments. Table 13.10 gives some estimated totals, decomposing exports and imports into a net balance on trade not related to offshore assembly, and an item (3) giving the net balance on offshore production-related trade. 268/ While the 806/807 dutiable value figure overestimates the net drain on foreign exchange due to the offshore production arrangements of U.S. producers (some of the dutiable content may be U.S. materials which are materially transformed offshore, or otherwise ineligible for duty-free reentry), it is clear that offshore production arrangements have absorbed an increasing large portion of the surplus of trade in finished goods.

This is not to say, of course, that those arrangements have worsened the balance of payments. It may well be that by cheapening U.S. production costs, they have led to an expansion of exports and prevented growth in foreign imports. While a quantitative analysis of this question is, in principle, possible, there is little or no information available on the price elasticity of U.S. semiconductor imports and exports, in the presence of recently-arrived Japanese competition in international markets. Also, to some extent, products in which the U.S. has not yet faced significant international competition might be vulnerable to such competition in the face of price increases.

Table 13.10. U.S. Semiconductor Industry Adjusted Balance of Payments, 1969-1978

Millions of US $

	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1. Non-Assembly Exports	278	326	276	341	662	937	745	984	886	1036
2. Non-Assembly Imports	8	8	9	75	198	269	185	219	232	290
3. 806/807 Dutiable Value	58	69	84	125	226	373	326	477	503	592
4. Net Balance (1-2-3)	212	249	183	141	238	295	234	288	151	154

Source: U.S. Department of Commerce, Bureau of the Census printouts for total SCD exports and imports;

U.S. International Trade Commission data for 806/807 imports, dutiable value.

Non-assembly exports are total exports less U.S. content of 806/807 imports.

Non-assembly imports are total imports less 806/807 imports.

Summary

This section has been concerned with tracing out the effects of U.S.-offshore production on the structure of the U.S. semiconductor industry. After examining what little evidence exists on price elasticities and cost structures, some simple calculations revealed that (assuming protection prevented an influx of foreign imports) the relocation of U.S. offshore plants back to the United States would have been equivalent, roughly to a welfare loss on the order of magnitude of perhaps 10 percent of the value of U.S. consumption.

These calculations ignore the social costs of readjusting and retraining the workers displaced when the offshore move first occurred. Such costs may have been substantial, and impacted disproportionately on relatively low-income, unskilled women in the U.S. labor force. To some extent, the labor force participation of these women may have been the direct result of the previous employment practices of U.S. electronic firms. On the other hand, there is some evidence that shifting these production jobs offshore may have stabilized employment in the U.S. semiconductor industry as a whole, since non-production employment is less affected by business-cycle fluctuations.

The magnitude of these employment losses has been subtantial, with perhaps on the order of five to six thousand jobs associated with the repatriation of 7 percent of U.S. semiconductor assembly back to the United States. On the other hand, these calculations assume that protectionist policies eliminate the danger that a rise in U.S. costs will lead to loss of market share to foreign imports. In the long run, very little in the way of employment might be gained witnout offshore production, if the industry remained open to international competition.

Finally, a cursory examination of the balance of payments in the U.S. industry showed that imports of offshore value added substantially reduced what otherwise would have been a very large positive balance on finished goods exports and imports. Again, however, the cost increases associated with U.S. assembly might have substantially cut U.S. producers' domestic market share (in the absence of protection), and driven the balance of payments into the red.

We conclude, then, that on balance, offshore production arrangements have indirectly benefitted the U.S. consumer. Important numbers of workers, however, have been displaced by the movement offshore, and unskilled female workers, in particular, were likely to have been forced to suffer the costs of adjustment.

14. Conclusions

The large-scale migration of labor-intensive production operations to offshore locations began in the U.S. semiconductor industry in the early 1960s. This move was born and baptized in the fires of Japanese competition, beginning life as an essentially defensive response to cheap foreign transistor imports. It was a very successful strategy for maintaining U.S. market share in the U.S. market, since wages in most of underdeveloped Southeast Asia were even lower than wages in Japan, which were the original basis for Japanese competitiveness in the international semiconductor market. Japanese success in industrializing their economy guaranteed that this was to remain an effective strategy for dealing with the low-wage competition to the U.S. industry, as Japanese wages moved to even greater levels relative to the rest of Asia through the late 1960s and 1970s.

The success of U.S. SCD firms in dealing with foreign low-wage competition through the use of offshore production arrangements was imitated by the European electronics firms who made up the other major force in the international electronics market. European trade policy, however, (unlike U.S. trade policy in semiconductors) veered toward a highly protectionist stand, which prevented the offshore strategy from being a terribly effective means of supplying semiconductors to the European market. As a result, European and American plants producing for the European market were forced to site most of their assembly operations within the European tariff walls. The exceptions to this rule were the relatively minor amounts of assembled semiconductors permitted entry under the quotas for outward processing and generalized preference tariff-sparing arrangements, and the very simplest sorts of devices, whose very large labor content, relative to the total value of the assembled product, made it economically worthwhile to assemble offshore in spite of high tariffs. When the Japanese entered the European semiconductor market in the late 1970s in a big way, they too were forced by the economic logic of high tariffs to set up European plants to penetrate the market. Other non-tariff barriers to SCD imports emphasized the need to set up European plants.

A number of characteristics of semiconductor production were essential to the success of the offshore strategy in the U.S. market. The extremely high value-to-weight ratio, for one thing, made transport costs a negligible cost of producing offshore; in fact, insurance costs probably dominate the cost of international semiconductor flows. The rapid pace of technological advance, and the rapid obsolescence of existing types of devices, made automation (the other major response to competition based on low-cost foreign labor) an unsuccessful strategy. And the type of labor preferred by employers -- unskilled, female workers, often participating for the first time in a formal way in the industrial labor force -- was in ample supply in the cities and villages of Southeast Asia and Latin America.

This strategy was not the only reason, however, for the continued U.S. dominance of international semiconductor markets. Heavy investment in research and development by U.S. firms continuously pushed forward the technology of microelectronics. The introduction of a new and superior types of devices, and the receipt of the technological rent charged by the few firms producing that device, were at least as profitable as becoming the lowest cost manufacturer of an older existing device, whose technology was widely diffused and whose market was therefore much more subject to competitive price-cutting pressures. Many U.S. firms, husbanding their scarce managerial, financial and technical resources, were surely correct in deciding that investing in new products yielded a higher return than investing in low-cost manufacturing technology for older, existing product types.

This situation did not remain static, though. In the early 1970s, it was apparent to the Japanese semiconductor industry that it had serious competitive problems, in the dubious quality and reliability of some of their products, in the relatively small amounts of resources (essential to keeping up with technological advance) invested in research and development, and in the continued advance of labor costs in the Japanese electronics industry relative to the rest of the world. The Japanese, who had since the late 1950s made development of their electronics and computer industry a matter of explicit national priority (recognizing, presumably, that the social return to technological investment was likely to far exceed the private return), proceeded with a multi-faceted program designed to make their semiconductor industry internationally competitive in the shortest possible time.

The Japanese program methodically analyzed the international market, and applied resources to areas where it was possible to gain some sort of competitive advantage. Often, the Japanese solution exploited the particular structure and strengths of their industrial system. To solve the problem of driving the Japanese industry to the frontiers of technological advance, enormous resources were pumped into research and development, financed by government subsidy, and by guidance of substantial amounts of nominally private capital into the industry through implicit guarantee, and the direct supervision of the loan portfolios of finanacial institutions. The Japanese system of labor relations, guaranteeing firms an essentially strike-free environment in return for assurances of lifetime employment for workers, made it possible for firms to go heavily into debt to finance these investments. The labor relations system, which relied on a system of paternalistic relations between employer and employee, emphasizing cooperation and interaction between managers and workers, also helped the Japanese to improve the quality of their output through the widespread use of so-called 'quality circles.' These are now being imitated in widespread experiments throughout the U.S. electronics industry.

The other Japanese response to the quality problem was to automate all stages of the production process, including, in many cases, assembly and bonding operations that were largely performed offshore by U.S. firms. The trend toward automation was especially significant in the area of integrated circuits, particularly computer memories, where the rapidly growing market size made automation economic even when product life was relatively short. This also solved the problem of rising labor costs for those products whose market was sufficiently large to warrant a heavy capital investment in automated machinery.

For less advanced products, where quality was not so important, and where labor cost was a relatively greater portion of total cost, the Japanese adopted the offshore strategy, especially for export to foreign markets. Throughout the 1970s, offshore production of simpler discrete semiconductor devices, and simple integrated circuits, expanded rapidly. At the very end of the 1970s, especially, Japanese use of offshore assembly plants seems to have increased markedly.

The siting of assembly of simpler products offshore was also consistent with the realities of the Japanese labor relations system, and rising protectionist sentiments within Europe and the U.S. Because labor was often a quasi-fixed cost to Japanese producers, the operations that were most profitably transferred offshore as the volume of Japanese semiconductor output increased and made labor requirements exceed existing employment, were those in products which were most labor-intensive, where the relative cost savings to be obtained offshore was greatest. Increasingly protectionist attitudes within the U.S. and Europe, where national producers and trade policymakers were especially concerned about Japanese competition in the most advanced types of products (where a strong national industry was important for strategic reasons, and for reasons of technological dynamism) made it politically imperative for Japanese exporters to begin production operations within those markets. The lesser role of labor cost in more complex devices provided economic reinforcement to that decision. Also, it may be that the large offshore capital investment required for the assembly of complex, high quality integrated circuits, would have disturbed the broad social consensus that permitted the government to funnel large amounts of capital, public and private, into the industry.

These moves by the Japanese, to some extent, caught the U.S. industry off guard. For one thing, U.S. producers (with the exception of the largest producers, including ATT and IBM, whose production is entirely consumed internally) were late in recognizing that quality and reliability were associated with significant cost savings in the assembly and testing of the increasingly sophisticated electronic equipment using semiconductor components. For another thing, the historical legacy of heavy reliance on sales to the military market (which no longer dominated U.S. consumption, since the late 1960s) was brute force, 'burn in,' quality control techniques, which were far less economic than the statistical techniques used by the Japanese. Also, capital was probably relatively more expensive to the smaller U.S. firms, making highly automated assembly methods (and the quality increases associated with them) less attractive to U.S. firms.

In the late 1970s, however, it had become obvious to U.S. producers that they would have to respond to the Japanese quality innovations by automating their assembly operations. As a result, U.S. offshore operations benefitted from heavy investments in automated equipment. The greater capital requirements (and reduced importance of labor costs) and scale of efficient plants, however, coupled with the political risks of offshore investment, make it likely that an increasingly large fraction of output destined for the U.S. market will once more be assembled and tested within the U.S.

The effects of the offshore migration of operations intensive in the use of unskilled labor, in the 1960s and 1970s, are reflected in the changing structure of the U.S. industry. The U.S. industry's employment was increasingly dominated by higher skill non-production occupations, whose lesser susceptibility to the viscissitudes of the business cycle probably stabilized overall U.S. employment in the industry, to some extent. On the other hand, the costs of dislocation and unemployment that were imposed on the U.S. assemblers who were displaced, were felt disproportionately by the relatively unskilled women who make up the bulk of the industry's production work force.

This social cost was mitigated by a gain to U.S. consumers, through lower prices of goods using semiconductors as an input, equivalent to an income increase of perhaps ten percent of the value of U.S. SCD consumption, a not insignificant amount. These calculations assume prohibitive tariffs would have shut off competitive imports; in the absence of such tariff increases, competitive imports might have reduced U.S. employment, and output, even more than the movement offshore (and reduced the welfare gain).

The impact on the developing countries, where the assembly operations were located, is even more difficult to judge. Because of the relatively limited amount of employment generated, in relation to a rather large overall labor force, these offshore operations seem to have had only a minor impact on the employment and unemployment figures for the Asian host economies (with the exception, perhaps, of the small island economies of Singapore and Hong Kong). Also, since the predominantly unskilled and female labor force was largely drawn from demographic strata with little prior formal labor force participation experience, the employment created could have had but little impact on existing pools of unemployed and underemployed workers. There also seem to have been few linkages created to locally-owned input supplier industries, although some foreign companies have set up limited operations to supply semiconductor assembly plants with certain inputs.

On the other hand, offshore assembly operations seem to have made a significant contribution to the foreign exchange position of the host economies. And while the evidence on the contribution of offshore assembly to the transfer of useful technology to the host economy is negligible, it might be argued that the transfer of more capital-intensive testing and automated functions to offshore assembly sites will inevitably lead to some training of local personnel in more skilled technical and maintenance occupations (though the assembly and testing operations themselves probably require less training with more mechanized techniques). Some local firms in Hong Kong, Taiwan, and Korea have, in fact, started up completely integrated plants to fabricate and assemble simpler types of semiconductors, but since the design and engineering skills required are far removed from what an assembly worker or plant manager are required to understand, it is doubtful that this trend is related to the offshore assembly operations servicing foreign-based chip production (other than, perhaps, through example).

Offshore assembly, then, began as, and continues to be, a competitive response to low cost foreign labor. Its utility as a strategy depends on the importance of quality (and hence the need for automation), and the economic costs of the major alternative to labor-intensive assembly, automation (which in turn hinge on the scale of output and the costs of capital). The continued existence of differentiated markets, of vastly different sizes, for different types and qualities of semiconductor devices, suggests that offshore assembly will continue to be an important feature of production flows in the international semiconductor industry. It will be of possibly increasing significance to the Japanese industry, as output and labor costs increase in relative terms, and of possibly diminished significance in the U.S. industry, as large capital investments in automated machinery lead to the transfer of some operations back to the U.S. Just as it served as an example of competitive response for other

U.S. industries beleaguered by foreign competition in the early 1960s, it may well serve as an augury of the effects of increasing automation in U.S. industry in the 1980s.

Footnotes

1. Otherwise known as microchips or microcircuits, they are silicon chips treated with metal impurities in extremely precise quantities and locations, functioning as a circuit which would otherwise (with older technology) have contained hundreds or even thousands of discrete components wired together. The discrete components replaced include active components (tubes and other SCDs) and passive components (resistors, capacitors, etc.).

2. Inductors are the most important electronic device that cannot be replicated in a semiconductor device. See Meindl (1977).

3. A complete and highly entertaining history of semiconductors may be found in Braun and MacDonald, (1978).

4. *Ibid.*, p. 79

5. *Ibid.*

6. Linvill and Hogan (1977), p. 1109. See Tilton (1971), p. 92-93 as well. Braun and MacDonald (1978), p. 80, report that the industry in 1955 had the capacity to produce 15 million transistors a year, compared to an actual output of 3.6 million.

7. U.S. Department of Commerce, Office of Producer Goods (1979), p. 8; Linvill and Hogan (1977).

8. Linvill and Hogan (1977), p.1108.

9. U.S.I.T.C. (1979), p. 21.

10. Electronic components, computer, photographic equipment, radio and television sets, and telephone and telegraph apparatus.

16. Scherer, *et al.*, 1975, Appendix Table 5. 3, pp. 437-439. SCDs were worth, on average, $30.40 per pound. The runners-up were radio and communications equipment ($12. 36), radio and telegraph apparatus ($12. 05) computing machines ($7. 68), scientific instruments ($6. 30).

17. R. Moxon, 1974, Appendix 1, Table D.

18. Cited in K. Yoshihara, (1978), p. 134. Price per kilogram (in yen) was 100 for steel, 500 for autos, 1,000 for bearings, 3,000 for color televisions, 10,000 for cameras, 100,000 for computers, and 200,000 for integrated circuits.

19. For SCDs in general, see Rada (1980) p. 23; for ICs the figure is calculated from Tables A-21 and A-36, U.S. I. T. C. (November, 1979).

20. According to the 1977 Census of Manufactures.

21. See A. L. Robinson, "Are VLSI Microcircuits Too Hard to Design?" *Science* (July 11, 1980), p. 258; I. R. Saddler, "Can VSLI Growth Continue?" *Military Electronics* (February 1980, p. 98).

22. See C. Norman, "Inmos Enters the 64K RAM Race," *Science* (May 8,1981).

23. See *Business Week*, (April 20, 1981), pp. 44-48, *Asian Wall Street Journal* (June 2, 1980), p. 15

24. *Business Week*, (July 21, 1980), p. 189.

25. "Automated Semiconductor Line Speeds Custom Chip Production," *Electronics*, (January 27, 1981).

26. Webbink (1977), p. 57.

27. Testimony of H. D. Samuel, U.S. Department of Labor before U.S. Senate Subcommittee on International Finance, Committee on Banking, Housing, and Urban Affairs, April 4, 1979.

28. See the Science Policy Research Unit studies.

29. See Tilton, (1971), p. 83; Webbink, (1977), p. 131.

30. See U.S. Dept. of Commerce, Office of Producer Goods (1979), p. 54.

31. See Tilton (1971), p. 83; Webbink (1977), p. 57.

32. A. McCue, "U.S. Firm's Plan to Assemble Semiconductors on West Coast Could Threaten Asian Producers," Asian Wall Street Journal, (June 23, 1980), p. 16.

33. Webbink (1977), p. 57.

34. This point is often overlooked in the current debate whether U.S. or Japanese microchips are higher quality (have lower reject rates). See, for example, "Japan Makes Them Better," The Economist, (April 26, 1980), p. 55-56. See, "U.S. Reject Rate Still Trails Japanese," Electronics, November 6, 1980, p. 46; "U.S. Makes Raising Processor Quality," Electronics, (December 18, 1980), p. 41.

35. Tilton, 1971, p. 85. These ideas on learning curves were developed in the late 1960s by the Boston Consulting Group (BCG), a private management consulting firm.

36. See Finan (1975), PP. 21,68.

37. See Finan, 1975, Chapter 3, for a more complete discussion of the technology, and its various economies.

38. Japanese producers, on the other hand are reported to have automated more of the bonding operations, and may enjoy scale economies.

39. "Tape automated bonding meets ULSI challenge," Electronics, (December 18, 1980).

40. At IBM in the late 1970s design costs were about $100 per logic module on an integrated circuit. A. L. Robinson, "A Giant Corporation from Tiny Chips Grow," Science, (May 2, 1980), p. 483.

41. These ideas on cost curves are taken from Robert Noyce (1977).

42. Ibid.

43. See Tilton (1971).

44. It is made in Haggendorn and Brown (1979), pp. 240-243.

45. See Finan (1975) Chapter 4; Webbink (1977), pp. 96-101; and U.S. Central Intelligence Agency, (1979), pp. 6-8, on this point.

46. Since firms cannot pay for the innovation, and charge only marginal production cost, without incurring losses, a patent or licensing system is a second-best solution to the problem of allocating resources to technical innovation. Even achieving such a second-best solution may not be possible if it is difficult to appropriate an innovation, as seems to be the case in the semiconductor industry.

Another consequence of the peculiar economics of invention is that the presumption is that a monopoly may have less incentive to make a cost-saving innovation than an inventor in a competitive industry (See Arrow, 1962).

The existence of learning and scale economies, as well as the importance of major investment in R&D, may explain a principle feature of growth in the semi-conductor industry. On the one hand, as Tilton first noted, small firms account for a disproportionately large number of innovations [Finan (1975, Chapter 3-4) also has useful discussion of this point, as does Webbink (1977, pp. 104-112).]

On the other hand, an industry "shake-out" generally occurs later, leaving several large firms producing the vast bulk of a specific product line; little firms are often taken over by larger established firms, or end up becoming large firms, as such scale and learning economies come into play.

(A wave of mergers and acquisitions in the late 1970s suggest such a "shake-out" was then occurring. See "Can Semiconductors Survive Big Business?", Business Week, December 3, 1979. The picture is complicated, however, by a growing tendency toward vertical integration with large users of semiconductors guaranteeing the stability of their supply through the purchase of their suppliers, and by foreign firms acquiring technology or access to the U.S. market through the purchase of smaller U.S. firms.)

Such large firms, if they face a downward-sloping demand, and some monopoly power, have less incentive to invest in a given invention or improvement than smaller marginal producers (or individual inventors). Inventors who pioneer a cost-cutting device or process are able to capture the entire rent of a monopolist producing with that process or product, while an existing monopoly reaps only that incremental portion of the rent which exceeds the rent previously earned in its pre-innovation market.

This is necessarily less than the full value of the post-innovation rent (See Arrow, 1962). Hence, one can discern an economic rationale for the SCD industry's apparent pattern of small firms or individuals pioneering a new invention, growing or merging into large firms whose advantageous scale or learning economies reduce competition, establish market power, and eventually repeat the cycle as invention again becomes more profitable for outsiders than for large established firms.

47. The undervaluation by the market of the returns to invention may be offset by pecuniary economies that arise as the assets of innovating firms increase in value at the expense of other firms in the industry. See Dasgupta and Stiglitz, (1979).

48. See Finan (1975), pp. 71-75; U.S. Department of Commerce, Office of Producer Goods, (1979), pp. 95-98; U.S. International Trade Commission (1979), pp. 54-67. These policies may be radically altered by the outcome of the Tokyo Rounds.

49. Finan (1975), p. 58.

50. See Cooper (1971), Baldwin and Murry (1977).

51. EEC (1979), p. 233.

52. EEC Commission Regulation No. 148/79 (1979).

53. UNCTAD (1974), p. 134.

54. Cooper (1971).

55. EEC Council Directive 76/119/EEC of 18 December 1975.

56. This discussion is based on the U.S. Commerce Department's Global Market Survey (1979); "Europe Joins Microchip Race," *New York Times* (January 29, 1980), p. D1; U.S. I. T. C. (1979), pp. 75-77; and *Electronics* (March 13, 1980), pp. 81-87.

57. And complain the Japanese have obstructed the establishment of U.S. subsidiaries in Japan. See U.S. I. T. C. (1979), pp. 59-60. Nevertheless, a number of major American producers (American Micro Devices, Fairchild, Motorola, and Intel) are preparing to begin production in Japan. See *Asian Wall Street Journal Weekly*, (April 27,

1981), p. 15.

58. In 1974 for ICs; 1975 for computer parts. See Yoshihara (1978), p. 146; GAO (1979), p. 28.

59. See U.S. Department of Commerce, (1979) in the Global Market Survey for Japan.

60. According to Erich Block, of IBM, quoted in Electronic Engineering Times (May 25, 1981), p. 89.

61. See GAO, (1979).

62. UNCTAD (1974), p. 183.

63. Yamagawa (1980), p. 7. Figures on all I.C imports are based on official Ministry of Finance Statistics for finished I.C imports.

64. See U.S. I. T. C. (1978), Table A-56.

65. See Finan (1975), p. 75; U.S. Department of Commerce, Office of Producer Economics (1979), p. 92.

66. Ibid, p. 96.

67. It is interesting to speculate that the establishment of silicon wafer production facilities by Monsanto and Dow in Malaysia, and by General Instrument in Taiwan (the latter diffuses the wafers as well, in the same facility), represents a trend toward raising national content in order to qualify for the Japanese and European GSP systems, or perhaps even the U. S . system. The inclusion of SCD's in the list of items eligible for the U.S. GSP has been under study, and discrete semiconductors (but not IC's) recently (in 1982) placed on the list.

See Malaysia, F. I. D. A. (1978), p. 27 and Free China Review (February 1980), pp. 40-41 on wafer production; OAS, Trade News, vol. V, No. 4, p. 6, on the U.S. GSP list.

Texas Instrument is also reported to be planning to produce chips in Singapore, starting in 1983. Asian_Wall_Street_Journal_Weekly (February 16, 1981), p. 6.

68. Conversation with Japanese embassy officials, May 1980. See also U.S. I. T. C. (1970), p. 32.

69. See, for example, statement of W. J. Sanders III before Subcommittee on Trade, House Committee on Ways and Means, March 24, 1976.

70. See New_York_Times (May 12, 1981), p. D1. The agreement was largely the result of pressure by the U.S. industry.

71. This is the so-called "BCG type analysis". See Abegglen and Rapp (1972), Hagendorn and Brown (1979), pp. 240-3, GAO (1979), Chapter 10.

72. To quote a quasi-official Japanese source Look_Japan, (May 10, 1981), p. 24. The "socioeconomic state" alluded to is a scarcity of raw materials, energy and land, and an abundance of skilled labor.

73. See Peckman and Kaizuka (1976), on the Japanese tax system. The Miller-Modigliani theorem, stating that firms are indifferent between debt and equity finance, only holds true in the absence of taxes and costly bankruptcy. With the most common sorts of tax structures (i. e. , interest on debt deductible from taxable corporate income, and roughly comparable personal tax rates on interest, dividends, and capital gains) firms ought to perfer debt. With uncertainty and the possibility of costly bankruptcy (but no taxes), firms ought to prefer equity (which requires no fixed service and therefore reduces the probability of bankruptcy).With both, there will be an optimal financial structure using both debt and equity. See

Gordon and Malkiel (1981) for an excellent exposition of these issues.

74. This is roughly the same account of how the government guides capital investment as can be found in the GAO's (1979) report on U.S. -Japan Trade, p. 185. Many of the same points are made in Ackley and Ishi (1976), especially pp. 203-205. On the functioning of 'window guidance' by the Bank of Japan, see Suzuki (1980), pp. 166-181.

The interpretation of great amounts of debt used in Japanese corporate finance as the product of the tax structure and implicit government guarantees of priority investments is also made by Abegglen and Rapp (1972), p. 35. The Japanese system of labor relations -- with its infrequent use of strike --also serves to reduce the risk of bankruptcy.

Semiconductor industry leaders have focused on the high Japanese debt to assets (or equity) ratio as symptomatic of the competitive disadvantages of the American industry in its access to capital markets (See Testimony of Robert Noyce and John Welty before Subcommittee on International Finance of the Senate Committee on Banking, Housing, and Urban Affairs, January 15, 1980). Noyce, for example, cites figures showing equity as 22 and 86 percent of Japanese and U.S. semiconductor companies' assets, respectively. The Japanese figure is roughly the same as in all Japanese industry in the aggregate, while the U.S. industry uses substantially more equity than U.S. industry in general. Wallich and Wallich (1972), p. 267 cite figures of roughly 18 and 51 percent for industry in general, in Japan and the U.S. in 1972; Abegglen and Rapp (1972), p. 34 cite figures of 21 and 56 percent equity in Japan and the U.S. in 1968.

75. See GAO (1979), pp. 178-184.

76. See U.S. Department of Commerce, Country Market Survey Electronic Components - Japan (1978), p. 8.

77. U.S. CIA (1979), p. 11. The program was funded at about $240 million 1976 U.S. dollars. See also U.S. I. T. C. (1979), p. 77.

78. GAO (1979), pp. 179-184.

79. Business Week, (April 13, 1981), pp. 123-124. The VSLI research program reportedly spent $140 million over the 1976-79 period. A new cycle of MITI semiconductor research is just getting under way. MITI recently asked Parliament to approve a logic circuit research program in the $100 million range Electronic News, (March 30, 1981).

80. See Abbeglen and Rapp (1972), p. 35; Namiki (1978), p. 128. The influence of these loans is viewed by some as overrated or no longer of great importance. See Treszise and Suzuki (1976), pp. 795-797; Namiki (1978), pp. 126-129.

81. Treszize and Suzuki (1976); Table 11-4; Japan Development Bank (1979).

82. Peck and Tamura (1976), p. 552.

83. Peck and Tamura (1976), p. 546.

84. U.S. C. I. A. (1979), pp. 6-8.

85. See U.S. I. T. C. (1979),pp. 59-60.

86. Tilton (1971), p. 147; Peck and Tamura (1976), p. 552.

87. Actually, a provision like 806.30 existed before 1963. See U.S. I. T. C. (1970), pp. 14-26. It is, however, more restrictive than item 807.00.

88. Data refer to customs value, and are based on information found in U.S. I. T. C. (1980, 1979) and unpublished U.S. Department of Commerce tabulations.

89. U.S. I. T. C. (1979), Tables 6 and 8.

90. See footnote 25.

91. U.S. I. T. C. (1978).

92. U.S. I. T. C. (1979), Table A-40; U.S. CIA (1979), pp. 6-9.

93. IBM was number 3 and Western Electric number 4 in 1972. See U.S. Department of Commerce (1979) p. 89. Webbink (1977), pp. 21-22, "Europe Joins Microchip Race," *New York Times* (January 29, 1980).

94. U.S. Department of Commerce (1979) Office of Producer Goods, p. 77.

95. Finan (1975), Table 6-3.

96. U.S. I. T. C. (November 1979), p. 75.

97. See *Ibid*, p. 76; J. Streb, "Technology Transfer from the VHSIC Program," *Military Electronics* (February, 1980).

98. Quoted in Braun and MacDonald (1978), p. 142.

99. *Business Week*, (April 20, 1981), p. 39.

100. See Chang (1971), pp. 40-44.

101. Stories are still told within the U.S. semiconductor industry describing how some Japanese producers even stuck extra transistors onto their circuit boards, often with no actual electrical connection to the radio circuit (since the number of transistors in the radio was often used by consumers as a measure of quality).

102. Tilton (1971), pp. 75-76, 119.

103. See section 4.

104. Of the $144 million in Japanese radio-imports, $116 million were transistor radios. U.S. shipments data are from the 1972 U.S. Census of Manufactures, U.S. import data are official Department of Commerce foreign trade statistics.

105. Fairchild in particular, set up first in Korea and Singapore, as well as Hong Kong. See Chang (1971).

106. As did a conversation with an industry representative (in early 1980), who pointed to Sri Lanka as the next area of industry interest. Note that the 1971 and 1974 samples differ in composition and definition. Also, only current assembly operations are considered.

107. The Mexican Border Industrialization Program and the Kaohsiung Export Processing Zone.

108. They might have a positive bias if foreign producers using a minor amount of U.S. content chose to export with 806/807; a negative bias if U.S. producers chose not to go to the bureaucratic trouble of using 806/807 (costly paperwork) or if foreign firms offshore exports to the U.S. had no U.S. content. Both problems are probably small.

109. According to the U.S. Tariff Commission's estimates, all 806.30 imports from the LDC's exporting to the U.S. in that year (Mexico, Hong Kong) amounted to under $300,000 in 1967. In 1968, if Taiwan, Netherlands Antilles, and Korea are added to that list, the possible maximum rises to $4.6 million. That figure must further be reduced by any 806.30 imports not composed of semiconductors; in 1969, in the aggregate, only ten percent of all 806.30 imports were SCD's. See U.S.I.T.C. (1[illegible] [illegible] to [illegible]

110. The figures for 806/807 imports, as well as total imports, reflect revisions to published statistics. Compare them, for example, to US.I.T.C. (1975), Appendix tables; U.S. Department of Commerce (1979), pp. 60-62. As an example of such discrepancies, the U.S.I.T.C. (1970) published an estimate of 1969 806/807 SCD imports equal to $126 million. The official figure published for <u>all</u> SCD imports was $104 million for that same year (see Table 4.3). That last figure was revised upward to $111 million by Commerce in 1979 (U.S. Department of Commerce, Bureau of the Census (1979b), Table 3b), still well below the U.S.I.T.C. figure of $134 million. The net effect of accepting the unrevised Commerce Department Statistics would be to increase the proportion of imports entering under 806/807 prior to 1970.

111. See IDB, <u>Opportunities for Industrial Investment in Haiti</u>, 1979, pp. 37-38.

112. See World Bank (1978b) pp. 23-24 on Thailand. Note that while the Bataan export processing zone opened its doors in 1973, most foreign electronics assemblers established operations outside the zone, near the Manila airport. See "Electronics fever hits Philippine Zones," <u>Philippine Daily</u>. <u>Express</u>, November 02, 1979, p. 22

113. See Chang (1971), pp. 34-38; Moxon (1974), pp. 45-47.

114. In testimony before the House Subcommittee on Trade on March 24, 1975, David Packard (of Hewett-Packard) remarked that he was concerned about our long-term exposure in Malaysia and wondered whether we (H-P) could solve the problem by automating the assembly process and [illegible] we found that if we had to do that work in the United States the increased costs would force us out

of this particular business."

115. The conventional manner of calculating apparent consumption - taking the value of U.S. industry shipments, adding imports, and subtracting exports -- would double - count many U.S. SCD imports and exports. As noted before, the U.S. shipments estimates made by the Bureau of the Census already include the final value of unfinished 806/807 type imports when the value of U.S. shipments is calculated. Similarly, SCD parts exported to be fabricated into 806/807 imports, are actually consumed inside the U.S. when they return as 806/807 imports. Thus, the appropriate way to calculate U.S. apparent consumption is to take U.S. final shipments, add the value of imports _other than_ unfinished 806/807 imports, and subtract the value of U.S. SCD exports _less_ the U.S. content of unfinished 806/807 imports.

116. See U.S.I.T.C. (1980), p. 11.

117. Prior to 1980, when a new valuation code took effect.

118. See A.G. Lebowitz, _Item 807.00_, Mandel and Grunfeld Seminar notes, Mandel and Grunfeld, New York, November 1979.

119. Note that - except for certain special tools and dies unique to a specific product - depreciation and other capital costs ought properly be considered a general expense. Also note that research, development and design costs fall into a grey area of the law. When directly allocable to a U.S. made component, they are not considered a cost of fabrication. When numerous production stages take place inside and outside of the U.S. , before a finished product emerges, it is unclear what allocation of basic technical, administrative, and research overhead ought be made to be various stages of production. Does the silicon chip from which an integrated

circuit is assembled overseas, and then shipped back to the U.S. for testing and packing, embody the research cost that went into it as a chip, prior to export, as an assembled I.C. , or as a packaged I.C. after it has passed electrical tests and is actually ready for sale?

As might be imagined, the U.S. Customs Service has had great difficulty in interpreting this statute. An informal survey of Customs practice at various ports of entry along the U.S.-Mexican border, where a great deal of 806/807 trade enters the U.S., in early 1980, disclosed a great deal of variation in actual practice. Some import specialists ask for actual fabrication cost, general expenses, and profit, others make elaborate calculations comparing various cost ratios among the operations they are responsible for, in an effort to monitor "usual" expenses and profit; many simply accept whatever declaration is made with minimal scrutiny. Often, a wide variety of practices is followed within a single port of entry.

120. See Finan (1975), Table 3-3.

121. U.S. Department of Commerce, Bureau of the Census, 1977 Census of manufactures.

122. See Dickens (1980).

123. Additional support for this hypothesis may be deduced from data published by the U.S. Tariff Commission in its 1970 study of offshore imports. (See pp. 97-99, 126-128). They conducted a survey of 14 domestic U.S. SCD establishments, with a total value of shipments of $513 million in 1969, and final shipments of articles entered under 806.30 and 807.00 of roughly $21 million and $128 million, respectively. yet the Tariff Commission reports total 806/807 imports in 1969 to be about $127 million, well under the $149 million

in 806/807-based sales reported by these 14 firms alone. The difference can logically be attributed to a markup on 806/807 import value prior to final sales. The Tariff Commission also reported that those firms shipped about $47 million in U.S. components to 806/807 facilities in that year, or roughly 32 percent of the value of shipments of articles entered under the offshore assembly tariff provisions. If we attribute the entire difference between that 32 percent U.S. content figure, and the 54 percent U.S. content in 806/807 SCD imports in the official trade statistics, to a mark up on import value prior to final sale, an 84 percent markup on declared customs value appears to have been the norm for semiconductor devices entered under 806/807 in 1969.

124. To make this argument algebraically,
let total value added in U.S. shipments be TVA;
offshore value added in U.S. shipments be OVA;
U.S. value added in U.S. shipments be UVA;
value added offshore/unit assembled offshore be V_{off};
total value added/unit (onshore and offshore) be V_{tot}, a constant;
units assembled offshore X_{off};
all units assembled X_{tot};
Then $TVA = OVA + UVA = V_{tot} \; X_{tot}$

$$OVA = V_{off} \; X_{off}$$

and

$$OVA/TVA = (X_{off} / X_{tot}) \cdot (V_{off} / V_{tot})$$

If OVA is not directly observable, but is proportional to some index I_{off}, with constant of proportionality k, we have

$$X_{off} \;/\; X_{tot} = (V_{tot} \;/\; V_{off}) \cdot (k\, I_{off} \;/\; TVA)$$

$$= (V_{tot} \;/\; V_{off}) \cdot (k\, I_{off} \;/\; UVA + kI_{off})$$

$$= (V_{tot} \;/\; V_{off}) \cdot \left(k \;/\; \left(1 + \frac{(k-1)\, I_{off}}{UVA + I_{off}}\right)\right)$$

$$\cdot\; (I_{off} \;/ UVA + I_{off})$$

For k close to 1 (our measured index of OVA close to its true value), and (I_{off} /UVA + I_{off}) small (a small proportion of value is added offshore), we have, approximately,

$$\frac{X_{off}}{X_{tot}} = (V_{tot} \;/\; V_{off}) \cdot k\, (I_{off} \;/UVA + I_{off})$$

In reality, both (V_{tot} / V_{OFF}) and k have probably changed over time. (V_{tot} / V_{OFF}) has probably increased as more complex devices, with a greater portion of their value reflected in the costs of designing and producing a functioning chip, have been introduced, and assembly costs reduced as a proportion of total cost. On the other hand, increased testing offshore may have counteracted this trend, to some extent, since this would increase V_{off} relative to V_{tot}, ceteris paribus.

Since our measure of I_{Off} is dutiable 806/807 value, which includes some dutiable U.S. materials, k must be less than 1. As the unfinished chip came to be a greater and greater proportion of the value of U.S. materials used (and was the main item admitted duty-free) with increasing chip complexity, k must have been increasingly closer to 1 as the years passed.

Since, therefore, both k and (V_{tot} / V_{off}) probably increased over time, the index we are calculating $(I_{off}/UVA + I_{off})$ of offshore value added probably *understates* the true increase in offshore operations.

125. See the last footnote.

126. This is because materials (like wire, packages, epoxy, etc.) which are materially altered or transformed during the assembly process are dutiable as is the value of any assistance supplied by the U.S. parent. Actual cost data from customs records of 806/807 assembly operations for integrated circuits graphically make this point:

	Producer No. 1			Producer No. 2			
	Malaysia			1976			
	1973	1974	1975	Mexico Border	Mexico Interior	Malaysia	South Korea
Foreign Operating Expense (includes Labor and Overhead)							
as % of Total Reported Cost	20	8	7	33	33	29	21
as % of Dutiable Value	29	17	18	87	67	63	68

The data for the Malaysian operation, for 1973, probably reflects extraordinary start-up costs. There obviously appears to be substantial variation from producer to producer.

The information was supplied by the Regulatory Audit Division of the U.S. customs Service.

127. Also, Customs court decisions have substantially liberalized the definition of what sorts of operations are permissible on U.S. materials that can subsequently re-enter the U.S. duty-free. See Lebowitz (1979).

128. See references in footnote 24.

129. *Ibid*.

130. The ITC (1979, p. 6) noted this trend. The Office of Producer Economics, Department of Commerce (1979, p. 64) thinks that the increasingly costly and capital-intensive nature of the testing process for I.C.'s has led to a shift in testing facilities back to the United States, to take advantage of economies of scale in centralized facilities. The additional riskiness perceived in placing more expensive equipment in foreign locations may also explain some part of this shift.

In the early 1970's, however, most testing of U.S. devices intended for the U.S. market probably was sited in the U.S. See Finan (1975), pp. 18-19.

131. According to the U.S. Department of Commerce, *Country Market Survey-Electronic Components*, "Hong Kong," (Washington, 1978), some 75 to 95 percent of Hong Kong output returned to the U.S., where most testing was done. At that time, the vast bulk of output in Hong Kong was produced by U.S. multinationals.

132. It is not known how European production statistics account for offshore production.

133. See The Consulting Group, BA Asia, (1979), p. 109.

134. Calculated from MITI and MOF data, as reported in The Consulting Group, BA Asia Limited, The Japanese Semiconductor Industry: An Overview, (Hong Kong, 1979), p. 137. Original yen figures have been converted to dollars at 274 yen/dollar.

135. See Business Week, (October 6, 1980), p. 47.

136. U. S. I. T. C. , (November 1979), p. 44.

137. Asian Wall Street Journal, (March 14, 1981), p. 3; also New York Times, (June 27, 1981), p. D-1.

138. See Yoshihara (1978), Table A8.

139. See Yoshihara (1978), Table A8.

140. Korea and Taiwan, from the viewpoint of a Japanese investor, offer many of the same advantages that Mexico offers to a U. S. investor. They are quite close (Korea is a one hour ferry boat ride from Western Japan), have much lower wages, and have a long history of political, cultural, linguistic, and ethnic ties to Japan.

141. Yoshihara (1978), p. 161.

142. It is also interesting to note large volumes of parts exports from Malaysia to Hong Kong and Singapore, confirming the impressionistic evidence that more complex operations are being set up in Hong Kong and Singapore with increasing frequency.

143. See Section 5.

144. According to EEC (Eurostat) 1978 statistics, semiconductors accounted for roughly 15.6 million European units of account out of a grand total of 18.6 million EEC units of account imported from the

Philippines in NIMEXE section 85 (electronic goods), in 1978. According to Berthomieu and Hanaut (1980), outward processing imports from the Philippines in NIMEXE 85 in 1978 amounted to 12.9 million units of account.

145. In 1978, U.S.-based manufacturers were thought to have produced about 58 percent of the value of European consumption, and 78 percent of IC consumption, through European affiliate production and U.S. exports. In 1979, those percentages were thought to have been 52 and 63, respectively.

Increases in Japanese market share accounted for most of the decline. In 1979, the Japanese produced about 3 percent of European semiconductor consumption, and perhaps 6 percent of IC's. (See Office of Producer Economics, U.S. Dept. of Commerce, (1979), p. 90; *Fortune* (July 28, 1980), p. 80).

146. The Japanese have recently been investing heavily in European production facilities within the Common Market tariff walls. See *Business Week* (October 6, 1980), p. 47.

147. VLSI stands for Very Large Scale Integration (see section 3).

148. See *Electronics* (June 2, 1981), p. 118.

149. The VHSIC program (Very High Speed Integrated Circuit) is expected to advance the basic technology of ICs two to three years beyond what otherwise would be achieved. See *Electronics* (June 16, 1981), p. 39.

150. Both NTT and Bell do not compete with private SCD producers, and have no particular interest in obstructing the diffusion of technology. NTT does not produce circuits, and Bell's Western

Electric Manufacturing subsidiary produces only for internal ATT use.

151. See U.S. Department of Commerce, Country Market Survey - Electronic Components, Japan, (1973), for a contemporary diagnosis of these difficulties.

152. See Electronics (June 2, 1981), p. 117; Fortune (July 28, 1980), p. 80.

153. For evidence on the lag by U.S. SCD merchants in defect rates on memory chips, see The Economist (April 26, 1980), pp. 55-56; Electronic Engineering Times (March 2, 1981), p. 2; Electronics (November 6, 1980), p. 46, (May 19, 1981), pp. 141-148.

U.S. quality levels are apparently about the same as the Japanese in microprocessors, where the U.S. still had a technological lead. See Electronics (December 18, 1980), p. 41.

154. See Electronics (May 19, 1981), pp. 125-198.

155. We shall use the word quality to means both "quality" and "reliability." Technically, quality is measured by the portion of a batch conforming to the established electrical specifications of the product, and reliability by the rate at which devices' performance fails to meet these specifications over time in use.

156. A manager for quality control for GE's Television Business division put it this way:

> We try to get our engineering to design in the Japanese devices where we can, because from a manufacturing standpoint, it's a lot cheaper ... We're 100% testing them (U.S. and European components), and in some cases we're also paying

for high-reliability testing. We don't 100% test any Japanese device.

Electronics (May 19, 1981), p. 143.

157. According to the 1977 Census of Manufactures

158. According to the CIA (1979), p. 2.

159. This was also true for two of the largest U.S. semiconductor producers, IBM and Western Electric, which supply all of their output to other divisions of their own company. Both do all of their production (including assembly) for the U.S. market in the U.S., and by all accounts are even more advanced than the Japanese in terms of quality levels and automation.

160. This can be seen by examining the return to capital investment. Pechman and Kaizuka (1976, p. 344) point to a study which had shown the average gross rate of return on all assets to be about the same in Japan and the U.S. Effective tax rates are also roughly similar.

On the other hand, calculations by Rober Noyce (presented at a Hearing before the Subcommittee on International Finance of the Senate Committee on Banking, Housing, and Urban Affairs, January 15, 1980) show Japanese firms with a debt/asset ratio about five times greater than U.S. firms and an after tax return on equity about twice that of U.S. firms. Assuming similar tax rates, for the gross return on assets to have been the same, the average interest rate paid on debt would have had to have been about substantially lower than the U.S. interest rate. This is likely, but also suggests a much lower gross rate of return on assets in SCD's in Japan than in the U.S., which in turn suggests the availability of cheap capital to Japanese firms.

161. It is claimed that half of Japanese process equipment comes from the U.S. See Electronic Engineering Times (April 27, 1981), p. 2; New York Times (June 3, 1981), p. D4.

162. See Electronics, (July 14, 1981), PP. 89-90.

163. These "quality circles" are now being experimented with at many U.S. firms. See Electronics (May 19, 1981), p. 125, (April 21, 1980), pp. 106-108.

164. The stress on labor relations and the "human factor" in Japanese methods is quite remarkable. For example, NEC's U.S. affiliate, unlike some U.S. firms, uses a "clean room" for assembly operations, not only for controlling defects, but also because they claim "the sterile environment helps instill assembly workers with a sense of care." (Electronics [June 2, 1981], p. 38). The results are also, apparently, transferable.

Hewlett-Packard, after discovering that its Japanese plant was getting quality levels five times higher than the average of all HP plants, studied its operation and made major improvements in its other plants. See Electronic Engineering Times (May 25, 1981), p. 15.

In another famous experience, retail failure rates dropped dramatically when U.S. color television plants were purchased and reorganized by Japanese firms. See GAO (1979), pp. 96-97.

A Japanese electronics firm in California, much to the dismay of its non-union U.S. neighbors, recently agreed to bargain with a union. (Electronics [April 7, 1981], p. 41).

165. IBM and Bell's Western Electric subsidiary, which do not sell their product on the open market, adopted similar innovations before the Japanese, it should be noted.

166. See U.S. ITC (November, 1979), p. 133-34, for a description of some of these tax arrangements.

167. See Japan Electrical Machinery Industry Association (1980, in Japanese), p. 33. These "offshore" Asian countries are Korea, Taiwan, Hong Kong, Thailand, Singapore, Malaysia, The Philipppines, and Indonesia.

168. See U.S. Department of Commerce, U.S. Direct Investment Abroad--1977 (Washington, 1981), p. 149. Developing Asia and the Pasific is defined as all of Asia and the Pacific less Japan, Australia, and New Zealand.

169. It is, of course, possible that Japanese firms, by virtue of the small military power projected by Japan, face greater political risks than U.S. firms.

170. See Asian Wall Street Journal (June 23, 1980), p. 16. A crucial difference between U.S. and Japanese producers doing cost comparisons is that Japanese-made chips are charged duty when entering the U.S. while U.S.-made chips entering under the 806/807 tariff provisions are not.

171. See Asian Wall Street Journal article cited above; New York Times (June 27, 1981), and the analysis of the last section.

172. Japanese auto exporters' success was recently met with import quotas. Import quotas on Japanese color T.V. sets were successfully bypassed by Japanese producers who set up operations in the U.S. to assemble color T.V. sets with subassemblies and components

imported from Japan. U.S. trade authorities found this to be an acceptable way for Japanese producers to expand T.V. sales in the U.S. See U.S. ITC (May 1, 1980).

173. See Japan Electrical Machinery Industry Association, (1980, in Japanese), pp. 249-261.

174. See U. S. I. T. C. (September 1970), pp. 21-22.

175. See Lebowitz (1979), p. 15.

176. See U. S. I. T. C. (July 1976), p. 44.

177. See U. S. I. T. C. (January 1980), pp. 38-39.

178. i. e., ℓ = cost of foreign assembly/cost of domestic assembly m = cost of a fabricated chip/cost of domestic assembly.

Since the overall cost difference between domestic and foreign assembly is

cost of domestic assembly-cost of foreign assembly-tariff and transport cost

$$= \left[1 - \ell - (t + ¢)(m + \ell)\right] \cdot \text{ cost of domestic assembly.}$$

179. The U. S. Tariff Commission (September 1970) in its survey of the effects of 806/807, came to a similar conclusion, but only calculated duty-savings as a percent of total duty-paid value, in drawing its conclusion for all sorts of products. A complete analysis would also require an analysis of cost savings accompanying the use of foreign assembly <u>without</u> 806/807.

The technical condition required for 806/807 to be critical to the use of offshore assembly is that expression (9.2) be less than t_m, but greater than 0.

180. And as much has been said by the Japanese; see in Section 8.

181. One operator with an automated bonder replaces roughly 30 workers using manual bonding techniques. In trimming and forming, one worker and appropriate machinery replaces seven workers. See *Electronics*, (June 2, 1981), p. 38

182. Texas Instruments recently announced plans to start fabricating chips in Singapore in 1983. See *Asian Wall Street Journal*, (February 16, 1981), p. 6.

183. See *Asian Wall Street Journal*, (June 23, 1980), p. 16; testimony of Robert Noyce before Subcommittee on International Finance, Senate Committee on Banking, Housing, and Urban Affairs, (January 15, 1980), p. 113; *Electronics* (May 19, 1981), pp. 132, 145.

184. Frost and Sullivan Report No. 716, quoted in *Northern California Electronics News* (January 7, 1980), p. 1.

185. See *Electronics*, (June 2, 1981), p. 38.

186. Although this situation may have begun to change by the late 1970s, as the U.S. SCD producers increasingly began to make offshore investments in more automated assembly facilities.

187. To be precise, a Markowitz-efficient portfolio.

If capital markets work perfectly efficiently, decisions that improve the return on investors' assets, given some fixed level of risk, ought to result in increases in the market value of the firm that makes them. Since, in this simple view of things, firms are merely financial intermediaries with the technical and financial information to transform an investor's capital into a portfolio of tangible investments in products, processes, and production locations, a single firm has no determinate mix of products, processes, and production locations. In the aggregate, however, the market is assumed to reward marginal firm decisions, that make the market portfolio more efficient, with increased firm market value. Thus, production managers for individual firms would be guided by market signals to improve the aggregate market portfolio, and while the overall aggregate investment in products, processes, and production locations *would* be determined by risks and returns of invested assets, the composition of a single firm's portfolio of investments in these characteristics would be indeterminate.

188. If π_1 is return to a dollar invested in semiconductor assembly in location 1, π_2 the return in location 2, we are assuming that

$$\pi_1 = M_1 + \sum_{\ell=1}^{L} C_{1\ell} I_\ell + \varepsilon_1 \; ; \; \pi_2 = M_2 + \sum_{\ell=1}^{L} C_{2\ell} \; I_\ell + \varepsilon_2$$

where M_1, M_2 are mean return in the two locations; there are L underlying factors (I_ℓ) which affect the returns of these and all other assets in the market, with effect equal to $C_{1\ell}$ or $C_{2\ell}$ for location 1 or 2; and ε_1 and ε_2 are location specific disturbances ("country risk") that are independent of the returns to all other assets (including each other) in the market portfolio. Investment returns in locations 1 or 2 would then be related to each other or to returns in other locations or products, only through these underlying factors. The empirical content of this assumption is that all covariances among rates of return to offshore semiconductor production investments can be expressed as a fixed linear combination of the L variables I_ℓ (where L is the number of underlying factors) whose values change from year-to-year, but are the same for all semiconductor production investments, regardless of location.

See the technical appendix for a complete discussion.

189. See preceeding footnote. $C_{i\ell} = 0$ when underlying factor I_ℓ has no effect on returns in country i.

190. To see this, note that Π_i is a variable profit function (per unit capital) containing prices of inputs and outputs as its arguments. An output-augmenting technical change is equivalent to (and leads to identical input and output decisions) an increase in the price of output in the old profit function, holding other input prices constant. It will thus cause a shift in intercept H, which includes the term containing the log of output price. The same argument applies to output-augmenting technical advance shifting the values of e_0 and f_0 in (10.8) and (10.13).

191. See Muth, "Optimal Properties. . . "

192. I. e. ,producers' prior period expectations of the price level at time t (P_t^e) are equal to the rate of increase in prices observed in the previous period (P_{t-1}/P_{t-2}), times a weighted average of the actual and expected price levels at time t-1.

193. The value of capital to value of output ratio is just

$$P_k \, k'(P_i')/P_Q$$

where k^* is the physical capital-output ratio.

194. Substituting into (10.8) using (10.6), (10.4), and (10.3), we then have, adding an additional subscript to our variables to allow for our lag specifications for values that vary over time (and omitting t and i when values are constant over time or country)

$$
\begin{aligned}
(10.9)\quad \ln Y_{it} - \ln Y_{it-2} = {} & \left[2-\lambda-\delta\right]\left(\ln Y_{it-1} - \ln Y_{it-2}\right) - \left[\delta\lambda\right] \\
& \ln Y_{it-2} + \sum_j \left[e_j\right]\left(\ln P_{ijt} - \ln P_{ijt-2}\right) \\
& + \sum_j \left[\delta\left(1+\lambda\right) d_j - e_j \ (2-\lambda-\delta)\right]\left(\ln P_{ij-1} - \ln P_{ij-2}\right) \\
& + \sum_j \left[\left(d_j + e_j\right)\delta\lambda\right] \ln P_{ijt-2} + \Big[\delta(1-\lambda)\left(H^e_t - H^e_{t-1}\right) \\
& + \delta\lambda \ln H^e_t + (e_{ot} - e_{ot-2}) - (2-\lambda-\delta)(e_{ot-1} - e_{ot-2}) + \delta\lambda e_{ot-2}\Big] + \left[\delta(1-\lambda)\right]\cdot \\
& \left(J^e_{it} - J^e_{it-1}\right) + \left[\delta\lambda\right] J^e_{it} + \left[\delta(1-\lambda)\left(V_{it} - V_{it-1}\right) + \delta\lambda V_{it}\right]
\end{aligned}
$$

The easiest way to see this is to solve (10.4) to get

$$\ln K = \delta / (1-(1-\delta)L) \cdot \ln K^* \quad ;$$

using L to denote the lag operator, solve (10.6) to get

$$\ln P^e = (1+\lambda)L - L^2) / (1-(1-\lambda)L)$$

then substitute these expressions into (10.8) and (10.3) respectively, and multiply both sides of (10.8) by $(1-(1-\lambda)L)\ (1-(1-\delta)L)$. The result is (10.9). with brackets enclosing the coefficients of the variables used as data, and the 'e' superscript used to denote expectations of H and J The last bracketed term is a random error, with V_{it} an econometric error term added to equation (10.8).

195. Since the 806/807 tariff items amount to a subsidy to the use of U. S. components in imported manufacturers at a rate of subsidy equal to the tariff rate.

196. With this modification (10.9) becomes

$$
\begin{aligned}
\ln Y_{it} - \ln Y_{it-2} = {} & [2-\lambda-\delta] \; (\ln Y_{it-1} - \ln Y_{it-2}) - [\delta\lambda] \\
& \ln Y_{it-2} + [e_{PL}](\ln P_{iLt} - \ln P_{iLt-2}) + [\delta\,(1+\lambda)\, d_{PL} - e_{PL}\,(2-\lambda-\delta)] \\
& (\ln P_{iLt-1} - \ln P_{iLt-2}) + (d_{PL} + e_{PL})\,\delta\lambda \, \ln P_{iLt-2} \\
& + [\delta\,(1-\lambda)\,(H^e_t - H^e_{t-1}) + \delta\lambda \, H^e_t + (e_{0t} - e_{0t-2}) - (2-\lambda-\delta)(e_{0t-1} - e_{0t-2}) + \delta\lambda e_{0t-2} + \\
& \sum_{j\neq 1} (e_j (I_{jt} - I_{jt-2}) + (\delta\,(1+\lambda)\, d_j - e_j\,(2-\lambda-\delta))\,(\ln I_{jt-1} - \\
& \ln I_{jt-2}) + (d_j + e_j)\,\delta\lambda \ln I_{jt-2})] + [(1-\lambda)\,\delta](J^e_{it} - J^e_{it-1}) \\
& + [\lambda\delta]\, J^e_{it} + [\sum_{j\neq L} (d_j + e_j)\,\delta\lambda \ln q_{ij}] + [(1-\lambda)\;\delta\,(U_{it} - U_{it-1}) + \delta\lambda\, U_{it}].
\end{aligned}
\tag{10.10}
$$

197. As in footnote 187 to this section, the value of U.S.-component input per dollar of capital is just

$$P_{us}\,\mu'(P_i')/P_K$$

where μ' is the physical U. S. component per unit capital ratio, P_{us} and P_a the relevant input prices.

198. These data begin in 1969. Since consistent country-by-country estimates are available only for 807 trade before 1972, all 807 import data for the 1969 and 1971 period have been multiplied for each country, by the aggregate ratio of all 806/807 SCD imports to those imported only under 807.

I thank the U.S.I.T.C. for furnishing on magnetic tape the unpublished 806/807 import figures from which the SCD import figures were constructed.

199. The wages were converted to U.S. dollars using the market exchange rate. Since the wages refer to different pay periods and industries, it is assumed that they are comparable to each other after deflation by a country-specific scalar, related to each country's internal wage structure, fringe benefits, and norms for monthly hours worked.

Actual wage data used were

A. Mexico, Korea, Hong Kong: Average wages in manufacturing, 1967-1979, from ILO, Yearbook of International Labor Statistics, various years.

B. Singapore, 1967-1978 same as A. 1979 estimated on basis of 20 percent average wage increase reported in Asian Wall Street Journal, (May 25, 1981, p. 17.

C. Taiwan, hourly wage in manufacturing 1966-1977, from U.S. Bureau of Labor Statistics, Handbook of Labor Statistic 1978. Linked to official figures for hourly wage in manufacturing, 1977-1979, reported in Taiwan, _Statistical Yearbook of the Republic of China_.

D. Philippines, index of average hourly earnings for unskilled labor in non-agricultural occupations, from IMF, _International Financial Statistics_, various years.

All exchange rates are from IMF, _International Financial Statistics_, except Hong Kong, based on trade conversaion factor from U.N. ,_Monthly Bulletin of Statistics_, and Taiwan, 1979, from official statistical yearbook.

Since 806/807 SCD imports in significant volumes did not come from the Philippines until 1973, estimation of the model (which requires two years of lagged imports data) used only the years 1975-1979 for the Philippines. Data for 1971-1979 were used for all other countries.

200. The actual political shift dummies used were

(i) for Mexico, all years = 0, except 1975, 1976 = 1; (ii) for Taiwan, all years = 0, except 1978, 1979 = 1; (iii) for Philippines, all years = 0, except 1972 = 1/2, 1973 to 1979 = 1 (martial law was declared at the end of 1972).

To take into account that the expectations of country risk in year t (when optimal K^* is determined), depend on previous years' observations of country risk, the "expected" shift dummy used as a determinant of optimal capital stock K^* was taken, simply, to be the unweighted average of the dummies (i) to (iii) for the three years t-1, t-2, t-3, and called J^{e}_{it} in (10.11) and (10.14).

201. Note that when all country intercepts are constrained to equal zero, the overall intercept is the value for 1971, without reference to country.

202. Since we do not directly observe offshore production -- instead we have customs value, which as mentioned before, is a constructed value having an uncertain relation to actual sales value -- we assume that customs value, C_{it}, is related to unobserved production by

$$\ln C_{it} = \ln \Phi_t + \ln Y_{it} + \mu_{it}$$
$$(\text{or } C_{it} = \Phi_t Y_{it} e^{\mu_{it}})$$

Φ_t a year-specific constant relating customs to market value, and μ_{it} a random error.

If we substitute with this into (10.11), we have a relationship identical to (10.11), but with ln C_{it} on the left-hand side, Φ_t incorporated into the constant and the time dummies, and μ_{it} incorporated into $\hat{V}_{it}$. This was the relation that was actually estimated.

203. The bulk of duty-free U.S. value is probably the declared export value of the unassembled chips. Some other U.S. materials are permitted to reenter the U.S. duty-free, but most other U.S. materials, which undergo physical transformation, are probably dutiable.

204. To be precise, if the original V_{it} of (10.8) are independent, identically distributed, the transformed errors of equation (10.15A), with $\hat{V} = \delta(1-\lambda)(V_{it} - V_{it-1}) + \delta\lambda V_{it}$, will display first-order autocorrelation with autocorrelation coefficient equal to $-\delta^2(1-\lambda)$. Even with such autocorrelation, our coefficient estimates remain consistent. For λ small, the autocorrelation coefficient will be quite small, and little error introduced into our estimates of standard errors.

205. That is, two-stage least squares was used equation-by-equation to estimate the parameters of (10.15) consistently, then residuals were calculated to consistently estimate the variance-corvariance matrix of $\hat{V}$ and $\hat{W}$ (assumed constant over country and time). The estimated variance-covariance matrix was then used to transform the data, and the coefficients of (10.15) simultaneously estimated as part of a single "stacked" equation system.

The G3SLS procedure of SPSS

was used for SLS calculations, and the INST proceudre from TSP for an original single-equation analysis using two-stage least-squares.

206. Since our estimate of β_1 (= 2- δ -λ) applies an estimate of $\delta + \lambda$ equal to .59, with a standard error of .51.

207. *Since β_1 and β_2 are both functions of δ and λ, they can be solved for consistent estimates of δ and λ. The estimate of δ so produced using the second column of Table 10.1 is .59± .0461, for λ, our point estimate is -.11 divided by our estimate of δ. The imaginary roots are a consequence of β_2 (= - $\delta\lambda$) having estimate .11, when, in fact, it should be a negative number. If we set $\delta\lambda$ = 0, we have an estimate of .59 for one coefficient when the other is set to zero.

208. That is, if $e_{\rho L}$ in (10.10) is equal to $f_{\rho L}$ in (10.13), the value of U.S. components/output ratio will be constant. The special case $e_{\rho L} = f_{\rho L} = 0$ corresponds to both ratios being completely unaffected by the wage rate.

209. There is another price of evidence that supports the hypothesis that $\alpha = .45$, $\lambda = 0$. As mentioned in footnote 204, these parameters imply an autocorrelation coefficient of about $-(.45) = -.20$ in both $\hat{V}$ and $\hat{W}$ of system (10.15), if the original untransformed V and W were uncorrelated. When the residuals corresponding to two-stage least squares estimates of equation (10.15A) and (10.15B), with no restrictions imposed, were used in an autoregression to estimate the autocorrelation coefficient, about this value was produced for the autocorrelation in (10.15A) and for the autocorrelation in (10.15B). Both values are quite consistent, then, with this hypothesis. Using $\delta = .45$, we have

$$\ln K_t = \delta \ln K_t^* + \delta (1-\delta) \ln K_{t-1}^* + \delta (1-\delta)^2 \ln K^*_{t-2}$$

which gives us the weights described in the text.

210. This must follow, because if capital stock is fixed, and output rises, use of at least one other input must have been increased. It cannot be assembly labor, since demand for labor declines with an increase in the wage. The amount of duty-free U.S. components used per unit of capital will rise, but since it si fixed by the level of output, it does not explain how greater levels of output per unit of capital is attained. The only major remaining input is dutiable material and componentry, therefore, use per unit capital of dutiable materials must rise.

In more formal terms, the restrictions we have imposed imply a production function of the form

$$Y = \min \left[f(L/K, M/K), \quad U/K \cdot 1/a \right] K$$

(Producers will choose U, L, and M per unit K so that both terms in brackets will be equal, to minimize cost)

with L, M, U, and K labor dutiable material duty-free materials, and capital, respectively. Constant a is the U/Y ratio, which is assumed fixed. For Y/K to rise, either L/K or M/K must therefore rise.

211. In a formal hypothesis-testing framework, calculating a t-statistic, we cannot reject this hypothesis at the 90 or 95 percent confidence levels.

212. And it will *not* be true, as sometimes has been argued (See U.S. Tariff Commission, 1970) that measures that raise the returns to offshore production (such as the 806/807 tariff provisions) have no effect on the location of production in the cheapest location, when it would be cheaper even without such incentives.

213. This is the so-called Kemp-MacDougall optimal tax on direct foreign investment. See Kemp (1962).

214. See the appendix to this section.

215. 'Model' international tax codes, for example, forbid discrimination on the basis of the nationality of the investor.

216. See the appendix to this section.

217. This follows from the fact that $\eta_{kr} = -\eta_{kP_L} \cdot \frac{\phi}{P_L L}$

η_{kP_L} the elasticity of K with respect to the wage

$\frac{\phi}{P_L L}$ the ratio of gross profit to the wage bill;

Our estimated coefficient β_4 from section 10 is a rough estimate of η_{KP_L}; it was near -2. Because wages are a small part of assembly costs (see section 7), $\frac{\phi}{P_L L}$ is likely to be quite large (and exceed 1).

218. The logic can be reversed, of course. If, for social and political reasons, wages paid by foreign assembly operations exceed domestic economy market wages, then the tax rate should be set at a level below that which would be optimal if foreign offshore operations were charged the marginal social cost of labor.

See equation (11.A.5) in the appendix of this section.

219. Of course, in the presence of economies of scale, externalities, learning economies, or costly information, they would not necessarily reflect marginal social cost to start with, and the various sorts of taxes and controls described would be used to remedy the situation.

220. U.S. Department of Commerce, Bureau of Economic Analysis, U.S. Direct Investment Abroad, 1977 (Washington, April 1981).

William Finan (1974) and the office of Producer Economics, Department of Commerce (1979) have estimated offshore semiconductor employment by U.S. firms as follows: (in 1000 employees)

	1963	64	65	66	67	68	69	70	71	72	73	74
Finan (1974)	2	4	7	9	15	30	67	75	85	89	NA	NA
Dept. of Commerce (1979)	NA	NA	NA	4	10	20	40	45	50	60	80	85

Both series were supposed to have been estimated by the Commerce Department on the basis of information supplied by Finan on the offshore operations of selected semiconductor firms, expanded to cover [illegible] offshore operations. The methodology used to do so is [illegible]

The accuracy of these figures is open to serious question, though. For one thing, the Commerce Department revised these estimates downward dramatically between 1974 and 1979, with no clear explanation for their action made. Also, the closest thing to real statistics on U.S. offshore electronics employment in these years is an estimate made by Roger Stobaugh in 1970, on the basis of information furnished to him by the U.S. Electronics Industry Association. He concluded that the total, worldwide foreign employment of U.S. electronics firms in foreign plants producing items entering the U.S. under tariff item 807 amounted to about 66,000 workers in 1968, and 83,000 workers in 1969. Employment in products actually imported under 807 was estimated to have been 49,000 workers in 1968, and 46,000 workers in 1969. (See Stobaugh, 1970).

Since the U.S. Tariff Commission points out that, in those years, U.S. 806 and 807 SCD imports were essentially coming from the same plants, with 807 accounting for the bulk of imports (U.S. Tariff Commission, 1970), these figures must be considerably greater than actual offshore employment in semiconductors (since all electronic products, not just semiconductors, and all plants, not just plants mainly producing for export to the U.S. are considered).

If we take the qualitative shifts (rather than exact levels of employment) portrayed by these figures, however, we are left with the impression of great growth in offshore SCD employment in the period 1966 to 1969, and 1972 to 1973. This is consistent with other information presented elsewhere in this essay.

221. U.S. Department of Commerce, unpublished compilation of official trade statistics.

222. The firms in the sample accounted for about 85 percent of global semiconductor sales in 1972. This may be seen by comparing the names of firms in the sample with market shares published in Webbink (1979), p. 22.

223. See the U.S. Census of Manufactures, 1977.

224. See the overview essay in this study.

225. These arguments are considered in the overview and country case studies.

226. See Bruno.

227. Total income and total sales are virtually synonymous in this case, as may be seen by examining the data for MOFAs. (Total sales are not available for affiliates other than MOFAs).

228. Philippine exports of semiconductors were (in million U.S. dollars)

1976	84	1978	253
1977	125	1979	289

See *Business Week*, (June 16, 1980), p. 36. In 1980, Philippine SCD exports amounted to almost $516, and manufactured exports to a little over $2 billion. See *Asian Wall Street Journal*, (April 13, 1981).

229. See the Mexico case study.

230. In Section 9.

231. Some have permanent offices in the American "Silicon Valley," where the arrangements are made. A Philippine subcontractor even took the step, recently, of setting up a U.S. assembly line using Philippine immigrant labor. *Northern California Electronic News*, (May 12, 1980).

232. In Hong Kong, see U.S. Department of Commerce, *Global Market Survey-Electronic Components* (Washington, 1974).

233. In Korea and Taiwan. See *Asian Wall Street Journal*, (February 16, 1981), p. 9. ; (April 13, 1981), p. 7.

234. See Section 9.

235. See footnote 233, above.

236. *Ibid.* On the other hand, one firm is "sending its local engineers to a California semiconductor company with which it has close connections." All three firms expect China to be a major market for their output, emphasizing how difficult it is to prevent the export of technology even when strict controls are placed on the export of the products in which it is embodied.

237. Firms generally prefer to set up their own offshore operations because they are cheaper (perhaps because capital is cheaper for them), but smaller firms not yet ready to absorb the fixed setup cost often subcontract assembly. See Finan (1974), p. 63; Dickens, (1980)) p. 83.

238. Korean authorities, for example, frankly acknowledge that skilled manpower is the key bottleneck in the future development of their semiconductor industry. Korean Development Institute, *Long-Term Prospect for Economic and Social Development, 1977-91* (1978),

p. 259-287.

239. In Mexico during the 1975-76 period, there were suggestions that assembly plants acted in concert to create pressure for lower wage levels.

It may well be that relatively minor portion of employment accounted for by these offshore assembly operations in most countries is a consequence of host country desires to minimize export instability and dependence.

240. Which basically could be eliminated by an equally idealized system of lump-sum transfers.

241. For a discussion of optimal policy in the presence of these costs, see Lapan (1976, 1978, 1979) and Ray (1979).

242. Technically, D is a compensated demand; i.e. , the demand for semiconductors that would obtain if, as we changed the price of semiconductors and, therefore the cost (price, in a competitive consumer good industry) of finished consumer goods, we were to make lump sum transfers to consumers to maintain their satisfaction constant.

As an approximation, however, we shall use the market demand instead of the compensated demand curve. Willig (1976) shows that this is a reasonable (i. e. , generally relatively minor errors) approximation.

243. See Schmalensee (1976), Carlton (1979).

244. To see this, note that

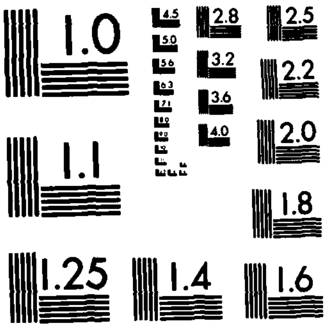
$$V(C_L) = \int_{C_c}^{C} - Q \text{ [illegible]}$$

or

$$V(C_u) = \int_{C}^{u - C_0} - Q(C \text{ [illegible]}$$

AD-A123 325   THE INTERNATIONALIZATION OF INDUSTRY ANNEX B OFFSHORE   4/4
PRODUCTION IN THE I..(U) DEPARTMENT OF STATE WASHINGTON
DC OFFICE OF EXTERNAL RESEARCH.. J GRUNWALD ET AL.
UNCLASSIFIED   NOV 81 FAR-284-GP-ANNEX-B   F/G 5/3   NL

END
FILMED
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Taking a second-order Taylors series approximation to V in the neighborhood of 0, i. e. , for $C_u - C_o$ close to zero

$$V = (C_u - C_o)(-Q(C_o)) + \frac{(C_u - C_o)^2}{2}(-Q'(C_o))$$

so

$$\frac{V}{C_oQ_o} = -\left(\frac{C_u}{C_o} - 1\right)\left(1 + \left(\frac{C_u}{C_o} - 1\right)\frac{\eta_{QP}}{2}\right)$$

which is just (13.1).

245. At fixed international prices. We are also assuming foreign exchange is in perfectly elastic supply, and that foreign imports are not allowed to be substituted for U. S. -produced semiconductors as U. S. semiconductors become more costly.

246. We have

$Q = q(P)\ X(h(P))$ with Q total demand for semiconductors, q demand per unit of consumer good output, $= \frac{Q}{x}$ (a function of the price of semiconductors), X demand for the final consumer good, a function of h, the unit cost of producing X (assumed equal to price), in turn a function of the price of semiconductors . Then differentiating with respect to P

$Q' = q' X + q X'h'$. By Shepherd's Lemma, $h' = q$,

so

$$Q' \frac{P}{Q} = q' \frac{P}{q} + x' \frac{h}{x} h' \frac{P}{h}$$

which is just (13.2).

247. This follows from the fact that input demands are homogeneous of degree zero in prices. That is, letting Po stand for the price of another input (we assume only 1 for expositional simplicity), and Px the price of output,

$$q\ (P,\ Po) = q\ \left(\frac{P}{Px}\ ,\ \frac{Po}{Px}\right).$$

Then, taking derivatives with respect to time

$$\frac{dq}{dt} = \frac{\partial q}{\partial\left(\frac{P}{Px}\right)}\ \frac{d\left(\frac{P}{Px}\right)}{dt} + \frac{\partial q}{\partial\left(\frac{Po}{Px}\right)}\ \frac{d\left(\frac{Po}{Px}\right)}{dt}$$

By our assumption of roughly constant relative prices for inputs other than semiconductors, $\frac{d\ \frac{Po}{Px}}{dt} \approx 0.$ Now, since $\frac{\partial q\ (P,\ Po)}{\partial P} = \frac{\partial q\left(\frac{P}{Px},\ \frac{Po}{Px}\right)}{\partial\left(\frac{P}{Px}\right)}\ \frac{1}{P_x}$

we have $\frac{dq}{dt} = \frac{\partial q\ (P,\ Po)}{\partial p}\ Px\ \frac{d\left(\frac{P}{Px}\right)}{dt}$

and $\frac{\partial q\ (P,\ Po)}{\partial P} = \frac{\frac{dq}{dt}}{\frac{d\left(\frac{P}{Px}\right)}{dt}}\ \frac{1}{Px}.$ Multiplying both sides by $\frac{P}{q}$,

$$\eta_{qp} = \frac{dq}{d\left(\frac{P}{Px}\right)}\ \cdot\ \frac{\frac{P}{Px}}{q}$$

which is (13.3).

248. The only other serious attempt that I am aware of is that of Webbink (1977), who regressed the log of aggregate demand for different types of semiconductor devices on log semiconductor price and the log of value of electronics sales. If the electronic output price index (which is unobserved) is negatively correlated with semiconductor prices over the period of his sample (roughly 1965-1972), which we

would expect, and positively correlated with output (also to be expected, as demand for electronic products increased in spite of price increases), his estimate of the price elasticity will probably be biased toward zero. This is because the bias in his estimate of the price elasticity will equal $-by$, with y the coefficient of the log of electronics sales, and b the coefficient of semiconductor price in an auxiliary regression of the (unobserved and omitted) log of electronics output price against the logs of semiconductor price and value of electronics output (the included independent variables). See Theil (1971, Pp. 548-550) for a description of the principles determining the specification bias when an independent variable that might be included (i.e., the log of electronic output price), is omitted.

Webbink's own-price elasticity estimates were

linear ICs	-1.4
digital ICs	-1.6
silicon transistors	-.65
germanium transistors	-1.7
silicon diodes	-.77
germanium diodes	.28
lead-mounted rectifiers	-.93
chassis-mounted rectifiers	-1.4
zener diodes	-.69

He made no attempt to correct for changes in the complexity of ICs over the 1960-1972 period.

The only other related estimate I found is that of Wilson, Ashton, and Egan (1980), who, based on the observed price-quantity relations for memory bits sold over 1971-1979, guess that the total (not per computer manufactured) price elasticity of computer memory bit demand (of MOS RAM ICs) to be about -2. Their estimate, because it does not take into account changes in computer demand, and because no actual price data for memory bits sold was used (instead, memory bit costs in the most advanced design chips manufactured, and guesswork, was used), is not particularly solid.

249. Noyce (1977), p. 67.

250. According to U.S. Census of Manufactures, 1972.

251. Call x the measured percentage rate of increase in output between 1967 and 1972, y the measured percentage rate of decrease in price between 1967 and 1972. Our calculated price elasticity (times - 1) is just x/y. If, however, 1 unit of semiconductor sales in 1972 is equivalent to N units sold in 1967 ($N > 1$), then the "true" price elasticity for 1967-equivalent devices is $\frac{x - \ln N}{y + \ln N}$, which will fall short of [illegible] measured elasticity as long as x/y is greater than 1 (which it is, for all sectors in Table 13.1).

To see this, note that

$$\frac{d}{d\alpha}\left(\frac{x-\alpha}{y+\alpha}\right) = -\frac{(y+x)}{(y+\alpha)^2} < 0 \text{ for } x,\ y > 0.$$

252. This is probably not a bad assumption, as a reasonable approximation. For example, an executive at NEC (one of the biggest Japanese IC makers) explained in 1981 why Japanese producers were delaying mass production of the new generation of 64K computer memory chips in these terms, stating that "If 64Ks are introduced in the market, there will be no demand, since four 16 Ks are less costly than one 64K." (*Asian Wall Street Journal Weekly*, April 6, 1981, p. 14).

The U.S. Census index of 1972 IC output at 1967 prices was first multiplied by four, and then multiplied by the (1967 dollar) price index for ICs to get a new estimate of the value of 1972 IC output at 1967 prices in terms of 1967-type ICs, and used in the numerator of the calculated elasticity. Then, the revised figure for (1967-priced) 1972 IC output was added to existing estimates of the (1967-priced) value of 1972 production of other types of semiconductors, then divided into 1972 SCD production of all classes of devices at current prices, to get an implicit price deflator for a unit of 1972 SCD output in terms of

1967 output. The original (cross-weighted) 1972 census price deflator for SCD output (1967=100) was 86.9. The implicit SCD price deflator after revaluing 1972 production at four times the original (1967-priced) quantity index was 30.9. This new price for 1972 semiconductors in terms of 1967 prices was then used to recalculate the change in the relative price of semiconductors over the 1967-72 period in Table 13.2.

253. That is, let price less manufacturing cost (with offshore assembly) equal a constant π. Let manufacturing cost offshore be M_o, manufacturing cost with onshore assembly M_u.

Then

$$\frac{C_u}{C_o} - 1 = \frac{M_u + \pi}{M_o + \pi} - 1 = \frac{M_u - M_o}{M_o + \pi} = \frac{M_u - M_o}{M_o} \quad \frac{M_o}{M_o + \pi} = a \cdot b$$

as defined in the text.

Since this difference between price and the cost of manufacture covers the costs of R and D, corporate overhead, and profits, it will remain approximately constant in a competitive industry as long as the technology of assembly does not change too much when brought back onshore.

For example, if the transfer of assembly back to the U.S. led to the use of automated assembly techniques using much more capital, Π (which contains the return to that capital investment) might increase somewhat. Since assembly has become a relatively small part of the cost, however, Π would probably not increase a great deal even with a switch to automation.

254. The estimates of manufacturing cost as a percent of sales price were

See page 220a.

255. The average price of a semiconductor if there is no offshore production, P_u, is just C_u. The average price with fraction α assembled offshore is $P_o = \alpha C_o + (1-\alpha) C_u$.

Therefore

$$\frac{P_u - P_o}{P_o} = \frac{\alpha(C_u - C_o)}{\alpha C_o + (1-\alpha)C_u} = \frac{\alpha\left[\frac{C_u - C_o}{C_o}\right]}{1 + (1-\alpha)\left[\frac{C_u - C_o}{C_o}\right]}$$

which is used in the text to get our likely parameter ranges.

In doing so, α was taken as equal to .7; see Section 9.

254.

Value	Description	Source:
.65	For Industry, early 1970s, with offshore assembly in Singapore	Finan (1975), P. 26
.40	16K RAM, computer memory IC, 1979, with offshore assembly	Dickens (1980), P. 82
.30	Simple linear IC, 1979, with offshore assembly	Dickens (1980), P. 83

256. See "World Markets Forecast," *Electronics*, (January 3, 1981), p. 131.

257. Statistics are taken from U.S. *Census of Manufactures*, 1977.

258. Some manufacturers trimming their operations in early 1981 reported that the bulk of their shutdowns affected their U.S. employment and not their foreign operations. See *Electronic News*, (March 30, 1981), "Semicon Firms Wriggle Work Schedules"; *New York Times*, (May 30, 1981), "Layoff Set by Texas Instruments"; *Asian Wall Street Journal* (Sept. 14, 1981), P. 14.

259. That is, regressions of the form $\ln X = a + bt$ were calculated for dependent variable X corresponding to production and non-production employment in the U.S. industry, and t a time trend variable with value 0 in 1963, incremented by 1 in every subsequent year. Coefficient b is an estimate of the trend growth rate. Over the 1963-1978 period, b was equal to .030 for production workers, .080 for non-production workers.

Deviations from trend employment were then calculated by comparing actual employment that predicted by the trend growth equation estimated.

260. That is to say, for a given average volume of semiconductor employment, increasing the proportion of that employment which is

non-production workers reduces the variations in total employment.

This follows from the fact that- based on Figure 13-2- variance of non-production employment around its predicted mean is less than the variance of production employment, and their covariance is positive (i.e., the fluctuations tend to move together).

To put this more formally, we are hypothesizing that total employment equals $(S_N \epsilon_N + S_P \epsilon_P)$ L, with S_N and S_P the fractional shares of non-production and production employment, respectively, in total employment L $(S_N + S_P = 1)$, ϵ_N and ϵ_P (mean 1) random errors associated with fluctuations around expected employment at any moment in time. Let σ_N^2, σ_P^2, and σ_{NP} be the variances and covariance of these random fluctuations.

The variance of total employment is then equal to

$$L^2 \left(S_N^2 \sigma_N^2 + (1-S_N)^2 \sigma_P^2 + 2S_N(1-S_N)\sigma_{NP} \right)$$

and its derivative with respect to S_N (i.e., the effect on variance of an increase in the portion of employment made up of non-production workers) is

$$2L^2 \sigma_P^2 \left[S_N\left(\frac{\sigma_N^2}{\sigma_P^2} + 1 - 2\frac{\sigma_N}{\sigma_P}\rho_{NP}\right) + \left(\rho_{NP}\frac{\sigma_N}{\sigma_P} - 1\right) \right]$$

with ρ_{NP} the correlation coefficient of ϵ_N and ϵ_P.

Using the residuals of the estimated equations described in the last footnote, we can form consistent estimates of ρ_{NP}, σ_N^2, and σ_P^2, taking on values of about .659, .00964, and .0280, respectively.

For an increase in S_N to reduce variation in overall employment, we must then have

$$S_N < \frac{1 - \frac{\sigma_N}{\sigma_P}\rho_{NP}}{\frac{\sigma_N^2}{\sigma_P^2} + 1 - 2\frac{\sigma_N}{\sigma_P}\rho_{NP}}$$

which, using our estimates, requires that $S_N < 1.07$.

Therefore, with the observed pattern of employment fluctuation, any increase in the employment share of non-production workers appears to reduce the instability of overall employment (since S_N must always lie between 0 and 1).

---

261. U.S. Department of Labor, Bureau of Labor Statistics, Industry Wage Survey: Semiconductors September 1977, (Washington, 1979), BLS Bulletin 2021.

262. See Rubenstein and Andrews, The Electronics Industry in New England to 1970, (Federal Reserve Bank of Boston, December, 1959), p. 9.

263. Ibid.

264. Since $\eta_{Q\alpha} = \frac{d}{d\alpha} Q(P) \cdot \frac{\alpha}{Q}$, P and Q the price and quantity of U.S. SCD output, respectively;

$$= Q' \frac{dP}{d\alpha} \frac{\alpha}{P} \quad \frac{P}{Q}$$

$$= \eta_{QP} \quad \eta_{P\alpha}$$

As before, we assume aggregate average SCD price is a weighted average of the prices of devices assembled onshore and offshore, so

$$P = \alpha C_o + (1-\alpha) \; C_u \quad \text{(see footnote 255)}$$

$$\frac{dP}{d\alpha} = C_o - C_u \text{, and } \eta_{P\alpha} = \frac{(C_o - C_u)\,\alpha}{P}$$

$$= - \left(\frac{P_u - P_o}{P_o} \right).$$

265. See footnote 255.

266. Given U.S. factor prices, and constant returns to scale, l_A and l_{NA} will be constant.

267. Technically, this should be the elasticity of demand for U.S. production (including net exports, as well as domestic consumption, which will be a weighted average of the price elasticities of U.S. consumption demand and net export demand. Since net exports are very small in relation to U.S. consumption, however, taking this into account would have no appreciable effect on the price elasticity estimates used. In 1978, for example net exports of finished goods amounted to roughtly $.7 billion, while U.S. consumption was almost $5 billion.

268. This net balance underestimates the true net balance on the international trade of the U.S. semiconductor industry, since the total export figure for the semiconductor industry does not include materials other than semiconductors which the industry ships, only to later reenter as part of the content of 806/807 imports.

END

FILMED

2-83

DTIC