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AUTOMATION, EMPLOYMENT AND THE THIRD WORLD - THE CASE OF THE ELECTRONICS INDUSTRY

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Introduction

The Impact of microelectronics on Third World societies, particularly with regard to employment generation and skill formation, is still a very much under-researched topic. What we do know however, is that in practically all of these societies, computers are being introduced to an ever increasing variety of social activities, and that this diffusion occurs in a completely anarchic manner, practically unchecked by any type of viable social control.

As the experience of major OECD countries demonstrates, job destruction and increasingly hierarchical skill patterns are likely to emerge on a massive scale if no countervailing policies are applied. In developing countries, the uncontrolled proliferation of computer power is likely to have even more devastating social and political implications. Thus, there is an urgent need to devise, if possible *ex ante*, countervailing technology policies. In other words, developing countries cannot afford any longer to leave the introduction of microelectronics to the "invisible hand" of global competition.

The present article explores how computer-based automation is likely to affect international transfer of technology and North-South industrial redeployment in the electronics industry and what implications are to be drawn for employment generation, skill formation and industrial policies in the Third World. It begins with an assessment of employment and skill effects of world market-oriented electronics manufacturing in South East Asia during the 1970's. It then outlines how the proliferation of computer-based automation is already transforming the prevailing modes of internationalizing the electronics industry and its implications for off-shore chip assembly. The article discusses in particular the rationale underlying the recent transfer of automated electronics manufacturing activities to a select number of Third Work growth poles. It is shown that, due to these structural transformations, electronics manufacturing in the Third World, in contrast to earlier periods, is unlikely to play an important role in employment generation. Worse still, employment in the electronics industry will be increasingly characterized by a very high degree of instability. This applies especially to production facilities in the Third World which seem to function as a buffer against the extreme crisis vulnerability of this industry. Given the highly unequal international division of labor, structural adjustment in the electronics industry is bound to lead periodically to an under-utilization if not closure of production facilities in the Third World. This instability in turn will increase the pressure to rationalize by means of computer-based automation, the utilization of capital invested in these locations, whether it is variable capital, i. e. labor, or constant capital, in particular extremely expensive equipment. Consequently, even in periods of high demand growth and consequent worldwide capacity expansion, employment in the Third World electronics industry is likely to remain flat, if not to decline.

II. Employment and Skill Effects of World Market-Oriented Electronics Manufacturing: A Tentative Evaluation

1. The Distorted Nature of Electronics Manufacturing in the Third World

Since the early 1960s, the electronics industry has experienced a trend towards the redeployment of manufacturing activities from "classical" locations in the OECD region to new production sites in the Third World. In terms of product categories, redeployment was restricted to the assembly of consumer electronic products (calculators, digital watches, and electronic games), and the assembly of semiconductor devices ranging from simple discrete devices like transistors to medium scale and large scale integrated circuits. Electronics manufacturing was heavily concentrated geographically in a handful of countries in South East Asia and a few locations in the Caribbean and on the border of Northern Mexico. [1] Perhaps the most pertinent feature of this redeployment process is that more than any other industry, electronics manufacturing in the Third World (with the possible exceptions of Brazil, South Korea and India) has been largely subordinated to the requirements of the "worldwide sourcing" strategies of multinational firms (particularly those based in the United States) in their search for low-cost production sites and a docile female labor force.

Table 1 displays the historical pattern of offshore investments in various Third World locations by US, Japanese and multinational semiconductor companies in the 1970's.

Table 2 documents that, until 1980, the electronics industry in Asia (outside Japan) has predominantly focussed on consumer applications. In fact, even in the four leading producer countries of that region (South Korea, Taiwan, Hong Kong and Singapore) entry into product categories outside consumer electronics had been very limited. The table reveals a comparatively low level of technological development and a truly outstanding dependence on exports, ranging from a minimum of 70% in South Korea to more than 90% in Hong Kong. Finally, it provides ample evidence of the predominant role which foreign investments (including joint ventures) plays in practically all countries except Hong Kong and Sri Lanka. [2]

Given its distorted nature, what have been the development effects of this particular type of export-oriented industrialization? Traditionally, five main benefits have been claimed by proponents of this strategy:

- it would help to absorb unskilled labor;
- it would considerably improve the balance of payments and the availability of foreign exchange;
- it would act as a vehicle for transferring skills and technology;
- and, finally, by contributing to a "modernization" of the economy, it would help to reduce economic dependence and instability over the long term.

Table 1 — The Development of Offshore Investment in Various Third World Locations by Major United States, Japanese and Western European Semiconductor Firms a) 1971-1979

Country	1971	1974	1976	1979
	Number of firms present (b)			
East and South-East Asia				
Korea, Rep. of	6	8	8	8
Hong Kong	1	6	6	7
Indonesia	0	3	3	3
Malaysia	0-2	11-13	13-14	14
Philippines	0	0	1	6+1 planned
Singapore	9	10	12	13
Taiwan	3	3	6	8
Thailand			1	1
Latin America				
Brazil	0-2	2	5	5+3 planned
Mexico			12	13
Barbados	0	0	0	1
Puerto Rico			2	3
El Salvador		1	1	2
Mediterranean Basin				
Morocco			1	1
Malta			1	1
Portugal			2-3	3

(a) The sample includes 24 United States firms (AMD, Burroughs, Fairchild, General Electric, General Instrument, Harris, Hewlett-Packard, Intel, International Rectifier, Intersil, ITT, Litronix, Maruman, Monsanto, Mostek, Motorola, National, Semiconductor, Pulse Engineering, Raytheon RCA, Rockwell, Texas Instruments and Zilog), 6 European firms (Ferranti, Philips, Plessey, S.G.S., Siemens and Thomson) and 7 Japanese firms (Hitachi, Mitsubishi, NEC, Oki, Sanyo, Toshiba and Toyo).

(b) Each firm is counted only once in each country, even if it owns more than one plant.

Source: Truel, 1980, p. 12

Table 2 : The Electronics Industry in Asia - Some Basic Characteristics, 1980

Country	Production (million $)	Composition	Dependence on (exports/production)	Number of workers (1000)	Dependence on foreign investment	Stage of development
Korea	3.300	Consumer applicances 40% industrial appliances 10% components 50%	70%	180	25% (50% including joint ventures)	exports base for consumer electronic appliances and components
Taiwan	3.200	consumer appliances 45% industrial appliances 6% components 49%	80%	230	45% (including joint ventures)	export base for consumer electronic appliances and component parts
Hong Kong	2.000	consumer appliances 68% industrial appliances 2% components 30%	more than 90%	90	approx. 10%	export base for low-to-medium priced consumer electronic appliances
Philippines	320	65% components otherwise mostly for consumer appliances	90%	34	extremely high	export base for components and assembly base for electronic appliances for local market
Singapore	1.850	consumer appliances 39% industrial appliances 2% components 59%	90%	66	extremely high (more than 80% of total production)	export base for consumer electronic appliances (dependence on imported components more than Korea and Taiwan)
Indonesia	541	more than 70% for consumer appliances	2%	43	high (foreign investment is restricted to some areas but most producers are receiving technical assistance)	assembly base for electronic appliance for local market
Malaysia	990	90% components	75%	61	extremely high (more than 90% of the total production)	export base for low-to-medium priced consumer electronic appliances and some components
Thailand	106	90% consumer appliances	10%	40	extremely high	assembly base for electronic appliances for local market
Sri Lanka	little	small production of radios	0	NA	low	assembly base of some electronic appliances for local market

Source: Journal of Asia Electronics Union, July 1982
Excluding India, Pakistan, Bangladesh and the PR China

In what follows, we will focus on employment generation and the transfer of skills and technology and discuss the available, albeit limited evidence of whether or not export-oriented electronics assembly has delivered the expected results. [3]

2. Employment Effects of World Market-Oriented Electronics Assembly

Direct Employment Effects

Table 3 summaries the scattered information available on employment in the Asian electronics industry during the 1970s.

The table shows that employemt in the Asian electronics industries increased considerably throughout the 1970s. It does not disclose, however, that practically all of these jobs were generated in consumer appliances and components assembly with low-skill, low-paid female labor clearly predominating.

Nevertheless, at first sight it seems that electronics has made an important contribution to employment generation. (See colomn 3).[4] Yet this contribution must be placed in the proper context. First, the very high figures for Hong Kong and Singapore reflect their status as city states relying, by definition, almost exclusively on urban services and industrial jobs. In both territories spatial constraints limit resource-based heavy industries to a minor role. Industrial manufacturing basically consists of textiles and clothing, consumer appliances of all kinds, and "screw-driver-technology" assembly work. Available evidence reveals that until the end of the 1970s, practically all of the jobs in the electronics industry were very simple and extremely volatile occupations in consumer applications and components assembly. Second, South Korea and Taiwan, which also show quite high percentage shares, are subject to similar qualifications, at least until the early 1980s.

Third, in all of these four alleged succes cases, it will prove difficult to sustain the preceding decade's growth of electronics jobs. In fact, high shares of electronics employment in the overall industrial labor force were a reflection of the very high labor intensity prevailing earlier in the assembly of consumer appliances and components. In the meantime, computer-based automation and new approaches to design and packaging

Table 3: Employment in the Asian Electronics Industries - Selected Indicators, 1970-1979

	(1)						(2)	(3)	(4)
Country	Employees in Asian electronics industries (thousands)						Active population 1979 (a) (millions)	Percent of labour-force in industry 1979	Percent of active population 1979
	1970	1971	1972	1973	1975	1979			
Korea	n.a.	n.a.	n.a.	86	n.a.	180	23.1	30	0.78
Taiwan	n.a.	n.a.	n.a.	99	n.a.	230	10.6 (b)	27 (b)	2.17
Hong Kong	37	45	41	n.a.	n.a.	94	3.3	57	2.85
Singapore	11	n.a.	27	24	32	67	1.6	38	4.19
Malaysia	6	7	n.a.	n.a.	n.a.	55	7.2	16	0.77
Philippines	n.a.	n.a.	n.a.	n.a.	21	35	30.1	17	0.12

Source: Calculated and rearranged after table 3.25 of Flamm, K.: "Internationalisation in the Semiconductor Industry", in: Grunwald and Flamm 1985, p. 111

n.a. = not available
a) = between the ages of fifteen and sixty-four
b) = figure for 1977

technology have already fundamentally changed the economics of chip assembly, leading to sky-rocketing capital intensity and considerably lower levels of labor intensity.

Thus, a more careful reading of the sketchy information contained in Table 3 leads to the conclusion that jobs in electronics manufacturing at best will make only a marginal contribution to reducing the all-pervasive mass unemployment of Third World societies. Column 4 in fact demonstrates that, with the exception of Hong Kong and Singapore (where, due to a lack of agricultural hinterland, unemployment has not been a major concern), there is only one country (Taiwan) where employment in the electronics industry exceeds 2% of the active population. In the more populous countries, South Korea, Malaysia and the Philippines, on the other hand, direct employment effects of the electronics industry have been negligible. Thus, optimistics projections on the employment effects of the electronics industry in the Third World should be treated with scepticism.

Indirect Employment Effects and Inter-Industrial Integration

Offshore chip assembly could also lead to indirect employment effects. Multiplier effects, for example, could materialize if foreign assembly operations stimulated the growth of industries that would use the assembled components in exports of other electronic products or in products sold in the internal market. Further, at least in principle, one could expect such indirect employment effects if backward linkages were established with materials and equipment producers.

At least until the early 1980s, there was virtually no scope for such indirect employment effects because of the extreme "enclave" nature of offshore electronics manufacturing. This was the case even in Singapore, where the integration of the components industry into a local electronics equipment industry is most advanced, and which, together with South Korea, is widely credited with a forward-looking industrial policy. In 1979, local sales in Singapore constituted less than 13% of component production, and about 17% of all electronics output.[5] In addition, foreign (most majority-owned) affiliates of multinational corporations dominate employment in most of the Asian electronics industries. In Singapore for instance roughly 95% of employment and of output in the electronics industry are accounted for by multinational firms.[6] With regard to US affiliates, it seems likely that at least half the electronics employment in Singapore and Malaysia, and perhaps a quarter of electronics employment in Hong Kong and Taiwan, was associated with US subsidiaries.[7] With such a high share of electronics employment depending on the strategies of foreign firms, there is every reason to be concerned about the viability of such jobs.

The Opportunity Costs of Export-Oriented Electronics Assembly

If it cost nothing for a developing country to shift resources to assembly activities, then most of our arguments would hardly matter. Yet, "...shifting... workers and fixed infrastructural or industry-specific investments are costs to the economy when demand falls in the industry in which those resources are employed. Variation in the level of output imposes costs on an economy, and the stability of demand is a factor with economic value when the return on resources committed to an industry is calculated."[8] Consequently, a developing country that allocates a significant share of its labor force and its capital in an electronics industry assembling semiconductor devices for export, may face a severe cost when the world business cycle moves into a trough. It has been claimed however that this type of economic instability is more a problem for the US economy than for South East Asian offshore countries. "Ironically, business-cycle swings have had much more drastic effects on the home industry than on operations abroad, since firms are inclined to shut down their higher-cost home operations when rationalizing operations".[9] This is not invariably the case. For example, when Mostek, the United Technology subsidiary based in Carrollton, Texas, laid off workers in 1985, it fired 500 of its 5,400 production employees in Texas (i.e. 9.3%), and another 120 of 550 people employed in Colorado Springs (i.e. 22%), adding up to 620 lost jobs in the

United States. Its lay-offs in Malaysia were much more drastic, involving cutbacks of 600 out of 2600 workers in Penang (i.e. 23%) and 400 out of a workforce of 700 in Kota Bharu (i.e. 57%), altogether nearly a third of its previous Malaysian work force.[10]

3. Structural Transformation and Employment in the Asian Electronics Industry: the Case of Singapore

Basic Changes in the Asian Electronics Industry: From Consumer to Industrial Electronics

The electronics industry in Asia today is undergoing important structural changes. While traditionally focussed on consumer applications, there are now signs that industrial electronics will gain considerably in importance. This would apply mainly to computer hardware - i.e. central processing units, components and peripheral equipment such as terminals, monitors, disk drives and printers, but also to some types of telecommunications equipment and industrial automation equipment.

Table 4 indicates how the Asian Newly-Industrializing Countries (NICs) are planning a major thrust into the production and export of industrial electronics.
As a result of these plans, Taiwan, South Korea, Singapore, and to a lesser degree, Hong Kong, are likely to become leading exporters of computer parts and peripheral equipment. While in 1982, exports of computer hardware originating from these countries were still insignificant (in none of these countries did they exceed $ 300 million), within a few years, computer equipment is expected to become a $ 1 billion-a-year export industry in each of these countries.

Already, there are initial signs of how various activities are likely to be divided between different locations in the region: Taiwan and South Korea are expected to become two of the world's leading terminal and monitor

Table 4: The Rush into Industrial Electronics - Projections for the South-East Asian Electronics Industry, around 1982/1983

	Country	At present	Projection
1. Share in Overall Electronics Production			
= Output of industrial electronics (1) / Total electronics production [per cent]	TAIWAN	8 (1979)	27 (1989) (- $3.6 billion out of $13.5 billion)
	SOUTH KOREA	12 (1982)	20 (1986) 31 (1991)
2. Share in Overall Electronics Exports			
= Exports of industrial electronics / Total electronics exports [per cent]	SINGAPORE	3.2 (1982)	20 (1990)
3. Share of New Investment Commitments in Industrial Electronics			
= New investment into industrial electronics production / Overall new investment commitments of the electronics industry [per cent]			
	SINGAPORE	44 (1982)	

Sources: Taiwan - Council for Economic Planning and Development: South Korea - Ministry of Commerce and Industry; and Singapore - Economic Development Board (EDB)

"Industrial Electronics" covers a great variety of computerised machinery, for which a consistent categorisation does not yet exist. Main segments include: computer hardware, i.e. central processing units (CPUs), components and peripheral equipment, such as terminals, monitors, disc drives and printers; telecommunication equipment; factory automation equipment, ranging from stand-alone NC machines to computer-aided design (CAD), computer-aided-manufacturing (CAM), and computer-integrated-manufacturing (CIM) systems; office automation equipment, ranging from word processing equipment, desk top computers to integrated office automation systems.

exporters, Singapore a major supplier of disk drives, and Taiwan, South Korea and Hong Kong could expect to play a considerably role in the expanding world market of personal computers.[11]

In order to proceed with such a strategy of increasing the share of industrial electronics, basic changes are required, not only in the product mix and in production technologies, but also in the organization and strategies of the firms involved as well as in the overall structure of the local electronics industry. Such structural transformation which seems to be well under way in Singpore, South Korea and Taiwan, is bound to influence the electronic industry's occupational structure and skill requirements and its capacity for net employment generation. In what follows, we will discuss these issues for one particular country, Singapore, whose government has been one of the most fervent proponents of this type of 'modernization' strategy.[12]

Employment in the Singapore Electronics Industry

As a result of its rapid growth during the 1970s, the electronics industry today plays a predominant role in the Singapore economy. Already by 1979, it had overtaken the petroleum industry as the largest single industry in terms of value-added. In 1980, the electronics industry presented 7% of GNP, 20% of the manufacturing industries' value-added and 20% of total exports. Has the electronics industry helped Singapore's labor market strengthen its capacity to generate viable industrial jobs?

Table 5 displays basic information on the sectorial structure of employment. It demonstrates that the number of employees working in the electronics industry has rapidly increased throughout the 1970s, and that in 1980 the industry absorbed 7% of the total active population and 25% of the industrial labor force.

Table 5: Singapore: The Sectorial Structure of Employment, 1970-1980

Active Population (1,000)	1970	1975	1979	1980 (a)
a) Total	651	834	1,021	1,077
b) Manufacturing Industries (b)	121	192	267	287
c) Electronics	11	32	67	74
d) Wearing Apparel/Textiles, Leather, Footwear	20	32	42	40
e) Transport Equipment	16	30	28	31

a) = preliminary
b) = excluding granite quarrying

Sources: Yearbook of Statistics, Singapore 1979/80, Department of Statistics, Economic Development Board, Singapore 1980

In the meantime, the electronics industry's capacity to absorb additional labor has drastically decreased. A survey conducted between November 1980 and January 1981 in fact concluded that "... the total number of workers in the electronics industry is unlikely to increase further at high growth rates." [13] As table 6 indicates, the surveyed companies planned to increase their overall employment by less than 3%.

Table 6: Projected Changes in the Employment Structure of Singaporean Electronics Companies, 1980/81

Category	1980	1981(a)	Difference	Growth Rate (%)
1) Total number of employees	29,542	30,410	868	2.9
2) Number of engineers	732	800	68	9.3
3) Number of technicians	1,378	1,490	112	8.2
4) Number of engineers and technicians with substantial R&D activities	170	205	35	20.1

a) = projections of companies

Source: Hillebrand et al. 1981, table 17

In other words, the employment generation capacity of the Singaporean electronics industry, which appeared quite robust during the 1970s, has been under heavy pressure in the early 1980s. Since the 1979 recession particularly, important structural transformation have occured in the nature of electronics manufacturing in Singapore which have modified the amount and the structure of employment required in the industry.

Table 7: Projected Changes in the Output per Worker in Singapore's Electronics Industry, 1979-1981 (in thousands of Singapore $)

Output per worker \ Year	1979(a)	1980(b)	1981(b)
1) All surveyed companies	61.2	63.0	72.0
2) Components manufacturers	63.2	64.0	77.0
3) Manufacturers of Consumer Electronics	59.6	62.0	67.0

a) = Figures for 1979 refer to the electronics industry as a whole and are taken from the Census of Industrial Production, Singapore 1979
b) = Estimates and projections of companies

Source: Hillebrand et al. 1981, table 9, p. 23

Table 7 reveals that the output per worker of the electronics industry - most probably as a result of the combined effects of an increasing capital and skill intensity of the production processes - is expected to rise considerably in 1981. In other words, since the late 1970s, electronics manufacturing in Singapore has "... entered into a new phase of qualitative rather than quantitative growth ..."[14], and its capacity to absorb cheap unskilled labor has been drastically reduced. Table 6 in fact shows that in the future, demand for labor will focus predominantly on engineers and technicians, providing fewer new jobs then the total number of jobs displaced. Overall, increasing mechanization and automation has created a significant shortage of engineers and technicians while low-paid, unskilled occupations have been displaced on a significant scale.

Implications for Other South East Asian Countries

While it is problematic to generalize from the experience of one particular country, it is obvious that, for other developing countries in Asia, employment perspectives are likely to be even more negative than for Singapore. In fact, while Singapore, as a result of its small size and its fairly effective planning bureaucracy, might at least be able to capture some of the "positive" employment effects in terms of engineering and technician occupations, other countries like Malaysia, the Philippines, Indonesia and Thailand, are unlikely to follow suit. For even if there is room for continued assembly operations in these countries (which we will argue is most likely to be the case), they will be increasingly automated. This in turn implies a drastic reduction of low-skill job opportunities, combined with a dramatic increase in the investment outlays required per new job created. Thus, export-oriented electronics manufacturing which once used to be perceived as an easy road to rapid employment generation, today is unlikely to fulfill this function, even if net investment in such activities increases.

4. Chip Assembly: A Vehicle for Effective Transfer of Technology?

In principle, foreign direct investment in chip assembly could lead to a transfer of technology on various levels. First, through different forms of training and education it could help to upgrade the skills, the knowledge, and, most importantly, the learning capabilities of the workforce engaged in assembly plants and in complementary local vendors, such as plastics companies and machine shops. Second, by transferring increasingly complex products, processes and machines, foreign direct investment could initiate a process of learning-by-doing, picking-up feedback information on actual performance and maintenance requirements, and thus securing a gradual strengthening of reproductive and adaptive engineering capabilities. Third, national entrepreneurs, engineers and workers could take a more aggressive stance on technology acquisition, for instance by "reverse engineering" imported machinery. If supported by a reliable "technology acquisition infrastructure", this could help selectively to improve the host country's capacity to reproduce, adapt, and further develop imported products and process technologies.

So far, however, export-oriented chip assembly has played a very minor role in establishing an effective transfer of technology to developing countries. For the great majority of the workforce, skill requirements have been quite low, and training has been of a rather casual nature. Furthermore, prevailing modes of organizing chip assembly treat human operators more as a nuisance than (at least potentially) as a precious force of production.[15] Thus, with but a few minor exceptions, management is hardly inclined to improve the skills, knowledge and learning capabilities of its assembly production workers.

Second, while the increasing complexity of the products assembled, of the equipment used, and of the operations performed in offshore plants has been raising the technological level of such activities, only in a very select number of cases has this been translated into viable reproductive and adaptive engineering capabilities. There are a number of reasons involved. The most obvious ones relate to weakness of the current educational and research infrastructure which constrain the scope for policies to generate adequate technical and engineering skills. What really matters, however, is that foreign firms engaged in automated chip assembly require only very small numbers of skilled technical personnel to run such equipment. So far, a demand for technical skill immediately on the spot has only emerged for maintenance tasks. Programming automated assembly equipment is still done predominantly in the US and Japan. It could be hypothesized, however, that this is an area where pressure is likely to increase, particulary from governments in South Korea, Taiwan and China[16], to lift the barriers to such a transfer. In fact, given the low cost of programmers and systems analysts in some of these countries, it might also make sense for US equipment firms to transfer and upgrade knowledge required for programming automated assembly equipment, and to increase the share of such programming executed at offshore locations.

Finally, a third area where automated chip assembly requires skilled labor is the design of such equipment. So far, US and Japanese semiconductor equipment firms alike have treated this activity as strategic proprietary knowledge, and thus have tried to keep it under strict control. Rigid policies of not transferring design know-how might have to be modified however in the not too distant future. On reason would be the increasingly severe "human capital trap" confronting in particular US and Western European firms. In addition, increasingly aggressive requirements, particularly by some South East Asian and Latin American governments, and new technological developments in the field of design automation might further add to a softening of this particular policy. Such developments, however, most probably require at least a decade to evolve.

What matters even more is that knowledge of assembly technology is of only limited relevance for waver fabrication, let alone for the crucial areas of chip and systems design. In other words, even if there were a significant transfer of technology, it is doubtful whether this technology, on which vast capital and human resources have to be spent, can be particularly useful in directing policy towards identifying and implementing priority applications for microelectronics.

III. Towards New Forms of Internationalization in the Electronics Industry

1. The Impact of Computer-Based Automation

The emergence of a new generation of flexible and integrated automation technologies (computer-aided design systems, computer-numerical-control units, industrial robots and flexible manufacturing sustems) would have been impossible without recent developments in microelectronic hardware and software and in complementary interface technologies such as sensor and transmission technologies. In fact, as microprocessors, memories and input-output devices have become increasingly powerful, computer, communication and control technologies which used to be strictly separated, are being increasingly linked into intregated information systems. This implies that, for the first time, the most crucial yet intangible production inputs, i.e. information and knowledge, can be generated, linked together, transformed and communicated practically at random. This development is likely to increase the scope for automating industrial manufacturing and complementary services drastically.

While manufacturing traditionally was geared to achieve factor savings by sacrificing product-line flexibility to economies of scale, the new generation of computer-based automation systems will allow firms to reconcile these conflicting objectives and thus open new paths to regain profitability. As a result of these developments, computerized automation systems are expected to transform the economics of many types of industrial manufacturing involving both mass and batch production. In particular, computer automation is supposed to increase the flexibility of machines, decrease the complexity and vulnerability of production structures, improve the productivity of capital and widen the scope for internationalizing industrial production.[17]

Though today computer-based automation in the electronics industry is still applied in a piecemeal fashion, integration seems feasible within the next fifteen years. However, even the present level of automation has imposed radical changes on the prevailing modes of designing and manufacturing semiconductors, computers and electronic consumer products. In all of these sectors, computer-based or programmable automation will be a key to competition in the 1980s. Firms that succeed in developing viable automation strategies will profit in a number of ways. Automation in particular will allow them to produce in a flexible manner better quality products at lower prices. Furthermore, due to the very high costs of automation, only the most powerful firms (particularly the captive ones) can afford it.

These firms thus can use automation as an instrument of oligopolistic competition, locking out potential newcomers to the market. Less powerful firms unable to afford automation will quickly lose their market shares. Sooner or later, they will be forced into small market niches or out of business altogether.

The semiconductor industry ,for example, was once characterized by a high degree of labor intensity, but currently is experiencing skyrocketing capital cost and a dramatic upsurge in capital intensity. As integrated circuits have become ever more complex, the costs of design and equipment have exploded. Currently, the industry rule-of-thumb is that the design cost per gate is about $ 100; since state-of-the-art chips normally have as many as 10.000 gates, the design cost for each device approximates $ 1 million. With available process technologies, it may well be possible to make chips with one million gates within a few years: design costs for such devices will be extraordinarily high. An integrated circuit with a density of one million gates would require more than 150 man-years and at least ten calendar years to develop.[18]

The capital costs of equipment -- lithographic systems, ion implantation techniques and ever more complex automated testing equipment -- have also dramatically increased. Table 8 documents the high costs of lithographic equipment and reveals the expanding minimum investment requirements for semiconductor production.

Faced with rapid increases in the capital intensity of semiconductor manufacture, semiconductor firms have been under tremendous pressure to pursue vertical integration on a worldwide scale. Consequently, new forms and mechanisms of the internationalization of production and complementary services are evolving in the electronics industry.[19] At the same time, offshore electronics manufacturing in developing countries has been experiencing major structural transformations, which, for the most part,

Table 8: Cost Increases for Lithography

Lithographic systems	line width (micrometers)	throughput (wafers per hour)	approximate cost per system	approximate capital requirement for production capacity of 1,000 wafers starts per week
Light				
Contact printing	10	60	$ 15,000	$ 30,000
Projection	2-5	60	$240,000	$400,000
Direct-step-on-wafer	1-2	30	$480,000	$1.6 million
Electron-beam	0.5-1.0	6	$1.5 million	$25 million

Source: US Congress, Office of Technology Assessment, November 1983, p. 80, adapted from A.J. Stein, J. Marley and R. Mallon: "The impact of VLSI on the Automobile of Tomorrow", VLSI Electronics: Microstructure Science, vol. 2, New York 1981, p.295

have been neglected in present discussions on future redeployment possibilities of this industry.

In the semiconductor industry for instance, new production sites have been emerging rapidly and new actors have entered the stage. Thus the "rules of the game" characterising the industry today are very different from those of earlier periods. Yet, most of these changes have been largely unnoticed, at least outside the inner circles of headquarters management of major firms, and attempts to analyse the international restructuring process for this industry are still to a large extent based on hypotheses drawn from the experience of the 1960s and the early 1970s. Due to the changing economics of semiconductor manufacturing, the nature of offshore chip assembly no longer corresponds to the methods and structure prevalent even five years ago. The introduction of new technologies to automate chip assembly has played an important role - but a somewhat different one than was expected by early observers.

2. Changes in Geographic Location Patterns [20]

Not so long ago it seemed that relocation back to the North was the most obvious implication of automation for offshore plants. But reality has not conformed to this rather simplistic prediction. It is now possible to identify four distinct trends in the international location of semiconductor manufacture.

First, locational shifts have occured among major OECD countries mainly between the United States, Japan and a few production centers in Western Europe. Until the early 1970s, inter OECD investment flows consisted mainly of investments by US firms in Western Europe which were geared to the computer industry and to serving government procurement markets in the military and the telecommunications sectors. Since then, three location trends have gained in importance: a move of West European and Japanese firms into US locations; increasing Japanese investment in Western Europe; and after 1980, recent shifts of US investment to Japan.

Second, there have also been locational shifts from the center to the periphery of the OECD region, particularly to Ireland, Scotland and Wales. This has involved predominantly investment by US and Japanese firms aimed at supplying the European and Middle East markets.

Third, in the classical "export platform" countries in Southeast Asia, i.e. Singapore, South Korea, Taiwan, Malaysia and Hong Kong, there was a period of stagnation in which little new investment occured between 1974/75 and 1978. This has been followed by the first attempts on the part of semiconductor multinationals to engage in more capital-intensive and integrated production activities.

Finally, there has also been a relocation from the original offshore sites in the NICs to new locations in the Philippines, Thailand, Indonesia, The Caribbean Basin, China, and Sri Lanka. These new operations have been restricted to the assembly of mature components and, in some cases, to final testing. Interestingly, both types of offshore sites have been characterized by rapidly increasing levels of automation.

Thus, since 1975, the bulk of international investment of semiconductor manufacturers went to locations within the OECD region. Throughout the 1980s, redeployment among locations in the US, Japan and Western Europe is likely to dominate the internationalization of this industry. Redeployment to Third World locations, however, has certainly not ceased. New actors and production sites have emerged and the first signs already exist of a new hierarchization between different types of Third World locations.

3. The Transformation of Offshore Chip Assembly

Offshore chip assembly has experienced major changes since the mid-1970s: net capacity investment into offshore assembly lines has been slowing down, while rationalization investment has accelerated; employment figures in practically all offshore locations have been stagnating, if not declining; output and export figures continue to rise for all major offshore locations; and the value-added in offshore manufacturing which initially increased annually until 1973 has been declining since. For instance, whereas the dutiable value of US semiconductor imports from developing countries in 1976 was 54.3 percent, this had declined to 36.9 percent by 1980..[21]

A number of future trends deserve particular attention. The decline of value-added in offshore chip assembly is a direct reflection of the fundamental changes in the economics of semiconductor manufacturing. Traditionally, automation focused on wafer fabrication and on design and testing. Assembly, on the other hand, up to the late 1970s at least continued to rely on manually operated equipment or, at most, on stand-alone pieces of semi-automated equipment. Consequently, the value generated at the "front end" of semiconductor manufacturing grew relative to the value generated in assembly. Developing countries should interpret this decline as a warning signal that future strategies to transform offshore assembly into an integrated electronics industry might encounter severe constraints. Whether or not the value-added in offshore locations will increase is a factor of crucial importance both for the employment and for the viability of strategies to successfully integrate these activities with overall industrial production.

Since early 1983, capacity investment into offshore chip assembly, and to some degree also into offshore final testing, has again started to gather momentum. In a situation of rising excess demand, where existing assembly capacity worldwide is run at full speed, a new round of assembly plant construction has commenced in all major offshore locations. Nevertheless, automation will remain the core issue in future assembly strategies. According to a recent review, a clear trend towards automated chip assembly can be discerned:most purchases of bonding equipment relate to automated machines(67%), 20% to a combination of manual and automatic bonders while only 13% are geared to manually operated machines.

Finally, while from 1980 to 1982 growth rates of offshore output and exports declined as a result of worldwide surplus capacities, they have increased again since early 1983 with demand exploding for all types of ICs, and in particular for memories and microprocessors under such conditions, even assembly lines based on outdated manual equipment have a fair chance to participate in growing sales.

It should be recalled, however, that semiconductor manufacturing, historically, has always experienced intense periods of feast and famine.[23] It is in this context that production facilities in the Third World seem to have their most important function, i.e. as a <u>buffer against the extreme crisis vulnerability of this industry</u>. Given this highly unequal international division of labor, structural adjustment in the semiconductor industry is bound to lead periodically to an underutilization if not closure, of production facilities in the Third World. This instability in turn increases the pressure to rationalize, by means of computer-based automation, the utilization of capital invested in these locations.

IV. <u>Automation and Industrial Redeployment: Complementary Processes Rather Than Alternatives</u>

It seems safe to assert that the issue of immediate concern is not so much the possibility of outright relocation of industrial activities from the South, particularly some Latin American and South-East Asian NICs, back to the OECD region. Manufacturing of semiconductors in the Third World will continue to expand, albeit restricted to a fairly small number of "exclusive" production sites - and restricted to certain product families and to those specific stages of production which are not essential for exercising systems control. Furthermore, at least some segments of computer manufacturing are likely to be increasingly transferred to South-East Asian locations.

One obvious reason for the expansion of offshore activities relates to the already very high degree of internationalization characteristic of contemporary electronic manufacturing. In fact, inside almost any electronic product - whether it is a computer or a consumer item - components can be found which have been made in more than a dozen factories in at least half a dozen countries. Even one subassembly may be the result of an odyssey.

Given this high degree of internationalization, and in particular the prominent role played by South-East Asian locations, a rapid retreat to less internationalized modes of electronics manufacturing is hardly conceivable. Considerable amounts of time and money have been invested to design, construct and consolidate international sourcing, production and marketing networks. Furthermore, painful adaptations had to be imposed on existing organizational structures and management strategies which are not easily revoked or discarded.

In other words, a retreat from existing levels of internationalization involves substantial costs, both in terms of closing existing plants, reshuffling supply and marketing networks, and in terms of benefits forgone which could be reaped once higher stages of internationalization had been achieved. Thus, the mobility of capital invested during previous rounds of internationalizing electronics manufacturing is likely to be much lower than originally expected. Consequently, firms are likely to increase rather than decrease their degree of internationalization.

The effects of rapid oligopolization reinforce the international strategies of the industry. In the US semiconductor industry of instance, of the ten major firms only two can still claim the status of formal independence: all the others are, to one degree or another, integrated into huge, highly diversified conglomerates. In fact such conglomerates currently dominate practically all major sectors of the electronics complex, and their criteria for international allocation hardly ever coincide with the simple "relocation back to the North" formula. [24]

On the other hand, some major US semiconductor manufacturers are constructing or have already established highly automated VLSI assembly lines (for both memory and logic circuits) onshore in the United States. Table 9 presents evidence on major new assembly projects in the US.

The table shows that, at least in the cases of Motorola and Intel, the move into automated onshore assembly and final testing can by no means be mechanically equated with a real transfer of production capabilities to the US. It can in fact be shown (see column (5) of Table 9) that both firms perceive the design and implementation of automated assembly and testing facilities in the US as an <u>experimentation field for developing modules of automated assembly and final testing</u> which could be transferred subsequently to locations outside the US, including some growth poles in the Third World.

Experimenting with such a "quantum jump" in automation had to begin in the US in order to coordinate it with the requirements of wafer processing and to find the necessary engineering and equipment support talent. Once major technical teething problems have been solved however, there is no longer any need to confine such systems to the US. In fact, Third World locations offering a sufficient supply of low cost engineers, technicians and skilled workers seem to be priority candidates for such transfers.

While we lack similar evidence in the case of Fairchild, it is plausible to expect a similar rationale to apply for this firm, for

Table 9: Major Onshore Assembly Projects - US Firms

(1) Firm	(2) Products	(3) Location	(4) Date of operation	(5) Comments
Motorola	Automated Assembly of high-quality ICs, in high volume; initially 14/16-lead plastic packages; later on, focus will be on memories, micro-processors and other VLSI	Chandler, Arizona	Operational since end of October 1983	- Perceived as a "...development site for ... Motorola's future automated assembly capabilities ...We will be able in the future to take and replicate the technology of this plant, in modules, anywhere in the world...", thereby strengthening offshore plant capabilities - US location essential for implementing such a quantum jump in assembly automation (a)
Intel	Automated assembly, test and finish of unspecified products. Most likely candidates: Intel's high demand microprocessors (80186, 8088) and ROM and EPROM versions of Intel's microcontrollers	Chandler, Arizona. Together with Penang, Manila and Barbados, this is Intel's 4th assembly plant (A4). For test and finish it is Intel's 11th plant (T11)	Expected to be running at full volume: early 1986	Perceived as a "technology development assembly/test facility where new packages and processes can be debugged and prototyped". "We'll develop technology there and then transfer it to our other plants so they will be able to increase their volumes." (b)
Fairchild	Automated assembly of unspecified digital devices	South Portland, Maine	Operational since end of December 1983	- (c)
Applied Micro Circuits	Automated assembly of unspecified semi-custom chips	San Diego, California	Operational since April 1984	- (d)

Sources: (a) Y.G. Lee, General manager of Motorola's Chandler Assembly and Final Test Plant Operations, quoted in Semiconductor International, March 1984, p. 120
(b) Author interviews at Intel, Santa Clara, May 1984
(c) "Is the Worst Over for Fairchild Camera?", in Business Week, 14 November 1983
(d) Global Electronics Information Newsletter, No. 42, April-May 1984

Fairchild has played a leading role in automating testing equipment and has acted as a pioneer in transferring state-of-the-art automatic assembly and testing equipment to some of its offshore locations, particularly in Singapore and Malaysia.

In other words, the mere fact that firms like Motorola, Intel and Fairchild engage in automated assembly and testing in the US does not imply that their offshore assembly and test plants will decay or be abandoned. In the case of Intel for instance, one of the responsible managers stressed that: "We absolutely have dedicated staffs, expertise, facilities and more that we are not going to walk away from. We intend that Penang, Manila, Barbados and Puerto Rico will remain critical portions of Intel's manufacturing team."[25]

Thus, the key issue is that in electronic components, as much as in consumer and industrial electronics, automation and industrial redeployment to developing countries are no longer alternatives. Rather they are taking place as a complementary processes and automation is increasingly the driving force. Moreover this trend towards increasing automation and capital intensity is not restricted to industrial restructuring within the US, Western Europe or Japan. It will also begin to apply to certain growth poles in the European periphery and in the Third World.

V. Shiftung Automated Electronics Manufacturing Activities to Third World Locations: The Underlying Rationale

Global sourcing for low-cost factors is bound to grow in importance, particularly as a result of intensifying competition, whether related to price, quality, or service. What is new today is that traditional forms of global sourcing are no longer sufficient. The real issue at stake is "... to combine the advantages of advanced manufacturing technologies with worldwide sourcing strategies."[26] In other words, for some major electronic component and system firms in the United States, Japan and Western Europe, it is perfectly rational to transfer, albeit in a strictly selective manner, automated electronics manufacturing activities to a few industrial growth poles in South East Asia, Latin America, the Middle East and the Mediterranean area. Viewed from the perspective of headquarters' management, three types of concerns seem to be of particular importance: (a) access to the huge demand potential for electronic applications in the Third World; (b) global sourcing for low-cost factors of production; (c) the need to rationalize existing global sourcing networks.

1. Access to Future Growth Markets

Electronics manufacturers in the US, Western Europe and Japan cannot afford any longer to neglect the huge demand potential available in the Third World. This is so because demand perspectives in OECD region remain depressed. With the exception of the electronics industry and some service activities, practically all manufacturing industries are confronted today with a structurally caused demand stagnation. Even for the electronics industry, the picture is much less than glamorous. While booming demand for personal computers, telecommunications equipment and military applications has improved somewhat the electronics industry's growth potential in major OECD markets, this is by no means likely to be a permanent development. There is in fact ample evidence that the electronics industry, if left to OECD markets, will hardly play its expected role as a key growth industry of the 1980s. Cases in point are the near stagnation of consumer electronics, the declining sales of cheaper computers, the fiscal limits to a further growth of military applications, and the high probability that supply of essentially similar personal computers will soon exceed even the most optimistic demand projections.[27] As result of these developments, the semiconductor boom that began in January 1983 has already fallen apart.

Faced with vast surplus capacities, electronics firms will try to tap the huge demand potential available in the Third World, in particular in the

Gulf region, South East Asia and Latin America. In the electronics sector for instance, the following application areas seem to be of primary importance for future market penetration: military electronics; telecommunications; electronic consumer items for the urban elites; the computerization of the tertiary sector, including the new technologies of social control; and the selective computerization of export-oriented industrial production, particularly for electronic components and consumer electronics, the textiles and clothing industry, and the leather and shoe industries.

2. Sourcing for Low-Cost Factors of Prodcuction

Reduction of direct labor costs is an important but by no means an exclusive concern for electronics firms in the current period. In fact, previous rounds of automation in the electronics industry have already considerably reduced the share of direct labor costs in overall manufacturing costs. This does not imply that the wage level (including indirect labor costs) will cease to play a role for international investment decisions. Even for increasing levels of automation, it still matters that, by and large, operators and maintenance personnel in developing countries receive significantly lower wages than their counterparts in the US, Western Europe and Japan.

Other cost factors are however rapidly gaining in importance. Caught in a severe "human capital trap", and in order to reduce the cost of R&D personnel and highly skilled technicians, electronics firms will have to rely increasingly on cheap human capital available in some of the more advanced developing countries. The need to run extremely expensive equipment practically around the clock -- to maximize its annual overall utilization and to minimize possible "downtimes" -- constitutes an important consideration for offshore location, as is the need to exploit the lower costs of materials, components and sub-assemblies. Based on confidential interviews with industry sources, I would estimate that the costs of producing electronic components in the main producer countries of South-East Asia tend to be more than 30% lower than in the US. The availability of a low-priced (i.e. highly subsidized) infrastructure, and a minimum of regulations with regard to environmental and labor standards, are probably increasing in importance, for instance for wafer fabrication and silicon foundries. In fact, governments in developing countries are likely to continue, if not expand, their programmes to promote foreign investment in so-called "high technology industries", through a variety of tax incentives and policies to reduce overhead costs (infrastructure; labor and environmental regulations). In fact, some Far East locations today have an excellent infrastructure which, more so than in OECD countries, is geared to the requirements of global sourcing in electronics. According to a confidential industry source "... automation today functions as well in the Far East as in the West."[28]

VI. Towards a Rationalization of Global Sourcing Networks

Since the mid-1960s, the internationalization of electronic manufacturing has led to the emergence of pervasive global sourcing networks linking together the most diverse production activities and complementary services irrespective of their geographic location. Viewed from the perspective of headquarters' management, global sourcing certainly provided a number of benefits. The most important advantages included: access to low-cost factors of production, particularly cheap and docile female labor; hedging the foreign exchange risk inherent in manufacturing in one country and selling in a second ; appeasing the concerns of local governments who want an increased local content (and thus employment) in the products sold in their countries; and access to business relations with local suppliers and customers.

Today however, it is equally apparent that proponents of the global sourcing strategy tended to neglect its substantial costs. Established in a piecemeal and ad-hoc fashion, existing patterns of internationalization have in many cases led to a wasteful allocation of resources, for example in the frequent transshipments of materials, parts and subassemblies over thousands of miles, before the final product reaches the customer. In the case of semiconductors, until very recently, processed wafers used to be sent by plane from the US to an offshore location in the Far East for cutting and assembly, and then sent back again to the US for final testing and burn-in. As semiconductor firms are struggling to improve both quality and cost, and to speed up their reaction towards changing customer requirements, the pressure to rationalize the existing global sourcing networks has been increasing. Since 1982, for instance, virtually every major captive or merchant US semiconductor firm has added final test and burn-in to its offshore assembly activities. In fact, substantial amounts of money have been spent on transferring expensive automated test equipment to offshore locations. In addition, independent testing and burn-in subcontractors in Singpore and Manila have substantially stepped up their activities. As a result, the test equipment which can be found today in Asia matches the equipment found at a US firm's domestic facilities.

It is in this context that applying computer-based automation systems to offshore production activities will probably have its most lasting impact. After all, strengthening the control capabilities of machines and making them mutually compatible is only one aspect of computer-based automation. Its main focus is on rationalizing the flow of information required for planning, coordinating and controlling manufacturing activities and complimentary services. As manufacturing has become highly internationalized, the strategic area of attack today for computer-based automation has become the computerization of command, control and communication networks required for global industrial manufacturing, so that complexity, rigidity and vulnerability can be reduced and overall efficiency be increased.

It is now technically feasible for multinational firms to establish integrated systems of transborder data flows, due to the convergence between information, communication, and control technology.[29] This has opened up new possibilities for multinational corporations to install captive worldwide information networks, through which headquarters' management can link together production facilities located around the world as if they were divisions within one factory. Thus, it has become possible today to synchronize, on a worldwide scale, decentralized production with a strictly centralized control over strategic assets (product design and plant layout; global cash management; logistic coordination; on-time operational control of production and complementary support services, particularly marketing and inventory). At the same time, global information networks open up new possibilities for headquarters' management to control affiliates and host countries around the world, to put them under pressure if need be, and even to force them into a ruthless mutual competition. It is possible for instance to transmit, via radio or satellite, over thousands of miles and within a few seconds, work results, feedback information, control figures from any affiliate to graphic displays in a company's headquarters or competing affiliates.

Viewed from the perspective of headquarters' management, there will be an increasing interest in integrating a growing number of affiliates around the world into such worldwide captive information networks, in order to take advantage of this extraordinary flexibility. Established patterns of subcontracting in assembly and final testing will be complemented by new forms of global sourcing related to design and wafer fabrication. In design for instance, there has been a proliferation of so-called "satellite design centers" linked to new start-up companies focussing on application-specific devices, particularly in the field of telecommunications. Such independent design centers are emerging in South-East Asia.[30] With regard to wafer fabrication, the 1983/84 supply crunch for key memories and microprocessors has forced leading US semiconductor firms to look for new and unconventional approaches to a worldwide sourcing of wafer fabrication. Intel for instance has established the concept of "die contracting" which means that other companies use Intel masks to produce each die, which Intel then puts into a package and sells as an Intel finished product.[31] While firms try to restrict information on these new forms of wafer fabrication sourcing, information obtained from our interviews suggests that a substantial share will go to locations in South East Asia.

VII. Implications for Developing Countries

In the light of the above discussion, what scope is there for developing countries to pursue, both individually and collectively, the development of an increasingly integrated electronics industry and the appliction of this technology in a way that will meet the real needs of these societies? Here we wish only to make a few tentative suggestions which, in fact, should be priority areas for future research in this area.

The application of microelectronics to industrial products and processes throughout the global economy is already turning upside down on a worldwide scale the established modes of industrial production and consumption. Consequently, the question is not whether to apply microelectronics but where and according to which criteria. The key issue, both for individual and groupings of developing countries, is to identify those application areas which are capable of strengthening their long-term development potential. This requires a highly selective approach which would aim at linking applications to the strategic sectors of each economy rather than to aim for a broad-range development of these technologies.

We have shown that computer-based automation is already imposing radical changes on prevailing modes of offshore chip assembly. As capital intensity increases, the positive development effects to be reaped by developing countries in terms of employment generation, skill information, forward and backward inter-industrial integration and technological spin-offs might become even smaller and less viable than they are today. So far, projections are based on very unsafe ungrounds, simply because they are necessarily deduced from incomplete knowledge of current trends which invariably outpace our research knowledge in such a rapidly changing area.

Two examples should at least indicate the order of magnitude of the structural changes involved:

(a) <u>The potential for job destruction</u>

The automated equipment now operating in practically all major offshore locations undoubtedly displaces labor. For instance a stand-alone automated bonding machine controlled by one operator typically replaces up to 30 manual operators.[32] With the transition towards flexible and integrated assembly systems, the displacement is likely to even higher. At Intel's new assembly/test plant in Chandler, Arizona, projected to be running at full volume in 1986, direct labor costs are expected to account for less than 8% of the finished package cost compared to 15% in mid-1984.[33] The widespread diffusion of these systems among developing country producers would mean that the much heralded capacity of the electronics industry for job creation will be severely restricted.

(b) <u>The impact on skill requirements</u>

The hierarchization of skill requirements is bound to increase substantially. On the on the one hand, global sourcing for cheap brains (i.e. systems analysts, computer scientists and programmers) in South East Asia, India, Brazil, Mexico, Argentina and elsewhere has become one of the main concerns of semiconductor firms worldwide. On the other hand, the skill requirements for those operators who have not yet been forced out of the factories, by and large seem to decline rather than to increase. For instance, while it normally took about three months for a worker to become competent at manual bonding, today, with automatic bonding equiipment, it takes only two weeks to train a machine operator.[34]

To conclude, we urgently need sound empirical research on the viability of employment generated in the electronics industry in general, and in offshore chip assembly in particular. The same applies for research on how the extreme fluctuations of demand for electronic products and services have influenced capacity utilization of Third World assembly lines over time. Only if such information is available, will it be possible to assess the opportunity cost of export-oriented electronics assembly and thus to clear the road for alternative policy approaches.[35]

NOTES

[1] Ernst 1983a; United Nations Centre on Transnational Corporations 1983.

[2] Due to the special status of Hong Kong as a Crown Colony and a regional banking center, the low percentage of conventionally defined foreign investment is hardly surprising. For Sri Lanka, the low share of foreign investment means that its integration into the global offshore assembly networks has started only very recently.

[3] For a detailed assessment see Ernst 1986.

[4] This position is taken by Flamm who however does not substantiate this argument, see Flamm, K., "Internationalization in the Semiconductor Industry", in: Grunwald and Flamm 1985, p.110-112

[5] Hillebrand et al.,1981, p.15-16, 52.

[6] Hillebrand et al.,1981, p.1.

[7] These figures however relate to 1977 and thus are quite dated. See US Department of Commerce, "US Direct Investment Abroad", Washington DC 1977, quoted by Flamm, in Grunwald and Flamm 1985, p.112.

[8] Flamm. K., "Internationalization in the Semiconductor Industry", in: Grunwald and Flamm 1985, p.117.

[9] Flamm, "Internationalization", p.118.

[10] For details see Electronics Week, 8 April 1985, p.14.

[11] See U.S. Congress, OTA 1983 and O'Connor, 1984 for details.

[12] So far, lack of empirical information prevents a comparative treatment of these issues for different groups of South East Asian countries.

[13] Hillebrand et.al.1981, p.51.

[14] Hillebrand et.al.1981, p.23. For additional information see Karen Berney, "Asia. The Four Dragons Rush to Play Catch-Up Game", special report, Electronics Week, 6 May 1985, pp.48-56.

[15] Author interview with Paul W.Gustavson, Director, Human Resources at Cygnet Technologies Inc., Sunnyvale. Gustavson is an expert in flexible manufacturing systems and was a member of the design team responsible for Zilog's flexibly automated Nampa, Idaho plant. A similar critique can be found in Gardiner 1984.

[16] India, which would be well qualified for such a policy, under the new administration of Rajiv Gandhi, is unlikely to take a very active stand. In fact, its main thrust is a return to across-the-board "open door" policies.

[17] For a critical evaluation of these expectations see Ernst 1986.

[18] Author interview with David D. Shearer, SRI International, Menlo Park, California, 23 May 1984.

[19] For an in-depth analysis see Ernst 1983a, chapters 4.2 "The Dialectics of Forward and Backward Integration" and 4.3. "Who Will Dominate the Electronics Complex?", pp.114-136.

[20] For details see Ernst 1983a, chapter 5.

[21] United Nations Centre on Transnational Corporations, 1983.

[22] Semiconductor International, April, 1984. pp.56-57.

[23] For a detailed discussion see Ernst, 1983a, Ch.1.

[24] For detailed evidence see Ernst 1983a, particularly chapters 4.2. "The Dialectics of Forward and Backward Integration - Towards a New Semiconductor Industry of Corporate Giants?", and 4.3. "Who Will Dominate the Electronics Complex? Recent Moves by Major Actors".

[25] Author interview, Intel, Sant Clara, May 1984.

[26] David F. Hefler, Head, Global Sourcing Division, Arthur D. Little Inc., author interview, Cambridge, Mass., 8 May 1984.

[27] Global Electronics Information Newsletter, November 1983; Electronics Times, 14 June, 1984.

[28] Author interview, California, 24 May, 1984.

[29] Economic Consulting Services Inc. 1983.

[30] Author interview with Luc Bauer, President Telmos Inc., Sunnyvale, 21 May, 1984.

[31] Author interview, Intel, Santa Clara, May 1984.

[32] Author interview, confidential source, California, May 1984.

[33] Author interview, Intel, Santa Clara, May 1984.

[34] Posa, 1981.

[35] For details see Ernst, 1985.

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