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The Product Cycle-type Diffusion of Electronics Manufacturing in an International Context*

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1. Introduction

The rapid diffusion of manufacturing industry from advanced to less developed nations has been one of the most significant economic phenomena of our time. Countries that had few manufacturing activities nearly twenty years ago now rank as major producers, with trade performances that are enviable even by the standards of many advanced nations.

Electronics, one of the most dynamic industries in the world, has been a major source and vehicle of international industrial diffusion. In the Electronics industry, the diffusion from advanced to less developed nations has been most conspicuous in consumer electronics manufacturing. The characteristics of production in this industry are such that assembly tasks can be easily separated from skill-intensive activities, such as R & D, allowing their location in nations where lower cost labor can be found. Such segmentation of production process is an important aspect of the current global diffusion of consumer electronics and, increasingly, of component electronics manufacuring, allowing greater flexibility in the operation of production tasks that are, or can become, more labor-intensive. Production process segmentation has been made possible by advances in telecommunications, in transportation technology, and through the broader diffusion of technology and organizational knowledge in management. Interestingly enough, these developments have themselves been largely made possible by the rapid growth of innovations in electronics. Indeed, the most significant products linked to the development of these activities are all electronics goods. Thus, the technological revolution spawned by the development of electronics manufacturing has come a full circle, to promote the global diffusion of this industry.

These shifts in the location and production of electronics manufacturing have attracted increasing interest in the study of technology and manufacturing diffusion, and their impact on electronics development in less developed nations. So far, little effort has been made to analyze the international diffusion phenomenon at work within electronics as a whole, and to relate this global diffusion process to the substantial changes that have occurred in electronics productive technology and organization over the product cycle.[1]

2. The Product Cycle and the Global Diffusion of Electronics Manufacturing

One of the major difficulties confronting location theorists has been that of finding suitable theoretical constructs that can adequately explain long-term changes in the location and production of industries. The overwhelming emphasis placed by modern location theory on static paradigms has been a major obstacle in this respect, and has

*This paper is reproduced from the Chapters 1 and 2 of the author's Ph. D dissertation (Han, 1989).

resulted in considerable neglect of the broader evolutionary perspective. Likewise, the inability of orthodox theory to explain long-term changes in the production, location and trade patterns of manufacturing activities has motivated some scholars to search for broader perspectives on this topic.

In the area of international trade and investment, Vernon (1966) and Hirsch (1967) introduced the product cycle as an alternative explanation of the process of international industrial change. The origins of the product cycle can, however, be traced to the early works of Kuznets (1930), and Burns (1934), who developed a life cycle analogy to explain secular industrial change and growth. The product cycle concept was first applied in the marketing field by Patton (1950), Kotler (1965), and Levitt (1965)-those who have explored the potentials of the product cycle in the formulation of product develpment and management, and marketing strategy. Then, Vernon (1966) and Hirsch (1967) formally introduced the product cycle concept to the study of international trade and investment. By adding technological and production considerations to Burenstam-Linder's demand factors, Vernon (1966) advanced the three stages of the product cycle — growth, maturity, and decline — as an alternative approach with which to analyze the flow of manufactured goods across international borders. Furthermore, the product cycle concept was assumed to be a possible alternative tool with which to analyze variations in international manufacturing locations. Although Vernon (1974) had not directly addressed the spatial implications of the product cycle, he examined some possible applications of the product cycle concept in analyzing locations of multinational firms.

Vernon's (1966) arguments may be summarized as follows. As new products are introduced in response to new demands, the consuming country is likely to be a location for production because "(1) producers at this stage are particularly concerned with the degree of freedom they have in changing their inputs...; (2) the price elasticity of demand for the output of individual firms is comparatively low...; and (3) the need for swift and effective communication on the part of the producer with customers, suppliers, and even competitors is especially high at this stage" (Vernon 1966, p. 195). At this stage, demand in other countries is satisfied through exports from the first producing country. The model further indicates that as a product matures it becomes increasingly standardized; increasing number of producers enter into the market to tap rapidly increasing, but price elastic demand; mass production utilizing standard processes becomes the rule, lowering production costs; prices tend to decrease as a result of strong competition and rapid market expansion, although profit margins are substantially reduced; and product differentiation may gradually appear as producers strive to maintain their share of the market. At this mature stage, as economies of scale are being fully utilized by producers, the principal difference between production locations is most likely to consist of differences in labor costs. Consequently, the original producer, to reduce production costs and maintain his share of the market, is likely to establish production facilities in lower cost locations. If labor cost savings offset transport costs, the trade flow may reverse, with the first producing country now importing from the lower cost locations. Subsequently Hirsch (1967) discussed the changing aspects of comparative advantages occurring throughout the product cycle, and related them to the international competitiveness of manufacturing industries. The comparative advantages enjoyed by advanced nations during the early stages of production are assumed by less developed nations as production processes become standardized.

Despite the criticism it has received, the product cycle has become an empirical phenomenon useful in describing not only the dynamic behaviors of a product (or an industry) throughout its lifetime, but also their impact on international trade and investment,

spatial shifts, and management and marketing strategies.[2] Particularly in the area of industrial location analysis, the product cycle has provided additional factors useful in explaining industrial location change: technological change, the changing importance of agglomeration economies throughout a life cycle, and changes in demand structure. As a result, various location theorists have accepted the product cycle as a dynamic perspective from which to explain the systematic changes in manufacturing location.

Thomas' (1975) work was the first to relate the product cycle concept to gorwth pole dynamics and technological change. This was later expanded by Hansen (1979), Norton and Rees (1979), Erickson and Leinbach (1979), and Sjafrizal (1981), to explain shifts in the location of U.S. manufacturing to the Sunbelt and to nonmetropolitan areas. Case studies on specific firms and industries have also been provided by Krumme and Hayter (1975) on aircraft munufacturing, and by Hekman (1978, 1980) on the steel and the textile industries. However, its use in industrial location analysis has been limited mainly to the study of interregional and intraregional shifts in advanced nations.

The product cycle can also be applied to analyze the international shifts of manufacturing activities, provided that regional delimitations are extended to consider nations. In other words, many of the previous discussions relating the concept to interregional location shifts can be extended in a straightforward manner to the international scene, with the exception that industrialization strategies adopted by less developed nations, together with other location factors, can be assumed to affect international shifts. This use is possible due to a major geographical extension of location factors already at work within advanced nations, caused by the decomposition of complex production processes, better transportation technology, improved telecommunications systems, and, of course, an international mobility of capital. The product cycle has been explicitly applied in this manner by Vernon (1974), who was concerned mainly with multinational corporations' shifts of production facilities, occurring in the form of foreign investment or the establishment of branch plants or subsidiaries. His approach could provide very useful insight into the international location of production facilities in oligopolistically structured industries. Following Vernon's argument, this section will explore the general aspects of the global diffusion of manufacturing activities within the product cycle framework. In other words, the underlying assumptions of the product cycle will be applied to the global diffusion of manufacturing to less developed nations, with specific reference to electronics manufacturing.

As shown in Table 1, the diffusion of manufacturing to less developed nations is most common at the mature stage of an industry's product cycle. At this point, the advanced nations' market for a given product, or an industry that produces that product, becomes saturated and extremely price competitive. At the same time, production processes become more readily adaptable to standardized mass production, and depend increasingly on less skilled labor. Consequently, the shift of manufacturing to less developed countries become conspicuous, caused, in great part, by the savings possible in both labor and fixed costs of operations (land, facilities, and taxes) there. An obvious candidate for these international shifts would be an industry with a high price-elasticity of demand for its product and a labor-intensive production that is relatively unaffected by external economies; this industry would be highly sensitive to spatial variations with regard to productive factors price, especially the differential between labor costs in advanced and less developed nations, since economies of scale in production inside firms at the mature stage are being fully exploited.

This international diffusion is best exemplified, in the electronics industry, by the shift in consumer electronics, "U.S. firms were pioneers in consumer electronics tech-

Table 1. Product cycle stages

Characteristics	New	Growth	Mature / LDC-I	Decline / LDC-II	LDC-III
Production scale and technology	short-runs, flexible, changing technology	mass production, segmented, partly automated technology	MDC:long-runs, systematic, highly integrated LDC:small scale, assembly operations based on imported technology	MDC:rapidly decreasing scale, less LDC:increasing scale, labor-intensive technology	LDC:mass production, segmented but labor-intensive technology
Skills	highly skilled professionals or technicians	management skills	MDC:less skilled blue-collar LDC:lower-skilled blue-collar	MDC:less skilled blue-collar LDC:lower-skilled blue-collar	LDC:local technicians and engineers
Capital equipment	non-existent	rapid expansion automation starts	MDC:increasing automation, limited obsolescence LDC:labor-intensive production	MDC:capacity reduction, obsolescence LDC:labor-intensive, limited use of capital equipment	LDC:labor-intensive, greater use of special-purpose equipment
External economies	critical	very important	MDC:less important LDC:better access to foreign technology and gov't subsidies	MDC:less important LDC:increasingly important (local entrepreneurs and capital)	LDC:important (better access to R & D and skilled labor)

Industrial structure	small number of firms	growing number of firms	MDC:fixed or declining number of firms LDC:small number of firms	MDC:declining number of firms LDC:growing number of firms	LDC:substantial number of firms
Demand structure	lower price elasticity	rising price elasticity	MDC:high price elasticity LDC:lower price elasticity in domestic market, high in foreign market	MDC:high price elasticity LDC:increasing price elasticity in foreign and domestic markets	LDC:high price elasticity in both markets
International trade	net exporter to LDCs and other MDCs	declining export to LDCs and other MDCs	MDC:import from LDCs LDC:start of export to MDCs	MDC:significant import LDC:growing export to MDCs	LDC:net exporter to MDCs
Spatial preferences	initial location close to major research centers	location in or close to major population centers, decentralization starts	MDC:decentralization to low-wage regions in MDCs, branch plants or relocation to EPZs start LDC:location in major ports or international centers	MDC:plant closings significant decentralization to low-wage regions or EPZs LDC:location in major population centers, decentralization starts	LDC:decentralization to low-wage regions in LDCs

nology and, until the 1960s, accounted for the largest share of world revenues and profits" (Linvill, LaMond, and Wilson 1984, p. 93). Thus, consumer electronics production was concentrated almost exclusively in the U.S., some nations of EEC, and Japan. Since the early-wide interest in reducing production costs — arising from increasing market competition characterized by substantial product differentiation and fierce price competition — caused its production to swiftly diffuse to less developed nations that could promise lower labor costs and a favorable labor environment.

Consumer electronics production consists mainly of routine, less complex assembly-type operations. Likewise, the lower complexity of production tasks, aided by increasing standardization, decreased their demand for scarce labor and managerial skills, reflecting the less developed nations' better access to less advanced, skill-saving technologies. This characteristic, in turn, makes it possible to substitute less skilled labor for management expertise, and labor for machinery. Another factor affecting the diffusion of consumer electronics production is that assembly-type operations, requiring a large pool of less skilled labor, are easily separated from R & D activities. Such separable, labor-intensive operations are readily shifted to developing countries offering cheaper labor, with R & D functions left behind in advanced nations.

A pivotal role in the transfer of consumer electronics assembly manufacturing — particularly of television and radio manufacturing — was played by multinational corporations. They have been among the first to initiate this sort of shift, since they already have in place an international organization based on a multidivisional form of enterprise — a form that embodies all the advantages of factor mobility and management communications. Particularly in the 1970s, these large corporations shifted labor-intensive assembly operations, mainly to industrial export zones in Asia and Latin America, by establishing branch plants and subsidiaries, or, sometimes, subcontracting to domestic electronics firms. There they could reduce production costs by taking advantage of lower labor costs, greater labor time, adequate infrastructure, and a variety of investment incentives.

The diffusion of manufacturing achieved by multinational corporations in this manner has been made further possible by improvements in telecommunications and transport — improvements that lowered the cost associated with planning, controlling and coordinating production, and with transporting components and parts. In fact, this phenomenon has become one of the most salient features of the current global diffusion of electronics components (particularly semiconductors) and of less technology-intensive industrial electronics (such as telephone apparatus, and computer hardware and peripheral equipment) — in other words, of products with a high value-to-weight ratio and an assembly operation involving a high proportion of less skilled labor.

In the early diffusion of consumer electronics manufacturing, production technology and processes are simply imported to less developed nations in the form of a "packaged technology" that includes assembly processes, product specifications, production know-how, technical personnel and parts and components [see, e.g., Kim (1980)]. In most cases, such importation was made possible by local innovative entrepreneurs with previous trade contacts with foreign firms. They generally inteded to replace imports with domestically manufactured electronics goods by adapting the packaged technology to an abundant labor supply. At this time, however, production in less developed nations is characterized by a simple imitation of embodied innovations and inventions already made and tested in advanced nations; production merely consisted of the assembly of foreign components and parts with equipment purchased from overseas. This type of diffusion is preferred to disembodied, technology-intensive, process-oriented diffusion because less developed countries generally lack the technical and organizational capabi-

lities to adapt and improve transferred foreign technology. Also there was little product differentiation and, in most cases, no production innovation. This lack would be caused, on one hand, by less developed nations' great depedence on advanced ones to supply technology, equipment and components, and, on the other, by low competitive pressure from domestic markets protected by government import substitution policies.

The pace of diffusion can be expected to be affected not only by the product cycle dynamics at play within electronics manufacturing, but also by the ability of a less developed nation to receive internationally transferred electronics manufacturing. Such receptivity would be affected by, among other things, lower labor costs advantage, geographical locations, indigenous technical potential, and, perhaps most importantly, government policies. The government policies of less developed nations — in particular, their export-promotion policies involving import protection, export concessions, the founding of national training institutes and of national research and development laboratories — could help them to quickly absorb foreign electronics technology by promoting full use of their relative factor advantages. In fact, not all less developed nations were able to assimilate the internationally diffused electronics manufacturing at the same rate. For although less developed nations as a whole offered lower labor costs and favorable labor environments, thereby providing obvious advantages in the production of labor-intensive electronics, the rate of diffusion within a given country was primarily affected by government subsidies. Active government subsidies, export-promotion policy in particular, could develop domestic technical and organizational capabilities by promoting the rapid adoption of inventions and innovations in electronics and ultimately enhancing competitiveness in the world market. Likewise, countries with strong export-promotion policies, such as Korea, Singapore, Taiwan, and Hong Kong, outstripped others in absorbing and subsequently developing electronics manufacturing, becoming, in the process, major competitors in export markets.

On the other hand, electronics sectors still in the pre-mature stage of the product cycle, such as the skill-or technology-intensive electronics exemplified by advanced industrial and innovative component electronics, exhibit a lower rate of diffusion to less developed nations, and, hence, a great concentration of their production capacity in advanced nations. Since their production processes require a high degree of technological know-how and extremely skilled labor, these pre-mature sectors diffuse relatively slowly to less developed nations, which generally lack the necessary skill and R & D activities. Also, their production routines, which must respond to rapid changes in productive technology and market demands, are less adaptable to large-scale mass production. The advantages provided by the lower labor costs available in less developed nations, therefore, offer these pre-mature electronics sectors little incentive to increase their production capacity. Likewise, except in cases in which some labor-intensive subprocesses (e.g., assembly operations in semiconductor production) have been strategically shifted to less developed nations offering reductions in labor costs, the production of these pre-mature electronics sectors remains primarily in skill- and R & D-abundant advanced nations. Recently, however, some developing nations have become locations for the assembly operations of some less technology-intensive industrial electronics products, particularly of computer hardware and peripheral equipment. For instance, Taiwan and Korea have become two of the world's leading terminal and monitor exporters. Singapore, a major supplier of disk drives, along with Taiwan, Korea and Hong Kong now play a considerable role in the expanding world market for personal computers [see, e.g., O'Conner (1984)]. This would apply not only to some types of telecommunications equipment (e.g., telephone apparatus) and industrial automation

equipment, but also to some less innovative components (e.g., discrete semiconductors, including transistors and diodes).

As these specific electronics products have become more adaptable to large-scale mass production as a consequence of rapid market expansion and standardization, they have come to require a large pool of less skilled labor, easily available in less developed nations. This phenomenon may be a sign of future developments in the diffusion of technology-intensive electronics to less developed nations — developments which will depend not only on the speed with which technology-intensive electronics production can be standardized, thus allowing less developed nations to make more competetive use of their labor costs advantage, but also on the effective transfer some R & D functions to those nations. These developments will also lead to substantial structural changes in the composition of those nations' electronics production; while they traditionally focused on consumer applications, technology-intensive electronics sectors will gain considerable importance in the future.

3. International Trends in Electronics Manufacturing

It is imperative to classify electronics product groups according to the product cycle concept before we proceed to examining the nature of the product cycle-type diffusion of electronics. with longitudinal data drawn from various international and individual censuses. It had already been shown elsewhere that a disaggregated analysis — the analysis of product groups — revealed intergroup variations that drawed a clear distinction, in regards to product cycle stage, between consumer electronics and industrial or component electronics: "mature" vs. "growth" stage industries, respectively.[3] In this study, we will adopt, without modification, the same classification that was used in the author's study (Han 1989); consumer electronics is categorized as a "mature" industry, and industrial or component electronics as being in "growth" stage.

In the selection of the various indicators utilized in this analysis, two distinct sets can be identified. Those primarily related to products are the conventional trade variables and statistics, and include analyses of trade balances on physical (unit) output and electronics industry mix and structure. Those indicators that are primarily related to productive processes will focus on the utilization of labor and the overall organization of production. The analysis of those two sets of indicators will provide insights on the provious section's discussion relating the product cycle to the global diffusion of electronics manufacturing. At the same time, this approach will help assess the performances of the two sets of nations considered — advanced and less developed nations — in electronics manufacturing.

1) Product-related Trends

Among the product-related trends, trade statistics based on physical output are most important. In general, international trade and the diffusion of production technology are closely intertwined. Trade can cause diffusion at the user (consumer) level to occur sooner and more rapidly than otherwise possible. At the producer (supply) level, trade stimulates diffusion in countries with a comparative advantage in the new goods, and impedes diffusion in countries that do not have the comparative advantage (Tilton 1971, p. 23). In this regard, a close look at long-term trends in international trade can provide insights into the relationship between shifts in comparative advantage and the resulting diffusion of production in electronics.

Table 2 indicates that, as the life cycle of consumer electronics progressed, the U.S.'s early favorable trade balance, for example, 3.52 in 1958, steadily became a trade deficit. Since the early 1960s, as early adoption countries with considerable skilled but less expensive labor forces, such as the E.E.C. nations, Japan, and possibly Canada, began producing consumer electronics pro-

Table 2. Trade Performance in Consumer, Industrial and Component Electronics Production

	U.S.			Japan			E.E.C.			Korea		
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
1963	0.34	5.30	2.88		0.07							
1966	0.24	2.89	2.31	50.01	1.63		1.96	3.19	0.75			
1968	0.18	3.20	2.38	51.10	1.42	1.69	1.52	2.68	0.66	0.61	0.003	1.60
1971	0.13	3.21	1.84	55.90	1.78	1.00	0.94	1.10	0.94	0.86	0.02	1.11
1974	0.18	2.80	1.74	56.50	1.92	1.39	0.86	1.35	0.84	2.24	0.36	1.06
1977	0.14	2.71	1.21	58.70	2.88	2.52	0.78	1.08	0.77	4.41	0.84	0.88
1980	0.23	2.74	1.10	67.30	4.54	2.65	0.59	0.96	0.67	6.34	0.46	0.83
1981	0.18	2.62	1.06	62.50	5.91	2.79	0.47	0.91	0.70	7.63	0.36	0.76
1982	0.13	2.18	0.96	64.00	6.32	3.00	0.42	0.92	0.71	8.99	0.34	0.88
1984	0.08	1.71	0.87		8.36*	3.38*	0.42*	0.89*	0.71*	8.75	0.62	1.01

	Hong Kong			Singapore			Mexico			Brazil		
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
1963								0.03			0.002	
1966		0.27	0.90	0.24					0.06		0.001	0.01
1968	1.04	0.37	1.08	0.21			0.18	0.08	0.56		0.002	0.005
1971	1.69		2.74	0.54	0.21	2.93		0.04	1.16	0.06	0.28	0.21
1974	2.49	0.54	2.40	1.27	0.66	1.65	0.19	0.24	1.17	0.66	0.32	0.19
1977	2.69	0.75	1.26	1.89	0.91	1.21		0.25	0.84	1.55	0.52	0.20
1980	2.11	0.61	0.95	1.62	0.67	1.78	0.17	0.59	2.03	1.52		0.27
1981	1.83	0.55	0.90	1.82	0.61	1.35	0.12	0.52	2.20	1.93	0.83	0.30
1982	2.24	0.64	0.74	1.44	0.57	1.30	0.25	0.69	1.33	0.84	0.64	0.16
1984	1.56*	1.32*	0.56*		0.58*	1.38*	0.20*		1.00*			0.37*

Expots / Imports, (a) Consumer, (b) Industrial, (c) Components.

*1983 estimates.

Soucres: *International Trade Statistics* and *Supplement to the World Trade Annual;* O.E.C.D. *Foreign Trade Statistics;* U.S. *Census of Manufactures* and *Industrial Outlook; Mackintosh Yearbook of International Electronics;* Electronics Industry Association of Korea. *Statistics of Electronics and Electrical Appliances* and *Electronics Industry Manual,* various years.

Industry classifications-*Consumer:* U.S. (SIC 3651, 3652); other nations, pre-1980 (SITC 7241, 7424, 8911, 8912), post-1980 (SITC 7611, 7612, 7621, 7631, 7638). *Industrial:* (SIC 366, 357), Korea (SIC 3832, 3825); other nations, pre-1980 (SITC 7249, 714), post-1980 (SITC 764, 7519). *Components:* U.S. (SIC 367), Korea (SIC 3834); other nations, pre-1980 (SITC 7293), post-1980 (SITC 776).

ducts, the innovating U.S. became a net importer. In the early 1960s, the less developed nations in the sample still depended almost entirly on imports from some advanced nations for their domestic demands. As consumer electronics entered its mature stage since the early 1970s, however, less developed nations like Korea, Singapore, Hong Kong, and possibly Taiwan began to emerge as net exporters, while all the other advanced nations except Japan became net importers. The significant shift of consumer electronics manufacturing toward less developed nations with lower-cost labor and export-oriented policies, indicated by the trade index statistics, reflect the maturing product cycle characteristics of this industry. In other words, the comparative advantage in the production of "mature" consumer electronics shifts from the innovating U.S. through early adopting, advanced nations, and finally to late adopting, ones, as the

importance of less skilled labor in the production of consumer electronics increases over the product cycle. This has undoubtedly been a major aspect of the 1970s. The shift's greatest impact was felt in the "open economy" advanced nation (U.S.), while the flight of manufacturing capacity abroad has been most conspicious. At the same time, such industry flight, supported by the diffusion of technological and organizational innovation from the U.S., also promoted a substantial growth of imports in this nation's economy. Low imports duties, and tariff regulations that eliminate duties on all but labor's value added for components originally manufactured in the U.S., helped this trend. Japan's export / import ratio in consumer electronics has the best overall performance among the advanced nations. Japan's gradual rise with this indicator is due to its aggressive export strategy, that promoted a shift toward upscale consumer electronics goods, and secondly, to domestic market protection. The higher indexes or the E.E.C. nations vis-a-vis the U.S. are due to both greater import barriers and postwar reconstruction, which promoted the adoption of newer technologies and organization. Korea's and, to a lesser extent, Hong Kong's and Singapore's performances reveal the significant success of aggressive export promotion in consumer electronics manufacturing in less developed nations, complemented by domestic market protection. The ratios of the import substituting less developed nations included in the sample are significantly lower. In Brazil's case, the changes brought about by a relative shift from import substitution toward export promotion in the 1970s, held by foreign investment, was a major cause of its better performance.

Japan and the U. S. are still the major exporters of industrial electronics goods, as shown . in Table 2. Japan's rising export / import index is a product of its aggressive and very successful export promotion, helped by domestic market protection. Also, the benefits of rapid and effective adoption of inventions and innovations originating elsewhere helped it to develop its productive capacity and product quality, with considerable savings on the R & D process, at least initially. Since the late 1960s, the E.E.C. nations' declining trends reflect their significant and increasing lack of international competitiveness in industrial electronics. Their dis-advantageous trade performances are a long-term effect of their substantially lower rates of innovation and inventions in this industry, resulting from strong market protection, along with disadvantages from high-cost labor, compared with Japan. The modest trade performances of less developed nations in industrial electronics, on the other hand, reveal the pre-mature product cycle status of this industry. The relatively greater skill and R & D-intensive character of industrial electronics, with production routines that are less adaptable to mass production, have thus kept this industry in the advanced nations.

To a great extent, trade performances in component electronics goods provide similar findings to those in industrial electronics. Japan's performance again leads the sample, while the U.S. sustains a significant but gradual decline in its export / import index, while that of the E.E.C. nations remains basically stagnant. The latter is best explained by the fact that its relatively protected domestic markets have restricted imports, while its exports remain less competitive internationally. Japan's increasing ratios since 1971 may be caused by its lead in price competition, based on organizational advances and greater scale economies, as well as aggressive marketing strategies. Fluctuations in the developed nations' performance can be best explained through the multiple sourcing phenomenon in international component electronics trade, except in the cases of Brazil and Mexico, where imports were significantly restricted. These two nations' ratios are therefore driven to relatively high levels through the restriction of imports rather than through substantial increase in exports. This becomes obvious when their very low shares of world output

in this industry are considered.

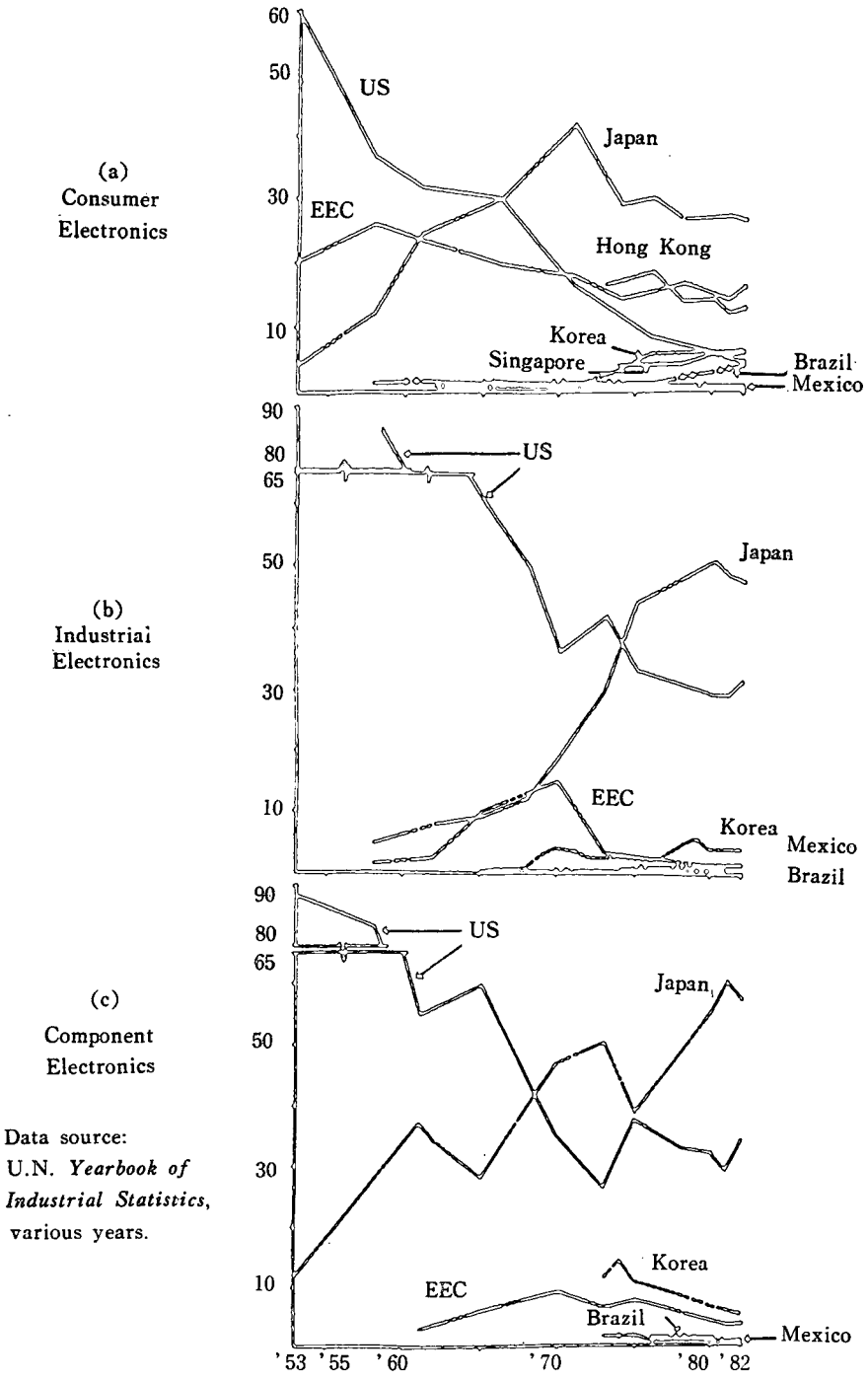
Date on physical world output, illustrated in Figure 1 (a), shows substantial and more gradual declines in the U.S. and E.E.C. shares in consumer electronics, respectively. This is in deep contrast with Japan's performance until the early 1970s. Among the less developed nations, Hong Kong's larger share is indicative of its early start in consumer electronics assembly. Its relative decline after the mid-1970s is offset by increases in Korea's and Singapore's shares. Brazil's relative shift from import substitution toward export promotion, accompanied by protection of its large domestic market, begins to show after the 1970s.

Here again, the onset of product cycle maturity in this industry in the advanced nations becomes quite obvious. Its impact is felt first in the U.S. despite its large domestic market, and can be explained by two important factors. One is the international industrial context of the years following the second World War, when all the major industrial nations were devastated, allowing U.S. industry to assume world predominance in many fields. Reconstruction, and the rise of these nation's industrial process, then caused a return to a more balanced and competitive international situation, where the U.S. share of global output was inevitably bound to decline. At the same time, the U.S.'s "open economy" strategy allowed the effects of product cycle maturity to be felt there earlier than in the E.E.C. nations or Japan, as the lack of import restrictions allowed industry flight toward the less developed nations to occur at a faster pace.

The concentration of industrial electronics production in Japan and the U.S. is most obvious in Figure 1 (b), indicating that the comparative advantage in production remains in their favor. Despite its sharp decline, the U.S. nevertheless maintains a significant share of output, while Japan surpasses it in the mid-1970s to become the world's most important producer. In contrast, the shares of the less developed nations remain small, with Korea leading the sample. The E.E.C. nations' share experiences downturn by the late 1960s, and actually declines below Korea's by the late 1970s, despite their large, protected markets, signaling increasing problems with the international competitiveness of their industrial electronics industry. In more than one way, the E.E.C. nations' trend indicates the failure of domestic market protection without an internally competitive export promotion strategy. This is especially significant, given the predominant concentration of this industry in the advanced nations.

The contrast between the U.S. and Japanese performances is also obvious in component electronics, shown in Figure 1 (c). Here, the U.S. trend stabilizes after the early 1970s, favored by the rise of new product in this industry, such as semiconductors and the microchip innovations. These effectively introduced a "new wave" of product growth that helped offset the mature product cycle of the older component electronics goods. The growth of the E.E.C. share until 1970s was undoubtedly favored by postwar reconstruction and its introduction of more modern production technologies, aided by these nations' large domestic markets. Korea's declining trend is more indicative of the obsolescence of the older component electronics goods and their impending substitution by more innovative products.

Shifts in the proportion of domestic output capacity allocated to any of the three electronics subcategories reflect the internal restructurings that have affected each of the various nations' electronics industry. In Table 3, the shift away from consumer electronics in the advanced nations becomes quite obvious, as product cycle maturity advances for most of the goods produced in this industry. Increasing standardization of production and the use of low cost assembly labor in the less developed nations are a major long term cause of these changes. In the U.S., Japan, and West Germany, the declining share of mature consumer electronics is partially offset by increase in indust-



Data source:
U.N. *Yearbook of Industrial Statistics*, various years.

Figure 1. Percentage of World Output.

Table 3. Domestic Percentage Shares in Consumer, Industrial and Component Electronics Production

	U.S.			Japan			W. Germany			Korea			Hong Kong			Singapore			Mexico	
	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(d)
1958	21.2	50.7	28.1	49.0*	22.0*	29.0*														
1963	16.2	58.4	25.6														(d)			
1967	19.1	51.6	29.3							29.0*	16.0*	55.0*				21.1*	78.9*		40.8*	59.2*
1972	19.4	64.5	16.1	40.5	32.5	27.0	27.2	45.7	26.7	31.0	10.0	58.0	52.0*	0.0*	48.0*	26.7*	73.3+		54.0	46.0
1977	15.0	66.3	18.7	37.5	33.1	29.4	27.9	50.6	21.5	37.0	9.0	54.0	69.0+	0.0+	30.0+	48.0	2.0	50.0	54.4+	45.6+
1982	4.8	76.0	19.2	32.4	35.3	32.3	12.9	66.4	20.7	38.7	15.9	45.4	62.9	24.2	12.9	41.8	17.5	40.7	29.9[0]	70.1[0]
1985	4.2	76.6	19.2	28.0	35.6	36.4.				33.1	20.8	46.1	42.5	46.3	11.1	30.6[0]	27.1[0]	42.3[0]		

(a) Consumer, (b) Industrial, (c) Components, (d) Industrial and Component electronics.

*1960 estimates (Japan), 1968 (Korea), 1970 (Singapore), 1972 (Hong Kong), 1969 (Mexico).

+1978 (Hong Kong), 1973 (Mexico), 1971 (Singapore).

[0]1981 (Mexico), 1983 (Singapore).

Sources: see Table 1.

rial electronics. Japan's increasing domestic share trend in component electronics contrasts with those of the U.S. and West Germany, as a shift toward technology-intensive components, coupled with aggressive export promotion, increase its international competitiveness. Similarly, Japan's emphasis on more technology-intensive consumer electronics goods slows the declining domestic trend of this industry, maintaining its share at substantially higher levels than in the U.S. or Germany.

As expected, mature consumer electronics maintains a large share in the less developed nations, despite recent fluctuations. Increases in the domestic share of industrial electronics in Hong Kong, Singapore, and Korea are significant, despite these nations' very low share of world output. This is partly a result of decline in component electronics, as previously discussed, and the expansion of capacity in the some less technology-intensive industrial electronics goods. The latter may signal the onset of product cycle maturity in the production of some industrial electronics goods, as some capacity is displaced from the advanced nations.

2) Process-related Trends

Employment, labor utilization characteristic and productive organization are the most important indicators of process-related trends. These process-related variables place greater attention on the crucial aspect of production, such as work organization and the overall organization structure of the enterprise which are so important in designing and implementing any factor substitution and modifications. At the same time, greater emphasis on the process aspects of production is essential in reducing production costs, and in improving product quality over the medium and long term. The analysis of these variables will therefore provide insights into the manner in which advanced and less .developed nations organize their respective aggregate productive structures and processes in electronics in order to make greater use of their relative factor advantages.

In Figure 2 (a), U.S. employment in electronics remains largest overall, and substantially above that of Japan. Japan's long term rise in electronics manufacturing, in consumer, industrial and components production has been substantially more capital and technology-intensive than that of the U.S. This becomes obvious when overall employment, world output shares and trade performances are compared (see Figure 1 and Table 2) The U.S.'s lower capital intensiveness has, on the other hand, been supported by immigration, promoting a significant reliance on lower cost labor in electronics assembly. This can, for example, be partly verified by the trends shown in Figure 3 (b). A leveling off and some decline in the U.S. trend during the 1960s and 70s gives way to significant increases in the late 1970s and 80s, as a "new wave" of electronics goods and processes are introduced and developed, in what amounts to the onset of the "high technology" era. Japan's overall employment trend follows a similar, though lagged, pattern, leveling off during the early and mid-1970s, but rising significantly after the late 70s. Among the less developed nations, Korea's overall electronics employment is largest, as could be expected from its success in export promotion. While domestic market protection has no doubt helped its performence, the international competitiveness of its exports has been the mainstay of its success in electronics production. The more modest employment levels of the other export promoting nation is nevertheless impressive, in proportion to their total population and manufacturing labor force. Their international success in electronics is thus very much out of proportion with their resources, domestic markets and population size.

Differences between the advanced and the export-oriented less developed nations in the sample are most obvious in the production labor / total employment estimates illustrated in figure 2 (b). Greater labor intensiveness

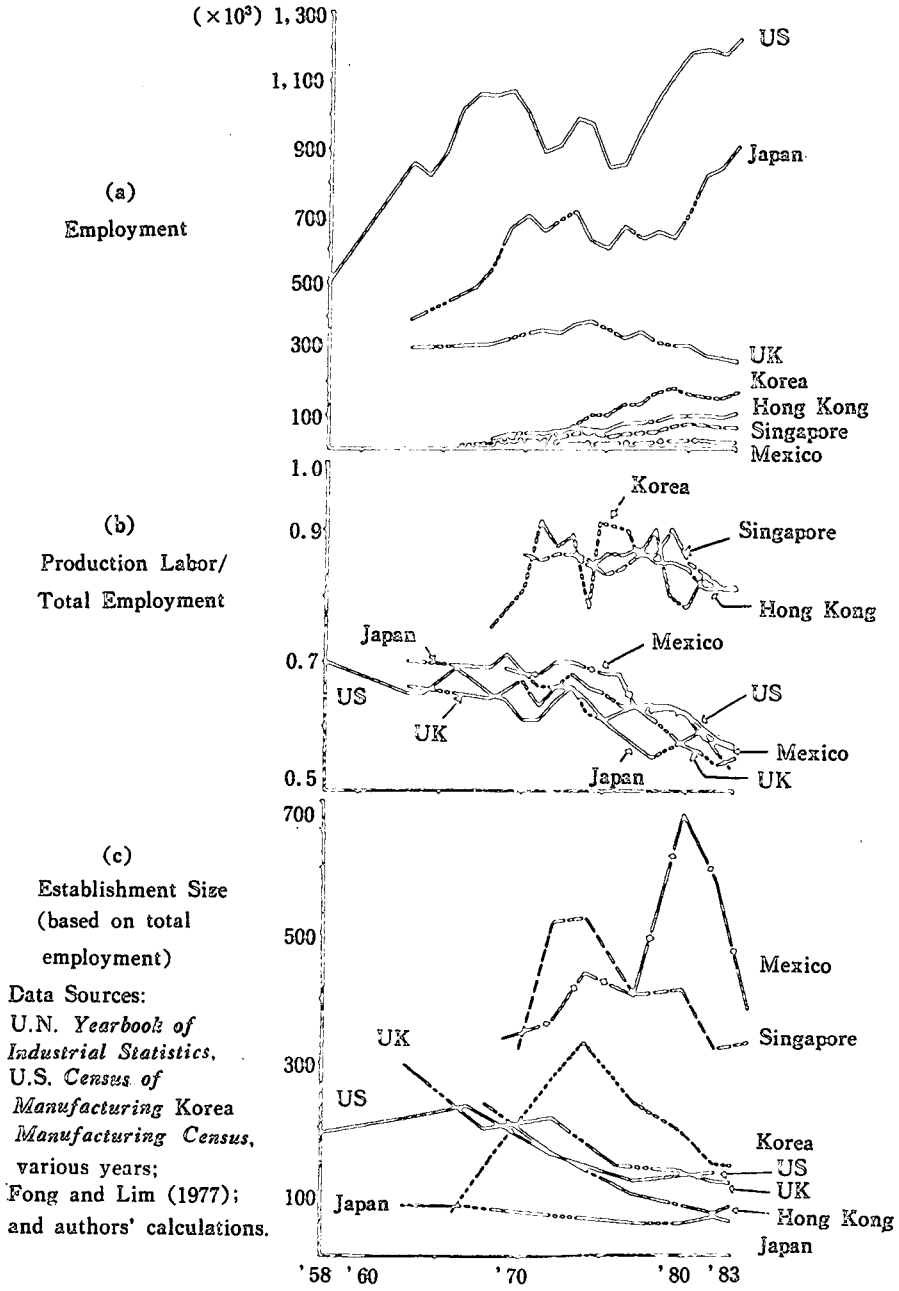
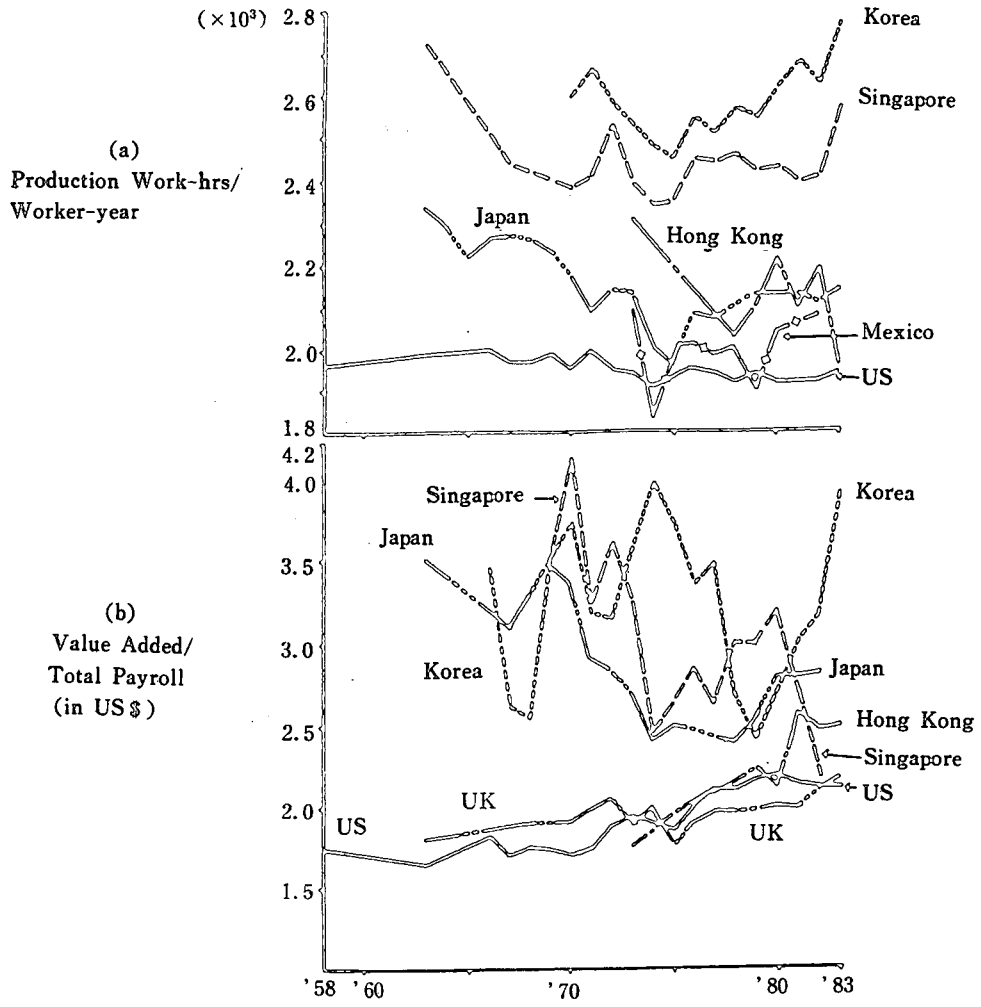


Figure 2. Employment Trends and Establishment Size.

and a lower proportion of administrative personnel and major determinants of the significnatly highest estimates for Korea, Singapore, and Hong Kong. This indicates a significant adjustment of these nations' aggregative productive structure in electronics, to better utilize their lower-cost labor advantages. This adjustment has been of more importance in assembly-oriented consumer and component electronics production. In



Data source:
U.N. *Yearbook of Industrial Statistics*, U.S. *Census of Manufactures*, Korea *Manufacturing Census*, various years; and authors' calculations.

Figure 3. Labor Time and Intensiveness.

contrast. Mexico's close approximation to the advanced nations' trends indicates less flexibility in adjusting productive organization and technology to make more competitive use of its labor advantages. Thus, while Mexico undoubtedly benefited from lower labor costs vis-a-vis the advanced nations, its performance may reflect more limited organizational possibilities and skills to adjust the productive process. Among the advanced nations the U.K.'s decline in these estimates, although very much in line with that of the other advanced nations, should nevertheless raise concern, given its declining employment trend electronics [see Figure 2 (a)]. This is very much a reflection of this nation's eroding competitive position vis-a-vis Japan and the United States.

The average plant size trends shown in Figure 2 (c) are underlain by significantly different approaches to productive organization. The smaller Japanese plant size reflects

greater use of automation, a more manageable scale, and greater concerns with process and product quality. Greater use of subcontracting in electronics production also contributes to smaller plant sizes by reducing the permanent labor force and diminishing risk and uncertainty with respect to market downturns and recessions. The trend toward smaller plant size is also noticeable in export-oriented less developed nations such as Korea and Hong Kong. Mexico's and Singapore's lager average plant size reflects a greater emphasis on labor intensive mass production, where foreign investment has played a major role.

4. Diffusion Factors

Two major factors are assumed to facilitate the product cycle-type diffusion of electronics from advanced to less developed nations: labor costs (along with labor time and labor strife) and government promotion policies. These factors are in some cases key elements affecting the establishment and growth of manufacturing activities in less developed nations. They also help shape the evolutionary path of the industrial development of less developed nations in a siginficant way.

1) Labor Costs.

Labor costs are the single largest production cost item in electronics assembly manufacturing, and are therefore a major determinant of the international comparative advantages possessed by each country. As expected, major differences in labor costs can be found between the advanced and less developed nations. The latter's success in attracting productive capacity in electronics is undoubtedly a function of the very substantial labor cost differentials shown in Table 4. Korea's advantage over all the other developing nations is especially obvious, and underlies its very successful performance in export promotion. This very significant advantage has been most capably applied to mature consumer electronics manufacturing, where it has made the strongest inroads in the world electronics market. At the same time, its very low level of manufacturing labor strife throughout the 1970s and early 80s has made it more attractive than its less developed Western counterparts. Hong Kong's and Singapore's positions, despite their significantly higher labor costs vis-a-vis Korea's, nevertheless remain substantially competitive when compared with those of the advanced nations and Mexico. The latter's advantage, given its substantially higher labor costs, could appear to be in its closer geographical proximity to the United States, a major advanced open economy. Thus, Mexico's advantage lies in the classical tradeoff between transport and labor costs.

Among the advanced nations, Japan remains most competitive in labor costs and incidence of labor strife. To a great extent, this is very much an outcome of its productive and labor organization. At face value, however, Japan's labor costs are not representative, given the common employers' subsidies and support of major social needs, such as housing, medical care and education, that are usually financed through public revenues in the advanced Western economies. Such "hidden" labor costs are a major motivation behind the Japanese effort to automate production. At the same time, widespread subcontracting tends to reduce labor costs by providing readily available labor that claims few of the benefits of the permanent labor force.

A consideration of labor time can provide additional insights on the labor cost advantages and differentials between the nations in the sample. In figure 3 (a), Korea's significantly higher level of labor time, combined with its lower labor costs, is a major determinant of its international comparative advantage. This is further enhanced by its relatively higher proportion of production labor to total employment and its low average plant size, discussed previously. Singapore's higher labor time also affects its international position favorably in relation to

Table 4. Labor Compensation and Disputes

	U.S.	Japan	U.K.	Korea	Hong Kong	Singapore	Mexico
1958 (i)	2.14		0.52				
			(24.3)				
(ii)	0.67	0.10	0.20)			0.98	
1963 (i)	2.57		0.66				
			(25.7)				
(ii)	0.79	0.29	0.22	0.005	0.007	0.79	
1967 (i)	2.89	0.84	0.88		0.29°	0.29	0.61°
		(30.0)?	(30.4)		(10.0)	(10.0)	(21.0)
(ii)	1.96	0.19	0.77	0.006	0.49++	0.02	
1972 (i)	3.81	0.94+		0.29++	(12.8)	0.29	
		(24.7)		(7.6)	0.03	(7.6)	
(ii)	0.81	0.34	0.65	0.006	0.84	0.90	
1977 (i)	5.58	3.07	2.96	0.35	(15.0)	0.60	1.00
		(55.0)	(53.0)	(6.3)	0.02	(10.7)	(18.0)
(ii)	0.78	0.04	1.54	0.006	1.19		
1982 (i)	8.53	3.92	5.66	0.70	(14.0)	1.16	2.56
		(46.0)	(66.4)	(8.2)	0.002	(13.6)	(30.0)
(ii)	0.32	0.01	0.31	0.002			

(i) Average hourly compensation for production labor in electronics, in current U.S. dollars, and percentage of U.S. hourly compensation.

(ii) Annual working days lost due to labor disputes, per employee, in the manufacturing sector. Data corresponds to 1960, 1965, 1970, 1975, 1980 and 1983.

°1969, +1970, ++1974 estimates.

Sources:(i) U.N. *Industrial Statistics Yearbook*, U.S. *Census of Manufactures*, I.L.O. *Yearbook of Labor Statistics*, various years; Grunwald and Flamm (1985, p. 80), (ii) I.L.O. *Yearbook of Labor Statistics*, various years.

the advanced and other less developed nations. Conversely, the U.S.'s lower labor time and highest level of labor costs have been a significant disadvantage with respect to its ability to retain the assembly components in electronics production. This has had a considerable impact in its decline in consumer electronics [see, e.g., Figure 1 (a)].

The differences between the advanced and less developed nations observed earlier with respect to labor time, costs and the proportion of production labor to total employment, are also reflected in the trends for the value added / total payroll index illustrated in Figure 3 (b). This index also reflects differences in labor productivity between the various nations. Again, Korea and Singapore have superior performance, despite the fluctuations. Among the advanced nations, the exception is Japan, with a substantially higher trend that is supported by greater and technology-intensive production. The exclusion of social benefits provided by employers in the payroll estimates may, however, bias Japan's estimates upwards significantly.

2) Government Promotion Policies: Export Promotion Strategy

Long term industrialization strategies (such as export promotion, import substitution, and the open economy regimen) are assumed to have a major influence both on the diffusion from advanced to less developed nations and on the international competitiveness of the latter's industries.[4] In particular, the effects of export promotion and its various forms of incentives are all the more significant in electronics manufacturing because of the footlooseness of this

industry, which makes diffusion and establishment easier, particularly in less developed nations.

The rapid adaptation and development of inventions and innovations have been important characteristics of export promoting nations, and are essential cornerstones of their industrial marketing strategies. These have enhanced labor and managerial skills considerably, despite the fact that a major producer such as Japan was not originally a significant source of the inventions that it applied. Labor and managerial skills have also been generally enhanced in the less developed nations adopting this strategy, all of which have become world leaders in electronics assembly, especially in the consumer appliances and components categories. Furthermore, a variety of incentives provided by the less developed nations adopting the export promotion strategies usually take the form of two road categories: fiscal or financial incentives and infrastructure provision. These provisions may be viewed as part of an effort to create a national comprative advantage, in competition with other countries, to help diffuse electronics productive technology and processes to the host countries.

5. Conclusion

The analysis of the product cycle-type diffusion of electronics revealed that, within the electronics industry, consumer electronics shows the most conspicuous diffusion from advanced to less developed nations. This diffusion is strongly influenced by the international comparative advantages derived from the lower labor costs — coupled with greater labor time and lower level of labor strife — government incentives provided by less developed nations, as consumer electronics manufacturing, having undergone a "deskilling" process, has come to depend increasingly on low cost, less skilled labor.

This diffusion has had its greatest impact on advanced nations, whose ability to compete in domestic and export consumer electronics markets has deteriorated, as indicated by their continuously declining trends in international trade and world output share. Japan proved to be the sole exception. With its successful shift toward more technology-intensive consumer electronics, its government subsidies, and aggressive marketing strategies, Japan has maintained an extremely competitive position in export markets.

With the comparative advantages moving in their favor, less developed nations found themselves increasingly able to compete in consumer electronics manufacturing. Their increased competitiveness has been achieved, in large part, as less developed nations adjusted their aggregate productive structure and process in consumer electronics to make better use of their international advantages of lower labor costs and greater labor time. Of the countries offering these advantages, however, those with a strong export-promotion strategy — Korea, Singapore, Taiwan, and Hong Kong, for example — were most successful in attracting production capacity in consumer electronics manufacturing.

The somewhat modest performance of less developed nations in industrial and component electronics, on the other hand, as indicated by the trade and world output share indexes, would suggest that these industries have not yet arrived at the mature stage of the product cycle. Their production routines are less adaptable to mass production, making them inherently slow to diffuse internationally. Further, their production requires a high level of technical skill and know-how, generally lacking in less developed nations. Accordingly, the lower labor costs available in less developed nations becomes less important that R & D resources and skills, and the production of industrial and component electronics generally remains in skill- and R & D-intensive nations. The only exceptions are cases in which some labor-intentive subprocesses (assembling, testing, packing, etc.) have been strategically shifted to reap the labor cost reduction available in less developed nations. The international division of labor in electronics manufacturing becom-

es obvious, then, when one considers the increasing concentration of consumer electronics' production capacity in less developed nations, on one hand and, on the other, the almost exclusive concentration of technology-intensive electronics' production capacity in advanced nations.

Without doubt, mature consumer electronics has already diffused to less developed nations, as its production technology became standardized and increasingly dependent on low cost, less skilled labor. Given this situation, one could question how the future diffusion process of industrial and component electronics will occur. The technology-intensive production of these electronics subsectors must first be standardized if less developed nations are to make greater use of their lower labor cost advantages, and to increase their production capabilities in these areas. The speed with which industrial and component electronics can be standardized, then, will be a crucial factor affecting its international diffusion. The diffusion of the technology-intensive electronics subsectors will be further supported by the rapidly increasing technical capabilities of some less developed nations, acquired through both the learning experiences accumulated from production in consumer electronics, and from vast investment in R & D. Likewise, the export-promotion policies aggressively pursued by these less developed nations will aid international diffusion by allowing them to rapidly adopt innovations and inventions originating elsewhere. Some of these nations are increasing production capacity both in pre-mature, though somewhat less technology-intensive, industrial electronics goods (such as telecommunications equipment and computer hardware and peripheral equipment), and in less innovative components (such as electronic tubes and transistors). This tendency provides some evidence that some diffusion to less developed nations is already occurring in these sectors.

Other issues must also be considered in relation to the diffusion of electronics to less developed nations. First is the ability of advanced, innovating nations to reclaim assembly production from less developed nations by moving towards greater automation and flexible production arrangements. Greater automation, in particular, can slow electonics diffusion to less developed nations, provided that it can offset those nations' advantages on labor cost and assembly production. Further, the effective transfer of some R & D functions to less developed nations takes on increasing importance, especially when we consider that R & D activities are indispensable to the successful diffusion and development of technology-intensive electronics in those nations.

Notes

1. Previous studies of the international diffusion of electronics have been confined, for the most part, to diffusion in the semiconductor industry, with special attention given to the shifts of the labor-intensive assembly components of semiconductor production toward low-wage less developed nations [See, e.g., Tilton (1971); Chang (1971); UNCTAK (1975); Flamm (1985); Sayer (1986)].
2. See the author's dissertation (Han 1989) for more detailed explanations.
3. The classification of electronics product groups can be performed by analyzing relative variations in the rate of growth of value added, the nonproduction / production workers index, the (value added-total payroll) / total payroll index, and value added / total payroll index, since these variables can be assumed to represent the basic characteristics of the product cycle stages. According to the author's classification following the above strategies, consumer electronics was categorized as being in "mature" product cycle stage, and industrial or component electronics as being in "growth" stage. for detailed explanations, see the author's dissertation (Han 1989, pp. 90~98).
4. See Surez-Villa and Han (1990) for an account of a significant relationship between the strategy of industrialization adopted by each country and its competitiveness in the world electronics market.

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