

**The Socio-Technical Basis of the Microelectronics Revolution:  
A Global Perspective**

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## Note on Currency Conversion

1956 - 1975	1 dollar =	12.50
1976	" =	15.43
1977	" =	22.57
1978	" =	22.76
1979	" =	22.80
1980	" =	22.90
1981	" =	24.51
1982	" =	57.17
1983	" =	148.47
(July) 1984	" =	168.76
(July) 1985	" =	336.00

Exchange Rate of Mexican Peso Against  
the U.S. dollar.

Source.- B.Balassa (1983), Barclays  
Bank (1984), NAFINSA (1984),  
Comercio Exterior (July 1985).

## Chapter IV

### Indigenous Microelectronics Capability in the Third World: The Case of Mexico.

In the previous two chapters the sociotechnical nature of an indigenous microelectronics capability has been analysed, with reference to the particular case of the most advanced capitalist society, namely, the US. We have seen that in the latter country the historical characteristics, tendencies and social forces dominating the process of development of microtechnology have given rise to a specific type of IMC ultimately related to the model of development dominated by capital accumulation and profits at a global scale. We have also seen that the systemic and pervasive nature of microtechnology has the potential for transforming the entire technical base of society and that this process is currently proceeding under the spur of the current crisis of the world capitalist system and the ensuing need to restructure the industrial and technological base of society.

For the Third World, the complexity, magnitude and global scale of the above developments portend momentous implications since they threaten to create a socio-technological whirlwind which will drag all underdeveloped countries into it, thus deeply affecting their possibilities of breaking with the technological and economic dependence which so patently inhibit their process of societal development. In these circumstances, and assuming that microtechnology will effectively diffuse into all countries to a greater or lesser extent and in some form or another, it becomes plain that the possession of an IMC constitutes the inescapable condition to harness and endogenize the development of microtechnology for the specific development purposes of a given country. As we have seen, however, there is no universal form of IMC and, ultimately, it will be the path of development of every country which will determine the kind of IMC being aimed at within the parameter established by the interaction between the degree of development of the scientific and technological base and, particularly, of the microtechnological resource-base of society, on one hand, and the overriding interests of the social forces making up the local social constituency of microtechnology, on the other. Indeed, given that in relation to Third World countries, the main problem is the absence of an IMC and hence,

the challenge of its build up, it will be the latter social factor which will first determine whether or not such possibility is viable or consistent with stated development goals.

On the whole, the above is basically the problem we shall be looking at in the present chapter, focusing on the particular case of Mexico, one of the most important and industrialized countries of the Third World and hence, one where it is possible to think of a great deal of possibilities of achieving an IMC for development purposes. The analysis will be divided in three parts. First, we shall look at the general socioeconomic characteristics of Mexico, the stated goals of its development process and the social forces actually controlling and directing it. This will help us to identify the general framework ultimately determining the kind of IMC Mexico is aiming at and the major social forces most likely to dominate its social constituency. Second, we shall look at the specific characteristics of the Mexican R & D system to see the state of development of its scientific-technological resource base without which the country can hardly expect to achieve self-determination in any science-based technology such as microelectronics. Thirdly, we shall look at the microtechnological resource-base of the country and the dominant social constituents in its development to determine whether or not Mexico is on the right path to achieve an IMC in accordance with its own development goals.

#### **4.1. The General Socio-Economic Framework of Mexico's Development Process: Goals and Social Forces**

The ultimate goals of the development process of the Mexican nation are explicitly put forward in the National Development Plan, 1983-1988.

"The essential priority of the National Project and of the political decisions is man, hence it is the responsibility of the State to ensure that he enjoys all the guarantees consecrated in the Constitution and the full exercise of his liberties...The principles of the National Project are permanent: nationalism, freedom and justice, democracy as a system of life, mixed economy, guidance by the State, economic freedoms, individual freedoms and social rights and internationalism... Promotion of a more Egalitarian Society is one of the original demands raised in the struggle of various generations of Mexicans and consecrated in the Magna Carta by the Constituents of 1917. Man, that is, every single Mexican in equality of circumstances, is the ultimate end of the National Project and of the strategy of integral development with which the present government intends to advance...In an Egalitarian Society individual and social rights conjugate, thus humanizing the relationship between persons, groups and society as a



whole. By consecrating the social rights, our Constitution intends to make equal the opportunities for all the Mexicans and, for this reason, it generalizes the individual guarantees and introduces the social guarantees by establishing: the right to justice, as a recognition of equality before the law; the right to work, as an essential requisite for dignity and well-being; the right to education, which enables the harmonious development of all the faculties of the human being and which, undoubtedly, includes the right to instruction; the right to health...the right of all families to enjoy a decent dwelling...and the right to political participation so that equal opportunities may be offered to all". (Poder Ejecutivo Federal,1983,pp.13,15,16-17).

In pursuit of these goals the Mexican Development Plan gives an instrumental role to the following factors: economic growth, national independence and state guidance of national affairs. Thus,

"The National Project and the content of the mandate received by the President of the Republic must translate themselves in a strategy of development that reaffirms the country's sovereignty and independence, on the basis of a greater internal strength... [This and the decision A.M.]...to promote solidarity by means of the political, social and cultural democracy of the Nation, confers upon economic growth the character of an indispensable instrument... [In this process A.M.]...The State is not a mere arbiter of social interests, it is the director of the economic process; it represents the Nation; it is responsible for asserting the viability of the National Project". (ibid.,pp.14-15).

Indeed, as we shall see, the Mexican state has undoubtedly played a major role in the country's development process, particularly, since the 1930s, in the process of industrialization which has constituted the fundamental lever of the model of economic growth and development. However, Mexico is far from being a centralized planned economy. Instead, it is what the government itself calls a "mixed market economy", i.e., an economy where private property of the means of production coexists and interacts with an important public and social sector. In practice, we shall see that the Mexican economy is a fundamentally capitalist economy deeply inserted in the workings of the world capitalist system and plainly dominated by the dynamics of profit-making capital accumulation. This means, therefore, that all the goals stated above are in fact advocated as achievable within the framework of a fundamentally capitalist process of development. That is to say, that the process of capital accumulation with the participation of, and regulation by, the state is the essential mechanism which will lead the Mexican society towards well-being, equality, justice and national economic independence. In practice, however, capital accumulation and hence, expansion and diversification of the economy, i.e., capitalist development, may well take place with little concern for goals that put man at the center of the development process. Indeed, quite often this is the case, and, as we shall see,

Mexico's capitalism, despite all the rhetoric, is quite far from fulfilling its advocated ultimate goals.

#### 4.1.1. Capitalist Development in Mexico: Overview of Economic Changes and Advances

In more than half a century, general socioeconomic changes have projected Mexico's presence high up in the world community of nations on many accounts. Table 4.1 shows Mexico ranking among the first 20 nations in 22 out of thirty major socioeconomic indicators. Only at the beginning of the 1930s, as the Mexican president recently recalled, "we were 14 million Mexicans, still dispersed and isolated in our vast territory. The economy was weak and predominantly agrarian and mining-based, with wide segments dominated by foreign capital. Society was strongly polarized and segregated with a weak and incipient middle class. Our levels of education, health and nutrition, clothing and housing, were at elementary stages of underdevelopment" (de la Madrid, 1985, p.846).

Nowadays the situation is different. Mexico has a population about 5.5 times that of 1930 and there have been socioeconomic transformations and advances of quite significant magnitude. In particular, the Mexican economy has undergone a quantitative and qualitative transformation. To quote the Mexican president again,

"The Mexican economy has also been radically modified. It is larger, diversified and dynamic; it has multiplied 16 times in the last 60 years and occupies the fourteenth place at a world level, in an international community of 159 countries. We have developed an important industrial sector, which currently is the sector that contributes in greatest proportion and most dynamically to the growth of national production. Agriculture continues to be a fundamental sector of the economy. Its production has increased by a factor of six during the last 50 years. We continue to be a country with an important mining sector; we are the world's fourth oil producer and now excel in fishing. Communications and transport have been multiplied several times. Commerce and services are constantly growing". (ibid, pp.846-847).

Tables 4.2 to 4.10 provide a statistical picture of the Mexican economy with emphasis on industrial indicators. As we can see from tables 4.2 and 4.3, Mexico's gross domestic product (GDP) has grown in real terms for most of the post World War II period, until 1982, the year when the internal contradictions of the Mexican economy reached their most critical moment under the pressure

Category	World Ranking
Territory(1980)	13
Population (1979)	11
Largest City (Mexico City) (1978)	2
Population Growth Rate (1970-75)	9
Life Expectancy (1975)	44
Gross Domestic Product (1970-78)	14
Per capita GDP (1970-78)	37
No. of Tractors (1977)	24
Cereal Producer (1978)	23
Livestock (1978)	9
Fish Production (1977)	23
Oil Reserves (1979)	7
Oil Production (1979)	12
Oil Refining Capacity	13
Electricity (1977)	20
Energy Consumption (1976)	20
Volume of Railway Services (1977)	13
Motor Vehicles in Circulation (1977)	12
No. of Telephones in Use	15
Steel Consumption (1977)	18
Cement Production (1977)	15
Fertilizers Consumption (1977-78)	20
Volume of Foreign Trade (1977)	45
International Tourism (1977)	20
No. of Medical Doctors in Service (1974)	17
Hospital Services (1974)	33
Teachers in Service (1976)	10
School Population (1976)	8
Book Production (1976)	29
No. of TVs and Radios (1976)	11

**Table 4.1.- Mexico's Ranking in the World  
in Various Categories.**

**Source.- NAFINSA (1981).**

Category	1978	1979	1980	1981	1982	1983	1984
Gross Domestic Product (GDP) (million 1970-pesos)	711,982	777,165	841,854	908,765	905,859	856,175	n.a.
GDP (million 1970-dollars)	80,091	87,459	94,803	102,338	101,783	96,416	99,791
Population (millions)	65.7	67.5	69.4	71.3	73.2	75.1	77.0
Population Growth Rate (%)		2.74	2.81	2.74	2.66	2.6	2.53
Per capita GDP (1970-dollar)	1,219	1,296	1,366	1,435	1,390	1,284	1,296
External Debt (ED) (million dollars)	53,900	59,700	50,700	74,900	88,300	92,100	95,900
ED as percentage of GDP <sup>(1)</sup>	25.5	22.1	18.4	23.6	61.4	n.a.	n.a.
Inflation (%)	17.5	18.2	26.3	27.9	58.9	101.9	65.4
Goods and Services Trade Balance (million dollars)	-593	-1,575	-2,225	-4,685	-5,584	13,952	13,808
Urban Unemployment (%)	6.9	5.7	4.5	4.2	4.1	6.9	6.3

Table 4.2.- Mexico: Evolution of Various Economic Indicators, 1978-1984.

Source.- NAFINSA (1984), SPP/INEGI (1984), CEPAL (1983,1985), E. Iglesias (1983,1985).

(1) Based on millions of current pesos. In 1970, the external debt was only 11.9 % of the country's GDP and 16.4 % in 1975.

Year	Population Structure (%)		Period	Growth Rates (%)		
	Urban (1)	Rural		Total Population	Real GDP	Real per capita GDP
1940	21.87	78.13	1950-60	3.1	5.7	2.5
1955	28.90	71.10	1960-70	3.4	7.1	3.6
1960	39.30	60.70	1970-80	3.2	7.0	3.75
1970	48.60	51.40	1980-81	2.74	7.9	5.1
1975	54.40	45.60	1981-82	2.66	-0.5	-3.1
1980	60.20	39.80	1982-83	2.6	-5.3	-7.6

**Table 4.3.- Mexico: Postwar Evolution of Urban and Rural Population and Growth Rates of Total Population, Real GDP, and Real per capita GDP.**

**Source.-** SPP/INEGI (1983), NAFINSA (1981,1984), CEPAL (1985), E. Iglesias (1983,1985).

(1) Urban Population is defined as that inhabiting places with 10,000 or more inhabitants.

Sector (1)	Structure (%) (3)								Growth Rates (%)		
	1950 (2)	1970	1975	1980	1981	1982	1970-75	1975-82	1970-82		
Agriculture, Forestry and Fishing	19.2	12.2	10.3	9.0	8.8	8.8	3.4	5.1	4.3		
Industry	26.5	32.7	33.5	35.2	35.4	35.0	7.1	6.4	6.7		
Services	55.0	56.4	57.4	57.1	57.1	57.6	6.7	5.9	6.3		

**Table 4.4.- Percentage Structure of Mexican GDP by Economic Sectors and Growth Rates, 1970-1982.**

**Source.-** SPP/INEGI (1983b), NAFINSA (1984).

(1) Based on millions of constant 1970-pesos.

(2) Based on millions of constant 1960-pesos.

(3) Yearly figures add up over 100 % because they contain imputed banking services.

Category	1970 <sup>(1)</sup>	1975	1980	1981	1982
Global GDP (millions constant 1970-pesos)	444,271	609,976	841,854	908,765	903,839
Industrial GDP (millions constant 1970-pesos)	145,070	204,057	296,046	321,418	313,163
Manufacturing GDP (millions constant 1970-pesos)	105,203	148,058	209,682	224,326	217,852
Industrial GDP as Percentage of Global GDP (%)	32.7	33.5	35.2	35.4	35.0
Manufacturing GDP as Percentage of Global GDP (%)	23.7	24.3	24.9	24.7	24.1
Manufacturing GDP as Percentage of Industrial GDP (%)	72.5	72.6	70.8	69.8	69.6
Growth Rate of Manufacturing GDP (%)	7.1(1970-75)	5.8(1975-82)	6.3(1970-82)		

**Table 4.5.- Mexico: Volumes of Global, Industrial and Manufacturing GDPs. Shares of Industrial and Manufacturing GDPs in Global GDP and Share of Manufacturing GDP in Industrial GDP. Growth Rate of Manufacturing GDP, 1970-1982.**

**Source.-** NAFINSA (1984) and calculations for the different shares.

(1) All data based on millions of constant 1970-pesos.

Year	Total (Thousands)	Primary Sector (%)	Industry (%)	(Manufacturing) (%)	Services (%)
1910	5,264	68.3	17.2	(12.8)	14.5
1930	5,151	70.4	15.0	(11.9)	14.6
1940	5,858	65.4	15.5	(11.4)	19.1
1950	8,272	58.3	15.9	(11.8)	25.7
1960	11,274	54.1	19.0	(13.8)	26.9
1970	13,343	37.5	23.1	(16.9)	39.4
1980	19,951	32.0	26.0	(18.5)	42.0
1985	23,810	28.5	27.0	(19.1)	44.5

**Table 4.6.- Economically Active Population by Sectors, 1910-1985.**

**Source.- NAFINSA (1981,1984).**



Category	1970	1972	1974	1976	1978	1980
Total Investment (millions of pesos)	82,300	97,800	173,600	267,600	476,100	1,049,224
Total Investment as percentage of GDP	18.5	17.3	19.3	19.5	20.4	24.5
Public Investment as percentage of Total Investment	35.5	34.0	37.3	40.6	45.7	46.3
Private Investment as percentage of Total Investment	64.5	66.0	62.7	59.4	54.3	53.7
Direct Foreign Invest- ment as percentage of Total Investment	2.8	2.0	2.1	1.2	1.8	2.3

**Table 4.7.- Participation of Public and Private Investment in Mexico's Total Investment, 1970-1980.**

**Source.-** SPP/INEGI (1983b), NAFINSA (1984).

Year	Agriculture, Forestry and Fishing		Extractive Industries		Oil and Derivatives		Manufacturing Industry	
	Import	Export	Import	Export	Import	Export	Import	Export
1970	5.8	37.6	3.1	7.0	1.9	2.8	89.2	52.6
1972	6.2	37.9	2.0	6.6	4.3	1.3	87.5	54.2
1974	14.1	23.9	2.4	6.9	6.6	4.4	76.9	64.8
1976	6.2	31.3	1.5	5.5	5.1	16.6	87.2	46.6
1978	9.8	23.2	2.0	3.9	2.8	29.4	85.4	43.5
1980	10.9	10.2	1.4	3.2	1.6	67.3	86.1	19.3
1981	10.3	7.5	1.1	3.5	1.5	74.5	87.1	14.5

**Table 4.8 .-** Distribution of Imports and Exports of Products by Origin of Economic Activity, 1970-1981. (Percent)

**Source.-** NAFINSA (1984), SPP/INEGI (1983b).

Year	Total (million pesos)	Percentage Structure by Economic Sectors (%) (1)					U.S. Share (%)
		Agriculture Mining and Oil Industry	Manufacturing Industry	Construction, Electricity and Transport	Commerce	Financial Establis- ments	
1970	35,278	6.9	74.4	0.7	15.5	n.a.	79.4
1972	39,678	6.3	74.9	0.6	16.2	n.a.	79.9
1974	51,536	4.7	76.5	0.8	8.4	9.5	77.5
1976	50,625	4.1	78.0	0.9	7.0	9.9	71.1
1978	107,998	3.6	77.9	1.1	7.4	9.9	68.8
1980	194,139	2.8	75.0	1.7	8.7	11.6	69.0

**Table 4.9.-** Volume and Sectoral Participation and U.S. Share of Cumulative Direct Foreign Investment in Mexico, 1970-1980.

Source.- SPP/INEGI (1983b), NAFINSA (1984).

(1) Figures do not add up 100% since there are other foreign investments not accounted for by the sectors shown in the table. Also percentage figures for 1980 are based on millions of dollars.

Year	Exports	Imports	Balance
1970	60.7	61.5	54.9
1972	70.2	57.2	26.0
1974	58.0	62.2	66.0
1976	62.2	62.4	61.8
1978	71.9	60.4	23.0
1980	61.8	61.5	60.0
1981	55.2	67.6	99.1
1970-81	62.9	61.8	55.8

**Table 4.10.- Participation of the U.S. in the Mexican Balance of Trade, 1970-1981. (Percent)**

**Source.- SPP/INEGI (1983b).**

of a huge external debt and the fall in oil prices caused by the world economic recession and the consequent oil glut in the international market (1). It is not our purpose to deal with the crisis except to notice that this was the first time that the Mexican economy registered simultaneously, a negative growth in the real GDP, a rate of inflation of over 100% and an abrupt rise in the rate of unemployment (2). Tables 4.2 and 4.3 clearly depict the fall in real GDP and per capita GDP coupled with the rise in foreign debt, inflation and urban unemployment.

Until 1982, however, Mexico had enjoyed, on average, substantially high rates of growth particularly in the industrial sector (3). As it can be seen from table 4.3, real GDP grew 5.7% in the 1950s, 7.1% in the 1960s and 7.0% in the 1970s. Real per capita GDP also grew during these periods and, most significantly, important structural changes took place, mainly as a result of the strategy of industrialization pursued by successive governments (4). Table 4.4

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(1) It is not our purpose to analyse the origins of the crisis in the present work. We shall only say that it is not a sudden event but has long historical and structural roots deeply embedded in Mexico's capitalist model of development. In this respect, see the works of Cockcroft (1983) and Ayala et al (1983).

(2) In the National Development Plan of 1983, the critical situation of the Mexican economy at the end of 1982 was described as follows: "doubling of the rate of unemployment and increasing deterioration of the labour market; contraction of manufacturing and agricultural production and a strong fall in construction activity; levels of inflation of 100% and acceleration of the latter to an unwonted speed; contraction of the national income and a strong reduction in the availability of resources to finance investment; public deficit of over 15 percent of the product; disproportionate relative weight of the debt service and virtual suspension of payments abroad" (Poder Ejecutivo Federal, 1983, p.35). Early in 1985, the crisis was still far from over and the government was hoping its economic measures to bring about the first increase in per capita GDP in four years (de la Madrid, 1985). Of course, Mexico was not the only Latin American country to suffer from an acute economic crisis in the early 1980s. The crisis was to a greater or lesser extent a generalized phenomenon throughout the Latin American region. See Iglesias (1983) for a description of the crisis for the region as a whole. Also Serrano (1984).

(3) Even in the worst year of the 1970s, that is 1976, the GDP still grew by 1.7% (Ayala et al, 1983).

(4) Although formally a democracy, Mexico has been effectively ruled by one party, the Partido Revolucionario Institucional (PRI) for most of the twentieth century. The party was founded in 1929 under the name of Partido Nacional Revolucionario (PNR) to give an institutional set up to the political forces emerged from the revolution. "By 1933, the old parties had disappeared and the PRM [Partido de la Revolucion Mexicana A.M.], a new and very powerful mechanism to keep all the members of the "Revolutionary family' in line, was born. In 1938, with the formation of the PRI, direct membership was replaced by affiliation through a national organization belonging to any of the four functional sectors: army, labor, the peasantry, and the so-called "popular" or bureaucratic sector... Since 1938, the most important political struggles have taken place within the party and its organizational network. The problem of succession at any level of government -municipal, state, or national- or within the organizations that form the party was finally institutionalized" (Meyer, 1977, p.15). Today, about 56% of the population of the country

shows how the participation of industry in the global GDP increased from 26.5% to 35% between 1950 and 1982, while that of the primary sector fell from 19.2% to 8.8%. The service sector increased its participation by 2.6% in the same three decades. In terms of GDP, therefore, the industrial sector has been clearly the most dynamic of the Mexican economy -see growth rates in table 4.4- and, to the extent that its largest contributor has been the manufacturing industry, this has elevated the country to its current status of newly industrializing country (NIC) or semi-industrialized country. In effect, from table 4.5 it is possible to observe that the manufacturing GDP accounted for about one-quarter of the total GDP and around 70% of the total industrial GDP in the early-1980s. In addition, the average growth rates of manufacturing GDP have remained high for most of the postwar period: 6.1% during the 1950s, 9.1% during the 1960s (Aspra,1977) and 6.3% between 1970 and 1982 (table 4.5). Such figures are certainly among the highest in Latin America and have underpinned the rapid rise of Mexico's share in the gross manufacturing product (GMP) for the region as a whole: from 21.3% in 1950, Mexico's share of the Latin American GMP was estimated to have increased to 30.4% in 1982 (Plaetzer,1984). Mexico is now the second industrial power in Latin America (5), behind Brazil which had an estimated 37.5% share of the region's GMP in 1982. In that year, both countries together accounted for more than two-thirds of the total GMP of Latin America, a substantial increase from their combined 43.7% of 1950 when Argentina was the leader with a share of 26.6%. In per capita GMP terms, however, with a population much smaller than Brazil's 120 million, Mexico was estimated at the top of the region with a figure of \$342 dollars in 1982 (ibid.).

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belong to PRI's organizations and the control from above is such that Meyer concludes that "in Mexico... the majority of the population have no political representation" (ibid.). See also Calvert (1972) and for an analysis of the unfolding of Mexico's political system in recent years Whitehead (1981).

(5) To put Mexico's progress into perspective, one has to consider that, in 1980, the Latin American industrial sector produced 5.2% of the total world manufacturing output, an increase of 1.2% from its 1950 level of 4%. Taking into account the Third World alone, Latin America and the Caribbean accounted for approximately 54% of the manufactured GDP in 1981 - \$70,986 million out of \$131,193 for all Third World countries. Asia accounted for 36% and Africa for 10%. In terms of exports and imports of industrial goods, the performance of Latin America shows the effect of a strategy directed more towards import substitution than to participation in world-wide exports. Thus, in 1975, the subcontinent exported only 7% of its manufactured output compared with 30% for Asia and the Middle East (without Japan and Israel) and 13% for Africa. On the other hand, Latin America accounted for 7.2% of world imports of industrial goods in 1975, almost half its 13% share of 1955. (Plaetzer,1984).

Concurrently with the relative growth of the industrial and manufacturing sectors of the economy, the structure of the economically active population has altered considerably in Mexico since the Second World War. Thus, the industrial workforce increased from 15.5% in 1940 to 27% in 1985 and that engaged in the manufacturing industry increased from 11.4% to 19.1% in the same period. Table 4.6 shows the evolution of the economically active population (EAP) by sector between 1900 and 1985. Together, the industrial and service sectors had 71.5% of the EAP in 1985 while those working in the primary sector (agriculture, forestry and fishing) amounted to less than a third of the EAP. This was a complete reversal of the situation in 1930 when the EAP engaged in the primary sector amounted to 70.4% of the total. In the last 50 years, therefore, Mexico's development strategy based primarily on industrialization and urbanization has completely changed the distribution of the EAP in the country. Most economically active Mexicans now belong to the service sector (i.e., transport and communications, commerce, government and other services) which, since 1940, has more than doubled to reach a share of 44.5% in 1985.

Undoubtedly, the scale of Mexico's urban and industrial advance is impressive and explains why the country always is included among the NICs despite some differences of interpretation as to the meaning of the concept (6). All the more so as "during the 1970s, Mexico was a rapidly growing exporter of technology" (Blomstrom and Persson, 1983, p.494) with many reported cases of technology exports based on what could be considered local innovation. In effect, a study by Dahlman and Cortez (1984)

"...identified 160 technology exports transactions related to the industrial sector by 42 different exporters. These exporters include producers of final or intermediate goods, producers of capital goods, industrial engineering firms and research institutes...Most of the exports are based on the experience accumulated by these firms in assimilating, using and adapting technology to local conditions. A number, however, are based on what may be considered local innovations motivated by different scale requirements, the desire to use locally available natural resources, or the need to replicate technology which could not be purchased from abroad" (Dahlman and Cortez, pp.614-616) (7).

Moreover, the same study noted that the cumulative value of capital goods exports between 1975 and 1979 was greater than that of any other type of technology export trade. And such export performance of the capital goods sector

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(6) See note 29 in Chapter I.

(7) See also Katz and Ablin (1978a, 1978b), Lall (1980, 1983), Jenkins (1979).

was not without internal correspondence, for, as Bhaduri (1985) describes, in the late 1970s, " *the manufacturing sector as a whole* in Mexico was undergoing significant structural changes insofar as the capital goods sector maintained a faster rate of expansion compared with other manufacturing production" (Bhaduri,p.3) (8). Quantitatively, the latter sector grew at an annual rate of 8.4% during 1977-1981, while capital goods production grew at 15.5%. In fact, in 1981-1982, Mexico was the largest investor in capital goods in Latin America, raising its share of the total Latin American investment from about one-quarter in 1976 to over one-third in 1981 (Plaetzer,1984).

All in all, therefore, Mexico's development process has greatly transformed the country's economic structure, leading to an expansion and diversification of its industrial and technological base. We shall see later on, whether this process has been accompanied by successes of equal magnitude regarding the ultimate development goals advocated in the National Development Plan. For the moment, suffice it to emphasize that development in the sense of local capital accumulation through the expansion and diversification of the country's productive base, particularly the industrial base, is something that has certainly taken place in Mexico.

#### 4.1.2. Structural Characteristics and Problems of Mexico's Capitalist Development

In the present section, we shall look at the qualitative issues behind the quantitative picture of Mexico's capitalist development process. Our aim is to find out what social interests have been in control and have primarily benefited from this process and to what extent the ultimate goals of the development process have been met or are in the process of being met. From this, we expect to produce an insight into the potential social constituents of an IMC in Mexico, since it is our view that, in a symbiotic relationship to the process of development as it actually takes place, a social constituency also develops which exercises a dominant role in the direction of this process of development. Such social constituency, as we have argued before, results from the convergent interests of different social forces within the context of a given development

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(8) For an analysis of the historical development of the capital goods sector in Mexico, see Lorentzen (1984). According to this author..."The overall industrial expansion of the sixties led to the first decisive expansion of a local production of capital goods. This process was a process of import substitution, which increased the overall internal integration of production" (Lorentzen,p.iv.20).



model and material limits such as the degree of development of the technical base of society.

For our purposes, what is most relevant about the Mexican case, is that the important industrial advances seen in the previous section took place mostly as a result of a model of capital accumulation based on import substituting industrialization (ISI). In Mexico, such a model had its origins in the 1930s when, as a result of the crisis of the world capitalist system and the consequent contraction of the international markets, the country was forced to seek methods to produce internally the products previously imported from the developed countries. This was the beginning of the rupture with the primary exporter model which had predominated before and whereby the country's role in the international division of labour was basically that of producer of raw materials and agricultural products. Import substituting industrialization was greatly favored in the 1930s, particularly under the administration of Lazaro Cardenas (1934-1940), so that by the end of the decade the foundations of the industrialization model which has dominated economic development in Mexico until today were established. Even so, as Gutierrez (1981) states, "the consolidation of the process of import substitution, the break with the primary-exporter model and the firm beginning of industrialization only occur after the Second World War" (Gutierrez,p.864). It is not our intention here to deal in detail with the characteristics of the postwar ISI in Mexico (9), except to unveil the characteristics of its dominant social constituency, i.e., the social forces making up such a constituency and the inter-relations established between them within the process of capital accumulation in Mexico.

There are various aspects in the process of IMC in Mexico which are fundamental to the understanding of its social constituency. First, it is the fact that ISI is, essentially, a process of local capital accumulation although, in theory, it represented a strategy to reach the industrial levels of developed capitalist countries and, along with it, the same levels of socioeconomic well-being and independence (10). Through ISI, Mexico attempted to close the 'gap'

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(9) Various scholars have dealt with the historical issues and characteristics of the process of ISI in Mexico. See, for instance, Furtado (1970), Villarreal (1977), Aspra (1977), Gutierrez (1981), Cockcroft (1981,1983), Levi de Lopez (1980).

(10) "It was thought that the strategy of import substitution would automatically generate not only growth, but also economic development; that is to say, that it would increase employment and improve the standards of living of the masses (through income redistribution). All this would be accomplished with domestic autonomy, since inward-looking growth would permit the emergence of a national industry" (Villarreal,1977,p.71).

with the developed countries while positing the latter as the ultimate goal to be achieved. Second, it is the decisive participation of the Mexican government in directing and promoting the process of industrial capital accumulation through ISI. In this respect, in a context of prolonged political continuity and stability, the involvement of the Mexican government greatly benefited the expansion of national private capital as the interests of both clearly converged on this basis. Thirdly, it is the major importance of foreign capital, particularly US's, in Mexico's process of industrial capital accumulation, both through direct investment and loans. It was to be the role of foreign capital to contribute with the technology and the financial resources which the rapid process of capital accumulation demanded. In this respect, government and private national capital interests converged with those of foreign capital seeking to expand its own process of capital accumulation on a global scale. As we shall see, however, such convergence has been limited and contradictory, resulting in a process of local capital accumulation which is far from autonomous and self-sustaining. Let us see the specific forms in which government, national private capital and foreign capital have articulated themselves in Mexico's development process and how this process has been shaped by their convergent and contradictory interests.

#### 4.1.2.1. Relations Between the State (Government) and Private National Capital

Without profound and protracted government participation, Mexican industrialization could not possibly have reached the levels it has today. The state has actively promoted the process of local capital accumulation by creating favourable conditions for private capital both national and foreign (11) and, also, by investing heavily in the industrial sector, thus creating a public industrial sector of considerable magnitude (12).

In pursuing the above activities the overriding interests of the Mexican state have been to ensure the reproduction of the present capitalist social order and, in particular, the control and stability of the political system. In this

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(11) "The State's main goal has been to promote capital accumulation. Towards this end, it has consistently strived to create a favorable climate for private capital" (Reyna,1977,p.157).

(12) "The State...became a public entrepreneur and key element in the orientation of the economic process from the beginning. The State as economic administrator...becomes a full-fledged reality during the Cardenas administration and, more particularly, with the initiation of the industrialization process directed by the State since the Second World War. Today, there are close to 500 enterprises, some completely public and others in majority or minority partnership with the State, which employ more than a half million people" (Leal,1975,p.59).

context, the state has not sought to monopolize the process of capital accumulation in Mexico, but rather to regulate it, keeping a balance with private national capital and foreign capital in accordance with its own goals and those of the other social forces. In relation to private national capital, most authors see the interests of the state clearly fusing with those of national capital in pursuit of capital accumulation. As Weinert (1977) has put it, "...The State has always acted within a capitalist context... and has encouraged private national capital where possible. The State has viewed its role as complementary, not replacing, private capital" (Weinert,p.124) (13). The way in which the state has complemented private national capital is reflected, according to Smith (1977), on two basic guidelines for governmental economic policy which Mexican entrepreneurs and politicians seem to have tacitly agreed upon since the mid-1940s.

"One has held that the state should permit the entry of desirable foreign capital but at the same time protect national industry from excessive international competition, principally through import controls and regulation on foreign investment. The other guideline...has assigned to the state the role of controlling and, when necessary, repressing the masses -the workers, the peasant and the poor. Together, these policy orientations have furnished a reasonably coherent and workable prescription for maintaining the country's capitalist system" (Smith,1977,p.141).

A similar view is proposed by Reyna (1977), who argues,

"What is specific to Mexico is the role of the state, which has been crucial in maintaining the capitalist dynamic. The Mexican state has created a climate very favorable to private investment, not only through attractive incentives such as industrial protectionism or tax exemptions but, perhaps more important, through a very effective political infrastructure which absorbs and neutralizes demands. The corporatist structure of the PRI is one of the key elements in the success of this neutralization process" (Reyna,p.158).

In the promotion of local capital accumulation and subordination of the masses, therefore, the state and private national interests complement each other (14). In Mexico, however, this does not mean that the state and the political elite controlling it are the same as, or mere subservients of, private capital.

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(13) See also Hamilton (1975) for a historical perspective particularly related to the role of the Mexican state under Cardenas.

(14) In subordinating the masses' demands and by keeping the wages low, for instance, the state clearly contribute to the process of capital accumulation by helping to raise the rate of profit. According to Cockcroft (1983), the state's enforcement of strict labor discipline and a low wage scale has been fundamental. "From 1939 to 1946, the manufacturing worker's real wage dropped 50 percent; it did not recover its 1939 purchasing power (when it was

Indeed, as Smith (1977) and Weinert (1977) have both noted, the political and business elites are clearly distinct, with the state pursuing its own goals rather than those of private capital. In other words, "...The business elite and the State are...not as close as the coincidence of class interests and state policies would suggest" (Weinert,1977,p.126). Instead, it is primarily because their goals have coincided in the process of capital accumulation that "what has been good for the state has been good for the country's capitalists. But this coincidence is a result of governmental policy rather than the guiding motive for it" (Smith,1977,pp.147-148). A good example, in this respect, is furnished by the state control of foreign capital which while benefiting and protecting national private capital, "seems to be prompted less by a desire to favor the upper classes than by a commitment to nationalism and to the protection of its own authority from the challenge to sovereignty posed by foreign capital" (Weinert,1977,p.126). The Mexican state ,therefore, has a clear degree of autonomy in relation to private capital and this enables it to take a longer-term and broader view of the country's development process. Such autonomy of the state, however, should not be construed as total lack of influence of private national capital upon its policies. Indeed, Whitehead (1981) argues that the social leverage of private capital vis-a-vis the state has increased with the social changes accompanying industrialization. On this score, Whiting's position seems to struck the right balance.

"The conclusion about the relation between the State and national capital is not that the State is a captive of the private sector. Rather the private sector has an effective power of veto on those chief initiatives threatening its economic power. On its part, the State is committed to follow a model of capitalist development and is *relatively* autonomous from the short-term specific interests of national capital to adopt policies which in the long-term will be in the interest of national capital" (Whiting,1981,p.88).

The same primacy of the state's own interests seems also to underly its major participation in the Mexican economy through the ownership of many key industries and a substantial share of the national investment. A leading Mexican sociologist, Pablo Gonzalez Casanova, has made this crystal clear.

"Public investment is part of the state's power. It entails a capacity to generate jobs, goods and services and an ability to negotiate with other states, particularly the U.S. The state-owned companies, through the investments and outlays of the public sector, help to implement a policy of concessions and negotiations with the large private foreign and domestic companies, with smaller companies and with popular and

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particularly low because of runaway inflation) until 1968" (Cockcroft,p.154).

political organizations. The public companies function as a stabilizing force, as a means of stimulating the economy during recessions and as complement to the government's system of stimulation and control" (Gonzalez Casanova,1980,p.159).

A brief historical review of the expansion of the public sector in the Mexican economy is given by UNIDO RCSB (1983). According to this source the first public entities were created in the twenties, including Banco de Mexico (central bank) and some mining enterprises. In subsequent decades, the state sector continued to expand through expropriations and the creation of new enterprises. In the sixties, in particular, the state sector experienced a strong expansion. It enlarged its areas of activity to diverse sectors of the economy and started large projects in the iron and steel, petrochemical, electric, capital goods and fertilizer branches of activity. During the 1970s, Echeverria's administration (1970-1976) created a larger number of public enterprises than any previous government. Overall, by the late 1970s, the state had the control of all utilities while dominating basic industries and finance (Weinert,1977).

As regards investment, the role of the state has been substantial. Thus, the public sector at large contributed 43% of total investment between 1940 and 1954, 31% between 1955 and 1961, 40% between 1962 and 1970 (Gonzalez Casanova,1980) and, after a relatively low start of 35.5% in 1970, public investment grew to a high level of 46.3% by 1980. Table 4.7 shows the evolution of total investment in Mexico during the 1970s and the changes in the participation of public and private investment. As we can see, public investment grew considerably in these years, reflecting, according to Gutierrez (1981), an important alteration with regard to Mexico's pattern of development of the 1960s. In his words,

"The most important change occurring in recent years has been the endogenization, by the State, of the central variable of the model of accumulation. This is transcendental and determines a clearly defined pattern for the economic development of Mexico in the years to come. By taking over the "lever" of the development model, the State has partially displaced the private sector from this privilege. Now the durable consumer goods industry is no longer the most dynamic industry, or at least the one which indicates best the growth trends of the domestic product. During the last years, this primacy has been shared with that part of the oil industry devoted to the export of hydrocarbons" (Gutierrez,p.866).

In effect, the combination of two crucial events during the 1970s gave the Mexican government the "lever" of the country's development process. One was the crisis of the model of ISI based primarily on the growth of the durable



consumer goods industrial sector (e.g., cars, electro-domestic goods, etc.) and the other was the discovery and subsequent exploitation of enormous oil reserves in Mexico. On the first account, by the mid-1970s, it became plain that the contradictions accumulated throughout the period of import substituting industrialization had reached a critical point in terms of the balance of payment deficit and the growing foreign debt. Since the 1950s Mexico had had a persistent deficit on its current account balance and this accelerated sharply in the 1970s reaching a cumulative level of over 25 billion dollars (ibid.) (15). On the other hand, and particularly since the 1960s, the government had made the external debt a systematic mechanism to adjust the current account deficit (external sector) as well as the internal budget deficit. By the mid-1970, the total external debt of Mexico had reached about \$30 billion [Green(1983),Reynolds(1978)] (16). In addition, the economic crisis was accompanied by a social crisis threatening the stability of the whole system. In effect, ISI based primarily on the growth of the durable consumer goods sector had proven to be regressive in terms of wealth redistribution. Its reliance on the concentrated market of the high middle income groups demanding these goods had resulted in these groups concentrating the lion's share of the benefits (17). Not surprisingly, in 1968, the government had suffered a major political challenge which was forcefully suffocated resulting in the massacre at the Plaza of Three Cultures (Tlatelolco) on the eve of the Olympics Games the same year (18).

Fortunately for the state, enormous oil reserves were found in Mexico, which brought about a substantial increase in the value of the country's exports

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(15) The deficit was intrinsic to the process of ISI and the rapid growth of the Mexican economy. As Reynolds (1978) put it, "Mexico was caught in a typical dilemma. Its rapid growth required the importation of raw materials and intermediate goods if rising internal demand were not to place serious pressures on the price level. Exports were unable to grow at a pace adequate to satisfy import requirements, partly because the new industrial capacity was not yet sufficiently competitive to permit rapid growth of manufactured exports, while growing domestic needs and a slowdown in agricultural development were reducing the export potential from that sector" (Reynolds,p.1977). See also Aspra (1977), Villarreal (1977).

(16) Since then the foreign debt has more than trebled (see table 4.1) and in 1982 Mexico was unable to meet its service and the country was plunged in the worst financial-economic crisis of the post- revolutionary era. For details about the evolution and characteristics of the external debt problem in Mexico, see Green (1981,1982,1983), Beltran del Rio and Klein (1984), Assereta (1984).

(17) Later we shall deal with the social issues in greater detail.

(18) "Conservative estimates put the number of dead at 49 and wounded at 500, but most observers estimated 500 dead, 2,500 wounded, and 1,500 -mostly students- arrested...Mexico's boasted political "stability" had come to a bloody and tragic end; a new era of crisis was

as oil production increased rapidly throughout the seventies, reaching an annual growth rate of 16% between 1970 and 1982 (Mendoza,1984) (19). This translated itself into a sizeable increase in foreign exchange for the country and, particularly, for the state, given that the oil industry is under its complete control through PEMEX (Petróleos Mexicanos), the state-owned company established in 1938 after the expropriation of foreign petroleum companies. Thus in 1980, the export of approximately 900,000 barrels a day meant for Mexico between \$10 and \$12 million a day, and by 1983, it was expected that 2 million barrels a day would earn Mexico \$32 million, or \$11.5 billion a year at 1980 prices (Villarreal and Villarreal,1981). It was this new source of capital accumulation coupled to the crisis of the pattern of industrialization based on durable consumer goods that gave the state the "lever" of the new oil-based model of accumulation.

As we said earlier, it is not our concern to discuss here the unfolding of the 1981-1982 Mexican crisis which took place within the new oil-based model of capital accumulation and which responded partially to the fall in oil prices in the world market (20). Suffice it to indicate that one major economic trend has been the so-called "petrolization" of the Mexican economy with the result that, as Cockcroft (1983) put it, "...Once more in its history Mexico is a mono-

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beginning" (Cockcroft,1983,p.241).

(19) "A decade ago Mexico was a net oil importer with reported production of 311,000 barrels a day and holdings of 5.6 billion barrels. In his September 1, 1980, State of the Nation Address, President Lopez Portillo proclaimed that daily output exceeded 2.3 million barrels a day, nearly 1 million of which was for exports. On the basis of current yields, Mexico claims fifth place (after the Soviet Union, Saudi Arabia, the United States, and Iraq) among the world's oil producers" (Grayson,1981,p.146). On the basis of total proven reserves which reached 72.5 billion barrels in 1984, Mexico was fourth in the world league behind the Soviet Union, Saudi Arabia and Iran (Mendoza,1984). In addition, it is estimated that the potential reserves of the country are approximately 250 billion barrels.

(20) Interestingly enough and contrary to expectations that oil would help Mexico to reduce her dependence on foreign capital and even to eliminate the \$30 billion debt it had in 1980, what happened was a huge increase in the external debt as investments in imports soared with the rapid expansion in oil capacity and industrial capacity in general. "Most new investments by PEMEX are financed by foreign loans. In recent years, PEMEX's income has been half its expenditures, leading to its mid-1982 debt of \$25 billion (or one-third of the nation's foreign debt, another 15 percent of which is owed by the state electricity complex CFE). PEMEX export earnings do not suffice to meet the service payments on Mexico's foreign debt, as PEMEX expansion fuels the vicious circle of technology imports/debt already described" (Cockcroft,1983,p.262). On the other hand, since 1981, the oil prices have never recovered forcing Mexico to cut the price of its own oil with huge losses in foreign exchange. Only recently, in February 1986, in the lapse of two weeks Mexico reduced its oil price by an average of \$8.68 a barrel, the sharpest cut ever. Averaged over a year, it means an approximate loss of \$4.5 billion in foreign exchange for Mexico as nearly, or nearly 40% of this year projected interest bill on the country's \$97 billion foreign debt" (*Financial Times*, 3 February 1986,p.1 and *Financial Times*, 17 February 1986,p.2)

exporter, as oil accounts for 75 percent of its exports earnings" (Cockcroft,p.262). Table 4.8 shows the rise of oil exports during the 1970s and the rapid fall in the relative share of other sectors, particularly, manufacturing which accounted for more than half the exports in the first half of the 1970s. For the moment, what is of special relevance to us is the fact that the Mexican state has become, even more than before, an inseparable and major constituent of Mexico's development process. The relative weight of its policies and investments, therefore, is bound to deeply influence the socioeconomic shape of the country and hence, of the electronics industry too.



#### 4.1.2.2. Relations Between the State, National Private Capital and Foreign Capital in Mexico: The Rise and Workings of the Social Constituency of Mexico's Postwar Industrialization

Along with government and national private capital, foreign capital is also an important social constituent of Mexico's postwar industrial development process. It has been so since the 1950s and, particularly since 1955 when "...Mexican planners...deliberately encouraged foreign investment and designed policies to attract foreign capital into new or undercapitalized areas of industry" (Weinert,1977,p.109). Certainly, foreign capital had been present in Mexico before the 1950s (21), but since the second decade of the present century, a combination of historical circumstances had meant a relative reduction of its presence in the Mexican economy at the same time that national capital, both state and private capital, experienced considerable expansion. The Mexican Revolution of the 1910s, the Great Depression of the 1930s, the Second World War and also later the Korean War, were all major events that favoured the accumulation of national capital while curtailing the activities of foreign capital (22). For instance, local manufacturing of light consumer goods became a dominant aspect of Mexico's economic development only after the Depression finally brought about the collapse of the primary exporter model. The Second World War further strengthened the local manufacturing sector (23) as the reduction in foreign supply of manufactured products *de facto* protected the growth of the infant Mexican industry. In addition, the strategy of the state

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(21) For instance, until the Revolution the mining sector -the most important export sector- was strongly dominated by foreign capital. The expansion of US capital had been particularly swift. Thus, from 1870 to 1912, Mexico had attracted more direct foreign investment from this country than any other nation in the world. In 1944, Britain and the US dominated direct foreign investment in Mexico with \$635 and \$542 million respectively (Evans and Gereffi,1980).

(22) "Between the Mexican Revolution and the start of the depression, there was a complete suspension in the growth of foreign investment in Mexico...After 1912 the only important growth of U.S.'s direct foreign investment took place in the petroleum sector. Even after 1929, when stability had been restored, the growth of direct foreign investment was slow. In fact, in absolute terms, U.S.'s investment fell during the depression and it did not recover the 1914 level until 1950" (Evans and Gereffi,1980,p.20).

(23) "The outbreak of World War II sufficiently distracted the major imperialist powers from attending to Mexico's internal affairs to permit Mexico to undertake the first steps of its industrialization program on its own. With its northern neighbor unable to export the usual quantity of manufactured goods, Mexico increased protective tariffs for its manufacturers and engaged in intensive import substitution; industrial production jumped 35 percent. The United States purchased copious amounts of silver to help finance its war production, as well as other minerals and varied foodstuffs. Mexico's exports doubled during the war. The United States also advanced large credits for Mexico's industrialization program, and a number of private investors, fleeing U.S. wartime price regulations and high

became one of industrialization via import substitution so that conscious protection and incentives strongly stimulated the nascent industries. Fundamental to it all was the existence of highly favourable financial circumstances for the country as the demand for Mexican exports increased greatly with the Second World War. By the early 1950, the Korean War increased even further the prices of Mexican exports, thus giving the national process of industrial capital accumulation an extended lease [Evans and Gereffi(1980),Villarreal(1977),Furtado(1970)]. By this this time, it appeared as if Mexico was on its way to become an industrial nation, thus breaking with its deep economic dependence of the past. The same events which, as we saw in Chapter III, had galvanized the social complex in the US (i.e., the Second World War and the Korean War), had also help the development of industrialization in Mexico and hence, the strengthening of the national social constituents of the process of local capital accumulation, namely, the state and private national capital.

By the 1950s, however, the bonanza of the international economic conditions for Mexico had come to a close with the end of the Korean war. The demand for Mexico's exports fell sharply after the Korean War and the country suffered a severe recession leading to a 45% devaluation of the peso in 1954 (24). In the face of the new circumstances, the government decided to deepen the process of ISI to include durable consumer goods, specially cars, and to try to promote local manufacturing of intermediate and capital goods. Such step, however, demanded investments which were much more capital- and technological-intensive than those associated to the industrial path Mexico had run thus far. In particular, Mexico's technological capabilities were not up to the standards required by the new phase of development, so that in an effort to accelerate the process, foreign capital investment was seen as the solution. For the US capital, whose postwar transnational expansion we have discussed in Chapter III, this was just what it wanted (25). Foreign capital began to pour into the Mexican industry and, for the first time, it went primarily into the

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taxes, invested in Mexico as well" (Cockcroft,1983,p.151).

(24) The Mexican peso fell from a value of 8.65 per dollar in 1953 to 12.50 per dollar in 1954 (NAFINSA,1981).

(25) "...toward 1940 it appeared that the Mexican State...had established the basis for capitalistic development, with considerable autonomy vis-a-vis the imperialistic system. Nevertheless, by the end of the Second World War, it was evident that the new standards for the international reproduction of capital were capable of influencing, at an ever increasing rate, the State organizations of dependent countries, no matter how nationalistic they were" (Leal,1975,p.61).

Mexican manufacturing sector (26), where it sought not only gain possession of existing concerns but also to benefit from the protectionism and incentives afforded by government policies (27). As a result, as one commentator has described, "...Between 1940 and 1970 foreign investment in manufacturing was multiplied 65 times, increasing from 7 percent of all foreign investment to 74 percent" (Gonzalez Casanova,1980,p.160) (28). Table 4.9 shows the share of total foreign investment accounted by different sectors of the Mexican economy during the period 1970-1980. Clearly, the manufacturing sector has remained the most important for foreign capital, with a share of 75% in 1980. Financial establishments and Commerce were coming far behind with a combined share of about 20%. In addition, table 4.9 shows that US capital has been by far the largest investor in the Mexican economy; its share of total foreign investment was about 80% in 1970 although it fell to 69% in 1980. As we shall presently see, this is only one of the several indexes describing the dependence of the Mexican economy upon that of the US.

The impact of the rapid multiplication of direct foreign investment in Mexico's manufacturing sector has been enormous. On the positive side, as Weinert (1981) argues, along with other factors, "...Through the 1950s and 1960s foreign investment...sparked rapid growth of the Mexican economy...Mexico put together practically twenty consecutive years of growth in the 5-8 percent range. Few, if any countries can rival such a healthy growth rate over such a long period" (Weinert,p.116). On the other hand, in the words of the same

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(26) "The period following the 1954 devaluation saw a large number of U.S. TNCs setting up manufacturing affiliates in Mexico. A study of 294 such affiliates operating in the early 1970s found that more than three-quarters of them had been established since 1955" (Jenkins,1979,p.25). Of course, one has to keep in mind that "...By the 1940s, the state had forced foreign capital out of such basic sectors of the economy as utilities, oil, banking, steel, communications and railroads. This process was extended in the 1950s with the nationalization of the telephone company and a remaining electric utility company" (Weinert,1977,p.113).

(27) For instance, imports of machinery and equipment were subsidized while quantitative controls were imposed upon imports of manufactured goods. Tax discounts were also used as incentives [Jenkins(1979), Evans and Gereffi(1980)]. According to Cockcroft (1983), US capitalists increased their investments immediately after the war and "began purchasing many of Mexico's new industries. U.S. direct investment in Mexico started to rise sharply in 1946, doubled in the 1950s, tripled in the 1960s and quadrupled in the 1970s" (Cockcroft,p.151).

(28) It is interesting to note that the postwar change of foreign capital investment into the manufacturing sector did not repeat itself throughout Latin America. "Since production outlay was geared towards internal markets, the countries with a high demand were favoured, namely, Argentina, Brazil, and Mexico" (Plaetzer,1984,p.26). In 1967, these three countries accounted for 48.1% of total direct foreign investment in Latin America and for 81.1% of investment in the manufacturing sector. In 1976, the figures were 59% and 79% respectively (ibid).

commentator,

"In deciding to attract foreign investment, Mexican planners committed themselves to a development strategy that rested on what foreign capital had to offer and in return was obliged to create and maintain conditions that would continue to attract foreign investment...[This A.M.]...required a certain constellation of policies. These policies were built around rapid industrial growth, import substitution (particularly of consumer goods), capital intensive production, the use of modern sophisticated technology, and a production structure oriented to high income consumers" (ibid.)

Not that foreign capital imposed this development orientation. Rather it was the internal forces, the state and private capital, which saw in this model and, consequently, in foreign capital, the solution to the accumulation problem associated with the deeper and more complex stages of industrialization. In other words, in the implementation of this model what actually took place was a convergence of interests and hence, the crystallization of a powerful constituency of social forces involving the state, national private capital and foreign capital, which came to shape the postwar process of industrial development in Mexico. In Evans and Gereffi's view,

"The local elites interested in development had found some common ground with the transnationals interested in global expansion. Local manufacturing increased, imports as percentage of total consumption decreased, direct foreign investment diversified and local manufacturing became more and more the property of foreigners...The vertical ISI created the foundations for the "triple alliance" of the State, multinational capital and local capital" (Evans and Gereffi, 1980, p.26) (29).

In Mexico, therefore, the galvanization of the social constituency of industrialization ("the triple alliance") was primarily the result of economic pressures and convergence of interests. The Mexican constituents urgently needed to revitalize and deepen the process of local industrial capital accumulation under the more difficult post-Korean War international economic conditions. In turn, foreign capital, mostly US foreign capital, was seeking for investment outlets abroad, driven as much by the opportunities arising from its almost complete hegemony within the world capitalist system as by the relatively slow growth of the market at home (see Chapter III). Thus, unlike the formation of the developed countries' social constituencies we saw in the previous chapter, ultimately, the galvanization of the Mexican constituency did not occur around a clearly identifiable "national objective", although, on the surface, it could appear

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(29) Whiting (1981) calls the alliance between national capital, multinationals and the state

so as the constituents converged around the Mexican process of industrialization. The key factor, however, is that the interests of foreign US capital, or of any foreign capital for that matter, in the latter process has never been as a goal but merely as a means to further its own process of capital accumulation on a global scale. This becomes clear as soon as we consider that foreign US capital is nothing but US corporate capital operating transnationally. In other words, since the main form of direct foreign investment in Mexico has been through corporate capital's own global organic expression: the transnational corporation (TNC) (30), it is plain that such investments are merely carrying onto the international arena the process of capital accumulation based on profit-making activity which constitute corporate's capital overriding goal. In this respect, only to the extent that there is a coincidence between the latter goal and Mexico's industrial advance, one could argue that transnational capital has been an effective part of this advance. However, and for the same reason, it is possible to realize that foreign capital not only will tend to control and shape this process but, in accordance with its own interests, will push it forward only up to the limit where it does not contradict the convenience of its own process of capital accumulation.

The social constituency of Mexico's postwar industrialization, therefore, is a highly contradictory ensemble of social forces. In it, not only the constituent forces need each other for the realization of an accumulation process in which they all have convergent interests, but, simultaneously, they strive to control and influence this process towards their own goals by playing on each other's relative strength and weaknesses. In practice, it will be this interplay of interests, weaknesses and strength that will determine the relative weight of the diverse social constituents and, ultimately, the shape of the industrialization process itself under given historical circumstances.

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as the "*non sancta* trinity".

(30) "TNCs are corporations that have their base in one country but draw much of their income, raw materials, and operating capital from several other countries, through ownership of foreign subsidiaries, joint ventures with foreign governments or investors, and a host of other means. The compelling force behind the rise of TNCs is the need for corporations to grow and maintain their profitability, as well as to gain control over as much of the world's resources and capital as possible. The TNC, a logical outgrowth of monopoly capital that has outgrown nations, constitutes the economic heart of modern imperialism" (Cockcroft, 1983, pp. 333-334, note 15). In Mexico, "...Some 85 percent of all foreign companies were owned or controlled by multinational firms in 1979; in 1978 of 4359 foreign companies 79 percent were North American" (Gonzalez Casanova, 1980, p. 160).



Thus, if we assume that none of the constituents wishes to jeopardize the participation of the others in the process of capital accumulation, we find that within the limits set by this general objective, in Mexico, the state will tend to make use of its legal and economic machinery of incentives, regulations and investments in order to safeguard and further its overriding interests. For the most part, Mexican private capital will be a beneficiary of the actions of the state and it will tend to use its own resources with little concern for factors other than the profitable opportunities arising from the market and from its relations with the state and transnational capital. On its turn, transnational capital, with its much broader interests than Mexico's industrial process, will make use of its capital-intensive investments and, above all, its technological strength to take advantage of the opportunities in Mexico while satisfying the needs of its own global process of accumulation. The latter means that technology and hence, the degree of Mexico's technological capabilities, becomes a key factor in the interaction between the transnational corporations and national capital as represented by both state and private capital. In this respect, and as a general rule, it can be said that the greater the technological strength of TNCs vis-a-vis host nations in a given industrial sector, the greater the possibility for these companies to exercise control over the process of accumulation and, consequently, the greater their relative weight within the social constituency of that particular industrial sector. From here and given that, in practice, Mexico's technological capabilities will tend to vary greatly for different industrial sectors (31), we can realize that there can hardly be a uniform pattern of interrelations between the transnational and the national social constituents, but that, in fact, their relative weights will tend to differ across the entire industrial spectrum of the productive sphere. Of course, it is not technology alone that will determine the actual pattern of interrelations between social constituents. For instance, the state's regulatory actions and TNCs' global interests will also play a major role. The former because, among other things, complete industrial sectors may be totally or partially reserved for national capital; the latter because it may simply not suit TNCs' global interests to seek heavy investment in one particular industry or one particular country for that matter. Leaving aside these cases, however, it seems plain that, wherever transnational and national capital have become willing social constituents of Mexico's industrial process, it

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(31) We have already seen that in some areas Mexico has even become an exporter of technology. This is particularly the case in the fields of construction, petroleum, geothermia and also in steel, paper textiles and some chemicals (Dahlman and Cortez). But as we shall see in the case of the electronics industry, Mexico's capabilities are relatively undeveloped.

will be the technological variable which will have largely determined the relative weight of these social forces within the social constituency as a whole.

In effect, if one look at the pattern of postwar investments of transnational capital in Mexico, it is possible to observe that not only US capital has been the dominant force (see table 4.8), but also that those investments have concentrated primarily in the most dynamic sectors of the manufacturing industry where the relative weakness of the country's technological capabilities make it easier for foreign capital to exercise control. Thus, according to Ramirez and Galicia (1972), "...it is evident that foreign capital's strategy in Mexico has as its fundamental objective the control of the industrial sector, and, within this sector, the control of those sectors which are the most dynamic and advanced in technological terms" (Ramirez and Galicia,p.114). Hence, as Weinert (1981) has corroborated,

"Within the industrial sectors, foreign investment has predictably flowed to newer industrial activities, where new technology and product innovation are required. Consequently, foreign investment tends to be most prominent in the fastest growing and more profitable sectors of the industrial sector" (Weinert,p.117).

Of course, the process above could not have happened without the participation of the government, who, as we know, actively promoted such investments as a way of deepening the process of ISI. Through incentives such as favourable conditions for the importation of capital goods and by protecting those existing industries where the internal market was already adequately supplied, the state actually created the right conditions for foreign capital to flow towards the new sectors of manufacturing (Jenkins,1979). Thus those industries which became the growth poles of Mexico's postwar process of ISI (i.e., chemical products, transport equipment, electrical and non-electrical machinery and, to a lesser extent, food processing) became the focus for most of the direct foreign investment. In 1970, for instance, it was found that two-thirds of the US's direct total investment in Mexico was actually concentrated in these industries (Evans and Gereffi,1981) (32). Furthermore, in various cases foreign investors also contributed with high percentages of total investments: 67% in chemical products, 79% in electrical machinery, 84% in rubber and so on (Gonzalez Casanova,1980). Such high proportion of US's direct foreign investment, which, incidently, has been heavily financed from internal financial sources (33), has given transnational capital a controlling role in many key

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(32) Wionczek (1972) has described that from a total of 315 US firms established in the Mexican manufacturing sector between 1946 and 1967, 70% of them concentrated their



sectors of the Mexican industry. In Cockcroft's words,

"By 1970, U.S.-based transnational corporations...had come to obtain the following percentages of control of key sectors of the economy: automotive, 57 percent; petroleum products and coke, 49 percent; paper and cellulose, 33 percent; rubber, 76 percent; mining and metallurgy, 53.6 percent; copper and aluminium, 72.2 percent; tobacco, 100 percent; industrial chemicals, 50 percent; food and beverages, 46.8 percent; chemicals and pharmaceuticals, 86.4 percent; electrical machinery, 50 percent; non-electrical, 52 percent; transportation equipment, 64 percent; computers and office equipment, 88 percent; commerce, 53.4 percent; construction materials, 38.9 percent" (Cockcroft,1983,p.158).

In addition, for the Mexican industry as a whole, a major study on TNCs found that by 1970 foreign firms (34) accounted for 35% of the total production and represented 45% of the capital stock of the 290 largest industrial concerns. Also, it was found that 55% of Mexico's industrial production was generated in sectors where at least two in four of the largest concerns belonged to TNCs. The latter figure increased to 79% when one or more TNCs concerns were considered (Fajnzylber,1975).

It is this degree of control achieved by foreign capital which has led some commentators to see a growing denationalization of the Mexican industry (Evans and Gereffi,1981). The more so, as the historical trends have shown that in fact transnational corporations have been growing with greater rapidity than private national enterprises. In effect, between 1962 and 1970, TNCs grew at an average annual rate of 17.4%, while national firms grew at a rate of 11% (ibid.). This trend was compounded by the fact that those industrial sectors where TNCs predominate have also expanded more rapidly than other sectors. Between 1960 and 1970, those sectors having more than 75% of TNCs participation grew at an annual rate of 16.5% while those having less than 25% expanded at a rate of only 9.5%. But perhaps even more worrisome for a nationalistic viewpoint was the fact that the relative growth of transnational capital within the Mexican industry has not only been the result of its more dynamic performance. It has indeed partially resulted from an additional trend towards denationalization, namely, the steady postwar rise of foreign acquisitions of Mexican firms. In effect, a US Senate Subcommittee study of US companies operating in Mexico

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operations in these industrial branches. See also Barkin (1975).

(33) "Between 1965 and 1970, Mexican private or public capital financed 71% of all foreign investment" (Cockcroft,1981,p.267). See also Fajnzylber (1975).

(34) It has become acceptable to define foreign firms in one country as those with 25% or more of their share capital registered as being in foreign hands. It is the criteria used by the US Department of Commerce in its studies on foreign investment and is also recommended

found that the share of new manufacturing affiliates established by acquisition of a Mexican firm rose from 6% in 1946-50 to 75% in 1971-72 (35). The study further showed that these were not all failing firms. In the year prior to takeover, 74% of the firms acquired were profitable, one-half earning 9% or more before taxes (Weinert,1977). Additionally, TNCs tended to favour the acquisition of large Mexican enterprises, i.e., those with a capital stock of over \$5 million. Between 1960 and 1972, 57% of the total value of acquired enterprises corresponded to this category and US TNCs accounted for 85% of all acquisitions (Evans and Gereffi,1981).

On the whole, therefore, it seems pretty clear that Mexico's postwar industrialization process has given US corporate capital a major relative weight in the Mexican industry (36). In this sense, transnational capital (mainly US) can only be considered as an intrinsic elements of the social constituency controlling and shaping the process of Mexican capital accumulation. Without US transnational capital, just as without the participation of the state, this process simply would not be the same and this is exactly what makes Mexico's dependence upon the US a structural phenomenon as profound as the major concentration of capital that has accompanied Mexico's TNC-based capitalist development.

In effect, the perennial force towards concentration of capital (see Chapter III) has naturally manifested itself in Mexico leading to the oligopolization of industry by both foreign US and Mexican large corporate capital. For instance, about 1.7% of the industrial enterprises create 42.3% of the employment and generate 53.7 percent of the industrial output (Gonzalez Casanova,1980). The

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by the International Monetary Fund. See Jenkins (1979).

(35) Comparing the decades 1946-1957 and 1958-1967, Wionczek (1972) has described that the total number of TNCs setting up quarters in Mexico increased from 156 to 335. But while the number of subsidiaries established independently increased from 80 to 119 that of acquisitions increased much more from 49 to 149. Among the most conspicuous fields where this particular form of denationalization has occurred are "the food industry in which United Fruit, Heinz, General Foods and Anderson Clayton are among the most visible foreign companies; consumer durables, chemicals, electronics, metallurgy; services like department stores, hotels and restaurants are also among the areas in which foreign interests have obtained control of local businesses" (Barkin,1975,p.71).

(36) Not only 79% of the 4,359 foreign companies in Mexico were North American in 1978 but, also, "...According to a study completed in 1970...of the 2,040 companies with the largest incomes in Mexico, foreign (mainly U.S.) capital controlled 36 percent of the income of the largest 400 companies and strongly participated in another 18 percent, while Mexican private capital controlled only 21 percent and the Mexican government 25 percent. Of the largest 100 industrial firms, 47 percent were foreign, 40 percent were private Mexican, and 13 percent were state" (Cockcroft,1983,pp.157-158). See also Jenkins (1978).

1965 industrial census enumerated almost 135,000 firms, but most of these were small, marginal operations with few resources. In fact, the 1,117 largest firms (0.82 percent of the total) accounted for 64.3 percent of total production and 66.7 percent of invested capital reported that year; the concentration in Mexican manufacturing was exceedingly high but similar to US levels (Barkin,1975). According to Fajnzylber (1975), 114 of the 230 sectors making up Mexico's industry showed a concentration of more than 50% (i.e., the four largest firms in the sector accounted for more than half of the sector's production). TNCs, in particular, were found to locate in those sectors having the highest degree of concentration. Thus, 61% of the TNCs' production and almost two-thirds of their investment were in sectors having over 50% concentration, while the average level of concentration for those sectors where TNCs' participation was over 75% reached up to 77% (37). Foreign capital has concentrated particularly in the areas of capital goods and basic intermediate industries. On their part, Mexican private capital has concentrated its investments in light industry, banking, agriculture, services and tourism. Here, stimulated by its own dynamic of capital accumulation, Mexican capital has centralized ownership in the hands of a few firms or economic groups. At the same time, there are innumerable examples of alliance formation between foreign capital and local-elite capital. The Banco Nacional de Mexico group, for instance, has developed alliances with such TNCs as Westinghouse, Celanese, Union Carbide, Kimberley-Clark, and Scott Paper. However, the best example of the foreign-domestic alliance is two economic groups: ALFA group (with sales of \$1.3 billion) and VISA group. In 1979, these two organizations were both listed in the Fortune 500 largest corporations in the world, and they together constitute the Monterrey group which is involved in virtually all key sectors of the economy and the most strategic parts of society (Velasco,1983,p.17). For this reason, Gonzalez Casanova (1980) has concluded that Mexico is not a case of a general dependence of one country upon another but rather of the dependence of a country and its government on foreign- and domestic-owned corporations. In a more precise way, all the tendencies we have analysed above, certainly define the very nature of the Mexican economy.

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(37) "This finding is supported by a U.S. Senate Subcommittee study of U.S. firms operating in Mexico. This study found that U.S. firms tend to operate in highly concentrated markets in Mexico and that they are frequently the leaders within those markets. Over 86 percent of firms surveyed ranked themselves among the four leading firms of their main product line, and 44 percent ranked themselves first" (Weinert,1977,p.116).

"Because of dependence on foreign capital and technology, because of large scale state participation, and because of domination by domestic and foreign monopoly capital, Mexico's economy may be described as dependent state monopoly capitalism. U.S. capital does not control the economy in its entirety, but it wields sufficient influence to make a critical difference - and therein lies Mexico's structural economic dependence" (Cockcroft,1983,p.269).

#### **4.1.2.3. The Contradictory Role of Transnational Capital (mainly US) in Mexico's Postwar Development Process: Technology and Decapitalization**

Going back to Mexico's impressive postwar industrial development, it is clear that the quantitative picture which has attracted so much attention actually reveals little about the deep qualitative social issues which have characterized such a development. In contrast, from our recent discussion, we now know that behind Mexico's advances in industrial capital accumulation there has in fact been a contradictory social constituency containing a strong foreign element whose interests obey purposes much broader than Mexico's own process of capitalistic industrialization. This means that, by and large, the purposes of this dominant social constituency is hardly consistent with the goal of an autonomous industrial development for Mexico. For instance, transnational capital major relative weight in important sectors of the Mexican economy mostly translate itself in the control of these sectors to satisfy the requirements of TNCs' own global strategies of capital accumulation. Admittedly, this can contribute to bring about economic growth, but insofar as transnational capital is certainly not in the business of giving away its key elements of control, for instance, by effectively developing R & D capabilities within the host countries, this development can only be of the dependent and subordinated kind. It seems to us that only this understanding help to explain why after many years of the Mexican government allowing a rather free flow of imports of capital goods and technology, the production of these crucial aspects never actually took a strong hold within the Mexican economy. Likewise, it help us to understand why foreign capital is actually contributing little to Mexico's process of autonomous capital accumulation while reaping the benefits of its investments in this country.

In effect, if we look more closely at Mexico's industrial performance, particularly, in the context of the country's economic relation with the US, we shall see that the high relative weight of US TNCs within Mexico's industrial social constituency has only reinforced the country's strong dependence on the

US at the same time that powerfully contributing to both balance-of-payment deficits and worsening of the foreign debt. Table 4.10 shows the extent of Mexico's dependence upon the US for most of her imports and exports. Between 1970 and 1981, the US accounted for an average proportion of over 60% of both Mexico's imports and exports (38). In addition, the balance of trade has been traditionally favourable to the US, with this country accounting for an important proportion of Mexico's deficits (39). US transnational capital has been fundamental in reproducing this situation through a variety of mechanisms contributing to its own process of capital accumulation but clearly having a negative effect on Mexico's accumulation process. Contrary to common wisdom, for instance, foreign investors have on the whole taken out much more than capital than they have put in the Mexican economy. Table 4.11 shows the pattern of remittances abroad as compared with direct foreign investment for the period 1970-1981. As we can see, with the exception of 1980, every other year, more capital went out of Mexico than it was actually put in. Cockcroft (1983) gives figures showing that foreign investors "have been taking out more than twice what they have been investing since from at least the 1960s" (Cockcroft,p.160). More conservative estimates suggest that, during the sixties, direct foreign investment amounted to \$1,600 million while gross direct investment outflows amounted to \$2,500 million; as a result the net outflow for the decade would have been \$900 million (Barkin,1975) (40).

Table 4.11 also shows that the share of profits in the annual remittances abroad is often less than 50%, whereas the share of royalties and other mechanisms has been correspondingly higher. This fact reflects the strategic importance of technology in the TNCs global process of capital accumulation. Patents, licences, trade-marks, and know-how agreements have become crucial mechanisms whereby the technological supremacy of TNCs and, correspondingly, the technological dependence of countries like Mexico, is transformed into a permanent source of extraction of capital from Third World countries. Little wonder why TNCs have almost complete lack of interest in helping to develop Mexico's autonomous technological and industrial capabilities (41). Technology

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(38) The US is also absorbing 80% of Mexico's oil exports.

(39) After an almost continuous deficit throughout the postwar period, only the 1981/1982 crisis forced the government to apply policies to alter this situation. See table 4.2.

(40) According to Ramirez and Galicia (1972), between 1939 and 1966 approximately \$2.2 billion came into the country as direct foreign investment. In the same period, approximately, \$2.8 billion were remitted abroad by foreign investors. That is, there was a negative balance of \$600 million for the Mexican economy.

(41) "...the scientific and technological development of underdeveloped countries may be seen

Year	Value of Direct Foreign Investment (DFI) (million pesos)	Annual Remittances Abroad			
		Value (million pesos)	As % of Direct Foreign Investment	Share of Profits (%)	Share of Royalties and Others (%)
1970	2,308	3,273	141	49.5	50.5
1972	1,951	4,055	208	44.4	55.6
1974	3,636	6,078	167	39.1	60.9
1976	3,271	10,199	311	52.5	47.5
1978	8,768	12,312	140	39.6	60.4
1980	24,581	22,006	90	51.7	48.3
1981	27,997	35,646	127	49.5	50.5

**Table 4.11.- Direct Foreign Investment and Structure of Remittances Abroad, 1970-1981.**

**Source.-** NAFINSA (1984), SPP/INEGI (1983b).



enables them to exercise a great deal of control on the shape of Mexico's accumulation process while providing an effective channel to transfer capital out of the country (42). For instance, through internal trade between the parent company and the subsidiaries in Mexico, TNCs have used technology to reduce their payments of taxes to the Mexican government. By increasing their declared technological costs they have reduced their declared profits and since royalty payments are valid for tax exemptions, they have used this mechanism to remit untaxed profits abroad. They have further reduced their declared profits and corresponding taxes by underpricing exports of goods produced in Mexico and sold to the parent company abroad [Weinert(1977),Cockcroft(1983)]. Such technique known as transfer pricing are very difficult to control by UDCs governments since they relate to TNCs' book keeping which normally UDCs have no access to (43). TNCs have also used technology to gain advantages in their dealings with Mexican companies. In exchange for technology, they have sometimes negotiated equity participation (44), charged excessive fees for often outdated technology and imposed a variety of restrictions, including, for instance, restriction on exports by local companies, obligation to purchase raw materials and other inputs, etc. [ibid., Nadal(1977)]. In all these forms, transnational capital has sought to benefit from the subordination of Mexico's industrial development to the logic of its own interests. Therefore, control of important sectors of Mexico's industrial structure, high remittances of profits, high level of imports of technology, prolonged balance-of-payment deficits and the profound technological dependence of the country, can only be seen as interrelated aspects

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as a potential danger by the MNC [multinational company A.M.]. This is so because a strong scientific and technological system will allow underdeveloped countries to: 1) increase bargaining power by undertaking efficient screening and identification of operations in worldwide searches for appropriate technologies; 2) improve their capacity to adapt ( *and imitate*) imported technologies; 3) ultimately, it will provide the domestic scientific and technological system with enough elements not only for the local generation of productive information, but also to develop a critical approach towards the relation of science and technology vis-a-vis society" (Nadal,1977,231).

(42) For instance,"...According to available data, royalty and technical assistance payments made to central countries by foreign companies established in Mexico, increased from \$12 million in 1955 to \$40 million in 1960; and from \$60 million in 1965 to \$80 million in 1972" (Ramirez and Galicia,1972,pp.129-30). According to figures provided by Chudnovsky (1982), these payments reached \$97 million in 1975, later falling in 1977 to a low of \$63 million as a result of Mexico's economic recession, and raising again to \$92 million in 1979.

(43) TNCs in the Mexican pharmaceutical industry, for instance, by using various tricks of internal bookkeeping...were reported as making up to \$400 million a year on transfer pricing alone" (Cockcroft,1983,p.163).

(44) "...one of the mechanisms for acquiring control over already existing firms is through the suspension or non-renewal of existing licencing agreements: this powerful leverage is used to obtain equity participation guaranteeing control of major decisions concerning the firm" (Nadal,1977,p.224).



of one and the same process of TNC-dependent capital accumulation.

In effect, we have seen earlier how Mexico's attempt to deepen the process of ISI led to extensive foreign capital (mainly US) penetration of Mexico's manufacturing base in the postwar period. We have also seen that TNCs have concentrated their control in the most capital intensive and dynamic sectors of this industry. Through examination of additional data, we can now see not only that TNC-dependent ISI has resulted in heavy imports of manufacturing inputs but also that such imports are accounted to a large proportion by the operations of TNCs. Tables 4.8 and 4.12 give an indication of the import/export structure of the Mexican economy for the period 1970-1981. As we can see manufacturing industry with a share of well over 80% accounts for the overwhelming part of Mexico's imports. Also, at the beginning of the 1970s, more than half the exports were accounted by manufacturing, although the rise of oil exports during the decade brought down this proportion to just about 15% in 1981. By type of goods (table 4.12), the import/export structure shows clearly the positive affect of ISI on import of consumer goods. Thus and notwithstanding the renewed increase in these type of imports in the late 1970s as a result of the oil-based spending boom, the share of consumer goods imports has been quite low with around 10% in 1981. This means that it has been productive goods (i.e., intermediate and capital goods) which have accounted for most of Mexico's imports, thus showing the dependence of the country's productive base upon external sources (45).

Table 4.13 shows the extent to which the domestic availability of the different type of goods was covered by imports during 1973 and 1980. The conclusion is obvious, the capital goods sector, long acknowledged as the key sector for an autonomous industrial capability, is the weakest in Mexico having less than 50% self-sufficiency in 1980 (46). The statistics for technology imports show an even more dramatic picture of dependence. According to one commentator, "80% of the technology employed is still foreign" (Gonzalez Casanova,1980,p.160), and, as expected, the highest proportion of the payments

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(45) "Import substitution has done little to alter the external vulnerability of the Mexican economy. The change in the structure of imports...made it more difficult to reduce imports without widespread effects on economic activity. What is more, despite import substitution, import grew more rapidly than exports" (Jenkins,1979,p.24). See also Unger (1985).

(46) It is interesting to note that the trend towards import substitution was reversed in 1977, when imports in every category increased, thus "making domestic production more crucially dependent on imports in virtually every major industrial line of activity" (Bhaduri,1985,p.6).

Year	Total (millions (current pesos)		Consumers Goods (%)		Intermediate Goods (%)		Capital Goods (%)	
	Import	Export	Import	Export	Import	Export	Import	Export
1970	29,085	17,162	19.9	55.6	33.6	36.7	46.5	7.7
1972	33,974	20,927	22.4	55.6	33.8	36.2	43.8	8.2
1974	75,709	35,625	21.7	47.8	41.4	42.7	36.9	9.4
1976	90,900	51,905	7.3	26.4	61.5	70.6	31.2	3.0
1978	180,258	140,533	5.8	23.6	68.5	73.3	25.7	3.1
1980	424,279	351,324	13.1	10.7	59.7	87.7	27.2	1.6
1981	566,381	475,057	12.0	8.2	56.9	90.0	31.1	1.8

**Table 4.12.- Distribution of Exports and Imports by Type of Goods, 1970-1981.**

**Source.-** NAFINSA (1984), SPP/INEGI (1983b).

Type of Goods (1)	1973	1977	1978	1979	1980
Consumers' Goods	7.8	5.2	6.3	8.3	13.2
Intermediate Goods	21.7	17.2	20.5	22.5	25.5
Capital Goods	43.6	41.5	44.1	50.6	54.8
Manufacturing Total	22.3	18.9	20.0	26.4	31.0

**Table 4.13.- Imports as Percentage of Domestic Availability by Type of Goods, 1973-1980. (Percent).**

**Source.- A. Bhaduri (1985), p.6.**

**(1) Based on 1970 constant prices.**

for technology, 86%, originates in the industrial sector. Clearly, foreign capital, which possesses the technological capabilities Mexico needs, has not been transferring them. Indeed, as we indicated earlier, it has been fully exploiting them in accordance with the dictates of its own process of capital accumulation. In this respect, TNCs want Mexico importing as much technology, machinery and other products from them as possible. Not surprisingly, "...While Mexican industrial output increased 5 times between 1940 and 1965, imports of foreign (mainly U.S.) industrial or capital goods and replacement parts increased 12.5 times" (Cockcroft,1983,p.162). Thus, TNCs are not interested in Mexico producing autonomously these products since this would lead to a reduction in the flow of imports and, perhaps, even to an increased competition against their own products. More specifically, the latter would mean the loss of control over an important source of profits and, consequently, a major reduction in TNCs' ability to shape the development of Mexico's economy in accordance with their purposes. Just consider the role of TNCs regarding imports and exports in Mexico, to realize why TNCs would not relish the prospect of losing that control. In the early 1970s, a major study on TNCs in Mexico found that 49% of the private sector's imports of production goods was accounted for by the TNCs operating in the industrial sector. This represented 28% of Mexico's total imports. Concurrently with their concentration in the most dynamic sectors of the Mexican industry, more than half of the TNCs' total imports was accounted by the chemical and transport materials industries. The import coefficient (47) of TNCs more than double that of Mexican firms (7.8% against 3.4% respectively). In addition, 74% of US TNCs' imports came from the US, that confirming the fact that most of the trade of subsidiaries of foreign companies in underdeveloped countries take place with the parent and other affiliates of the same TNC (48). The study estimated that the imports of foreign subsidiaries from their respective firms reached \$600 million. Considering the impact of technology alone, the role of TNCs was even more conspicuous. It was found that their technology-import coefficient (49) was approximately 7 times that of national enterprises. In fact, 80% of the payments originating in the industrial sector were made by TNCs (Fajnzylber,1975) (50).

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(47) Import of intermediate inputs over the value of production.

(48) Quite revealing of the global character of TNCs' strategies of accumulation and of its major impact on UDCs foreign trade activity, it has been estimated that in the early 1970s in Mexico, 41% of the country's total imports from Argentina and 35.5% of its total imports from Brazil actually corresponded to imports carried out by TNCs' subsidiaries located there (Fajnzylber,1975).

(49) Total payments for technology over the value of production of all foreign subsidiaries

In marked contrast with their import patterns, TNCs subsidiaries in Mexico have a similar export pattern to that of national firms. Fajnzylber (1975) estimated the export coefficient of TNCs and Mexican firms at 2.8% and 2.6% respectively. Proportionally, TNCs' exports represented around 35% of Mexico's total manufacturing exports. In comparison with the volume of their sales in Mexico, however, the value of TNCs' exports from Mexico represents a very small proportion. Table 4.14 shows that, until 1966, exports were less than 2% of the value of TNCs' local sales and most of them took place as a result of intra-company trade. This shows clearly that the overwhelming interest of US TNCs in Mexico is to supply the local market. Later, in 1972, TNCs exports jumped up to 5.1% of the value of local sales. This was mostly the result of the Mexican government promotion of exports which started around 1970 (51) with the aim of reducing the chronic and cumulating balance-of-payment deficit and also of expanding a demand that was showing signs of declining in the local market (Evans and Gereffi, 1981). The trend towards the increasing participation of intra-company trade in these exports, however, remained unaltered. Thus in 1972, 82% of TNCs' exports took place between affiliates. Most importantly, in line with their major relative weight in the most dynamic sectors of Mexican industry, TNCs were actually responsible for most of the exports from these sectors. For instance, in 1975, 70% of the exports from the

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in Mexico.

(50) According to a different estimate, "...In 1971 multinational corporations covered 93% of the payments for imports of technology" (Gonzalez Casanova, 1980, p.160).

(51) In 1971, the Mexican government instituted a system of incentives to promote exports. "This comprised the establishment of tax devolution certificates; import of productive inputs free of taxes; expansion of the range of short-term credits to exports given by FOMEX; creation of FONEI to finance investments oriented towards export and efficient import substitution, and creation of IMCE to increase the efforts in export promotion" (Balassa, 1983, p.215). Prior to the 1971 legislation "...The most important single development of the 1960s as far as the export of manufactures is concerned was the special incentives granted in 1965 for the development of labour-intensive industries in the border areas of the North of Mexico. This led to a rapid growth of the "maquiladoras" or in-bond processing industries in the late 1960s and early 1970s. These firms almost entirely US owned, were able to import machinery, raw materials and semiprocessed products duty-free provided that their entire output was exported. They were also able to take advantage of industrial estate facilities provided by the Mexican government with low rents and cheap electricity and water supplies" (Jenkins, 1979, pp.26-27). The "maquiladora" has been the Mexican version of the labour-intensive parts of the production process relocated to the Third World countries by TNCs. As we saw in Chapter I, this process began basically during the 1960's as US TNCs strove to exploit the cheap labour supply in UDCs, stimulated by favourable US tax legislation and pressures on the rate of profit. In Mexico, it is clear that not only cheap labour was involved but a host of other benefits granted by the government. As we shall see later on, the "maquiladora" industry has been an important part of the electronics scene in Mexico. For a more detailed examination of the development of the "maquiladora" industry in Mexico, see *Comercio Exterior* (1978), Martinez (1983), Dillman (1983), Rivas (1984), Carrillo (1986).

Concept	1960	1966	1972
Local Sales (million dollars)	413	1,164	2,689
Total Exports (million dollars)	5.4	22.2	137.1
Exports to Affiliated Companies (million dollars)	3.0	16.0	112.7
Exports as Percentage of Local Sales	1.3	1.9	5.1
Percentage of Exports which are Sales between Companies	56	75	82

**Table 4.14.- Exports as Compared to Sales of U.S. TNCs  
in Mexico, 1960, 1966, 1972.**

**Source.- P. Evans and G. Gereffi (1981), p.50.**

modern sector was made by TNCs (Unger,1985), and there was a heavy concentration in a small number of industries. Chemical and transport equipment were the most important accounting for 60% of the total exports and, if exports of electrical machinery are added, the combined share of total exports reached 70% (Jenkins,1978,1979). In this connection, considering the capital goods and durable consumer goods, Dahlman and Cortez (1984) have noted,

"...the bulk of Mexico's capital goods exports are by subsidiaries of multinational companies. Almost one-fifth of the exports are power machinery and equipment (most of which consists of internal combustion engines exported by multinationals to the United States and European plants) and another 10% are office machinery (mostly typewriters exported by multinational to Latin America), and another 7% are commercial vehicles (most of which go to Latin America). Relatively few exports are by Mexican firms, and these appear to be concentrated in equipment for the petroleum industry, glass-making machinery, and some agricultural equipment" (Dahlman and Cortez,p.606).

Now we can see, therefore, that Mexico's exports of capital intensive goods which has been, perhaps, the most impressive factor in the country's postwar industrial performance and hence, of its newly-industrializing status, is actually under the control of the transnational constituent of Mexico's industrial social constituency. Furthermore, within such social constituency, it is only a handful of corporations which control the largest proportion of total TNCs' exports from Mexico. According to Unger (1985), in 1975, only 36 firms, all of them exporting over 10 million pesos that year, accounted for most of the exports of capital and durable consumer goods from Mexico. Between them, they had a combined share of approximately 40% of the TNCs' total exports of manufactures from Mexico. More broadly, out of a total of 708 foreign firms which participated in external trade in 1975, only 65 firms (with exports of over 10 million pesos) accounted for approximately 90% of the manufactured exports from Mexico. As we can see, within the transnational social constituent, export, like investment, is highly concentrated in the hands of large corporate capital. This has important implications for Mexico's foreign trade policy since only a handful of companies have come to control the performance of crucial sectors in any export-oriented strategy of industrialization. This means not only that the performance of these sectors is largely dependent upon decisions taken abroad by the TNCs parent companies but, also, that the benefits of the Mexican government measures to promote exports are in fact accruing into the hands of a few large firms [Evans and Gereffi(1981),Jenkins(1979)].



In spite of its increase, the value of TNCs exports has been nothing like the imports we have discussed earlier. Indeed, during the period 1970-73, when TNCs exports augmented considerably (see table 4.14), their value still fell significantly behind that of imports. The result was a commercial deficit for the TNCs in Mexico averaging \$540 million a year. For the same period 1970-73, this TNCs' commercial deficit represented, on average, 47% of Mexico's total commercial deficit (Fajnzylber,1975). The negative impact of TNCs operations upon Mexico's balance of payments is thus all too clear. More importantly, since the Mexican social constituents sought to cover the chronic deficits through the mechanism of foreign debt and hence, through an increasing dependence upon foreign financial capital, eventually the circle of technological-industrial-financial dependence engulfed Mexico and put her economy under growing pressure which in 1982 left the country almost bankrupt, unable to meet the service of a near \$90 billion debt. Since then, it can be said that Mexico is to a large extent at the mercy of foreign capital and their willingness to negotiate more loans and postponements of service payments (52).

#### 4.1.2.4. The Efforts of the Mexican Government to Curb the Contradictory Role of TNCs in Mexico's Postwar Development Process: Legislation on Foreign Investment and Technology Transfer

As a major social constituent of Mexico's process of industrialization, national capital and, particularly, the Mexican government controlling the strings of political power in the country, has thoroughly participated in the shaping of present-day Mexico. As we have seen, in pursuit of its own interests the Mexican government has seen in foreign capital a fundamental force for the country's process of capital accumulation. It has designed the legislative framework ruling the actions of all the constituents and has effectively created the conditions for the development of a social constituency ("triple alliance") whose overall performance is simply contradictory to the goal of an autonomous industrial and economic development of Mexico. In other words, the quantitative

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(52) Interestingly enough, the Mexican debt is so huge that it is hardly possible for foreign banks to allow Mexico to default. Such a course of events would certainly threaten the whole structure of the capitalist financial system. Thus, Mexico seems to be protected by a paradoxical situation in which "the more you owe, the safer you are". Currently, Mexico has a \$97 billion debt and repayments for 1986 should be \$11.5 billion. Due to the fall in oil prices, however, it seems that far from being able to fulfill her obligations Mexico will be needing some additional \$6 billion to cover the projected deficit.

and qualitative characteristics of the processes we have discussed above have been the result of the interests as much of transnational capital as of the Mexican constituents themselves. Most probably, such characteristics reflect the practical limits of what foreign capital wants and can achieve in Mexico without contradicting the overriding interests of the Mexican social constituents. In this connection, as Weinert (1977) has suggested,

"...in promoting industrialization, the state was acutely concerned about the political challenge of foreign capital but was relatively unconcerned about effects on inequality, market distortions, or balance of payments. After the 1950s, the state's primary goal was to direct foreign capital into new economic activities, so that it would open up new areas of the economy, thereby promoting industrialization. At the same time, the state did not want foreign capital to increase its overall importance in the economy, further threatening control over policy making" (Weinert,p.111).

In the present circumstances, it is at least doubtful to contest that the Mexican government has actually succeeded in averting an increase in foreign capital's control over the economy since the 1950s. Efforts have certainly been made which would apparently keep the control of the industry in Mexican hands. Indeed, since the 1950s, a policy known as "Mexicanization" was selectively implemented by the government to contain the expansive tendency of foreign capital (53). As a result, foreign capital has been excluded from basic sectors of the economy such as utilities, oil, steel, communications and so on. In 1971, the basic petrochemical industry was also reserved to the state while 60% of Mexican ownership was required for companies processing petrochemicals and 66% for companies in mining. The requirement of 60% ownership was later extended, in 1972, to companies manufacturing autoparts (Weinert,1977).

All the above regulations were further extended, in 1973, in the most far-reaching attempt to provide the country with a coherent legal framework to deal with foreign capital and promote Mexican investment. The 1973 law, known as the Law to Promote Mexican Investment and Regulate Foreign Investment, codified all previous regulations and incorporated various new provisions, among which the most famous was the requisite that, from the time of the enactment of the law onwards, foreign capital could only have a maximum share of 49% in all new commercial ventures. There were some

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(53) In 1954, the government of Avila Camacho passed the first Mexicanization decree already worried by the increasing inflow and influence of foreign capital into the Mexican economy. It required that most of the ownership of Mexican companies was in the hands of Mexican nationals and that the majority of their directors was made up by Mexicans too

exception requiring special permission (54). Furthermore, the law reinforced the promotion of Mexicanization by introducing a structure of incentives which, in most cases, was applicable only to national enterprises (Whiting,1981).

The legal effort to control foreign capital, however, did not stop at the issues of investment. Almost simultaneously, another major law attempting to tackle the technological issues was enacted by the Mexican government. This was the Law on Registration of Transfer of Technology and Use and Exploitation of Patents and Trade Marks, which complemented the law on investment by purporting to control foreign capital's abuse of its technological power while simultaneously improving the position of national capital in negotiations concerning technology transfer (55). According to Whiting (1981), these two laws formed the core of the Mexican government's strategy to deal with foreign capital (56). In his words, "...they had as their main objective the strengthening of the national private sector and of the national economy at large" (Whiting,1981,p.81) (57).

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(Evans and Gereffi,1981).

(54) The law specified 17 conditions allowing for majority foreign ownership. "These exceptions are possible when foreign investment will not constitute a monopoly, will not displace national enterprises in industry and will offer such benefits as employment creation, increase on exports, decentralization of industry, greater national integration of products, preservation of the country's social and cultural values, etc." (Whiting,1981,p.82). It has to be emphasized that since the law was not retroactive, foreign companies which had a majority ownership before its promulgation needed not alter this situation unless they wanted to diversify production or to take advantage of incentives. Even then, they could still try to qualify for exception under the 17 conditions. At any rate, the spontaneous preference of foreign capital for at least majority ownership is shown by the fact that, just before the law, a study found that from 339 foreign subsidiaries in Mexico only 25% had Mexican majority ownership while 50% had total foreign ownership (i.e., 95% or more. For US TNCs alone the latter percentage was 55% (Evans and Gereffi,1981).

(55) "...the Law for the Register and Transfer of Technology purported to control the flow of technology, reduce its costs, and eliminate certain restrictions which were often included in foreign contracts... Among the conditions to reject or modify a contract are: payment for technology already available free; unjustifiably high costs for technology; guarantee of devolution of technological innovations developed in Mexico to the foreign partner; foreign control in the direction of the company; restrictions to investment and development in Mexico; prohibition to perform complementary technological development; requirements of imports of personnel or equipment; restrictions to the levels of prices and of production and the imposition of foreign courts to settle disputes " (Whiting,1981,pp.83-84). See also Nadal (1977a) and Campos (1975). The law also established that contracts having some of these restrictions may be accepted when the authorities consider that the acquired technology is of particular interest for the country (Leff,1983).

(56) Later in 1976 these two laws were complemented by a new law reforming the 1942 Law on Industrial Property. This was the Law on Inventions and Trade Marks intended to regulate the control over production exercised by the owners of patents for inventions, innovations and commercial trade marks. Among its most important provisions was the exclusion of patenting for processes related to fundamental sectors such as health, food, and energy and agricultural production (Leff,1983).

The crucial issue is to what extent these legal instruments have actually succeeded in effectively improving the relative weight of the national social constituents vis-a-vis transnational capital. Have they enabled a greater control of foreign capital in accordance with the goal of Mexico's autonomous industrial development ?, and, in this respect, have they contributed to reducing Mexico's technological dependence ? On the basis of what we have seen earlier a preliminary answer to the latter crucial questions is that they have not made a fundamental difference at all. Indeed, this is the conclusion arrived at by various scholars who have examined closely the impact of the abovementioned laws (58). As far as Mexicanization is concerned, it has been argued that the law on foreign investment is ineffectual not only because it can be circumvented but also because the state lacks the means and the political will to implement it fully. For instance, in relation to foreign investment only the names of foreign investors must be disclosed leaving the name of nationals anonymous. This has given origin to the practice of *prestanombres* ( i.e, borrowed names) whereby many Mexicans have lent their names to foreign investors, thus enabling effective foreign control of nominally Mexicanized enterprises [Whiting(1981),Cockcroft(1983)]. Another practice described by Velasco (1983) has been to construct dummy factories to circumvent the provisions requiring that a certain percentage of a given industrial process be carried out in Mexico. The dummy factories are shells only, with a few pieces of machinery, but with no real productive capacity. Yet another practice strengthening foreign control of Mexicanized companies is "the concentration of stock ownership in the hands of one or two foreign corporations and the dispersal of Mexican participation among a larger number of very junior partners" (Cockcroft,1983,p.158). In the latter respect, a study of 112 companies having foreign participation in the early 1970s

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(57) The first article of the law on foreign investment put the goal in terms rather more ambitious. It stated that its aim was to promote Mexican investment and regulate foreign investment "in order to stimulate a just and balanced development and to consolidate the economic independence of the country" (Quoted by Nadal,1977a,p.280).

(58) Even the current National Development Plan has acknowledged this reality even though it uphold the adequacy of the present legislation. "Despite the existence of an adequate law covering direct foreign investment, there has not always been a systematic policy to take effective advantage of its contribution to national development. In practice, transnationals have often tended to benefit from market protection, through the use of obsolete technologies and equipment in their countries of origin, and to generate excessive profits at the expense of national consumers. It has not been possible to induce this kind of investment to promote national technological development, to substitute imports efficiently, or to generate exports with a positive net balance in foreign exchange. Moreover, the process of Mexicanization of enterprises with foreign participation has been, in many instances, illusory and has had undesirable effects on industrial concentration, pricing policy, and on the available resources for investment" (Poder Ejecutivo Federal,1983,p.81).

showed that 35% of them had a widely dispersed Mexican participation, probably from private capital (Evans and Gereffi,1981). On the other hand, the same study showed that in 52% of the cases the Mexican partner was concentrated local private capital. Since the study was before the 1973 law, however, such concentrated Mexican participation did entail 51% Mexican ownership in only a minority of cases. Most importantly for the control purposes on the 1973 law was the fact that Mexicanization has mostly benefited local private capital which is not the same as benefiting the "national interest" for autonomous industrialization (59). If anything , the result has been the strengthening of the interpenetration of interests between Mexican and transnational capital, which is clearly not the same as promoting self-reliant technological and industrial capabilities. As long as national capital benefits from its alliance with transnational capital, there is no reason for it to pursue long term goals of autonomy which can only hinder the short term needs of its process of accumulation. For instance, it has been found that national enterprises are even more reluctant than TNCs to reduce their foreign payments for technology and assistance (Whiting,1981). Not that TNCs are more interested in Mexico's welfare since they can use means such as "transfer pricing" to accomplish the same, but this fact does show that national private capital's interests have little to do with any supposedly long-term abstract "national interest". Thus, national capital will benefit from both the state legislation it finds useful and its profit alliance with transnational capital. In turn, the latter will have a number of alternatives to keep Mexico's industrialization within the scope of its own global process of capital accumulation. "Prestanombres", whole-ownership, joint ownership, transfer-pricing, etc., are all means which the TNCs can resort to in accordance with their particular strategies (60).

As to the state, the "depository" of the long-term interests for industrial self-reliance, the reality seems to be that it is both incapable of implementing the available legislation and unable to legislate further into areas that will provoke strong reactions from private national and transnational social constituents. An

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(59) A similar conclusion is reached by Correa (1983) in relation to the Laws on Technology Transfer throughout Latin America. For him, although the laws entail policies described as being in the "national interest" or "public order", "their obvious beneficiaries are the national enterprises which resort to the acquisition of technology abroad" (Correa,p.33).

(60) For instance, apart from the "prestanombres", many firms remain 100% foreign owned -General Motors, Ford, Chrysler, Volkswagen, General Electric, Kodack, Sears, Anderson-Clayton and Dow Chemical. On the other hand, in booming areas like appliances, food products, and industrial chemicals, some 153 companies in the late 1970s choose to sell a majority interest to Mexicans. The reason: the structure of incentives since foreign capital's participation in joint enterprises also allowed it to borrow more easily from Mexican banks



instance on the latter score was the attempt by the government to implement some new provisions of the law on patents and trade marks which aroused the determined opposition of TNCs, lest that Mexico would create an example, and which, eventually, was also opposed by national private capital as a result of TNCs effective persuasion (61). In the face of common opposition by both foreign and national capital, the government finally gave in in 1979, thus indefinitely postponing the implementation of the conflictive measures. As Whiting (1981) rightly concluded, "the State backdown before the opposition of the strongest enterprises in the manufacturing industry" (ibid,p.86). But, as we have said earlier, not even the available legislation has been effectively implemented. Entangled in a *Kafkaesque* bureaucratic maze which gives responsibility for the application of the laws to different ministries and even different departments within a ministry, the administrative capacity of the state is severely limited by "lack of information, lack of coordination, reactions to particular interests and the shortcomings of a style of case-by-case study which has prevailed so far" (ibid,p.88). To this it has to be added that, due to the international nature of TNCs' operations, it is simply impossible to exercise an effective control of its operations in any given country. The fact that they can play one country against another with their investments is generally enough to persuade the governments interested in their presence that they should not push the national game too far (62). Perhaps, it is for all the above reasons, that in the present context of critical shortage of financial resources, the Mexican government has been quietly moving away from the ownership control imposed upon foreign capital operating in Mexico. As *Business Week* ( 19 July 1984) reported, "...Without formally changing Mexico's foreign investment legislation, the government will now allow "systematic and selective" foreign control of new companies in nine industrial sectors, ranging from machinery to hotels" (p.30). The new guidelines significantly eases the ownership rules for foreign investors in exchange for their commitment to develop local suppliers, provide them with permanent assistance programs, and provide grants and scholarships for research

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and to diversify into other lines of business. (Cockcroft,1983).

(61) The purpose of stipulating these provisions was to "increment the negotiating power of the Mexican concessionary of the original trademark as a resort against the threat of withdrawal of the foreign trade mark. The idea was to reduce the payments for foreign trade marks not entailing new technology, and to enable the Mexican concessionary to also benefit from the good will created by his own promotional efforts in Mexico" (Whiting,1981,p.85).

(62) For instance, Anderson-Clayton which controls Mexico's leading agricultural export product, cotton, also controls cotton production in the countries with which Mexico must compete: Brazil and the US. Thus, "Anderson-Clayton periodically engages in cotton

(Layton,1985,p.38). In other words, in its hour of crisis, the Mexican government turns towards foreign capital even more deeply in the hope that the latter can be effectively guided into contributing to the development of Mexico's indigenous industrial and technological capabilities. Past evidence with legislation on technology, however, suggest that this may prove a rather difficult task.

In effect, the legal attempts to enhance Mexico's technological position vis-a-vis foreign capital have on the whole proved as disappointing and limited as the law on foreign investment discussed earlier. Admittedly, the Law on Registration of Transfer of Technology was never intended to bring about any substantial qualitative change in the technological dealings between Mexican constituents and TNCs. After all, having seen the context of interests described above, the reason is not difficult to perceive. The general consensus about the limited role of the law was summarized by one commentator:

"...the basic concern of the law revolves around the *limitation of abuses* contained in the agreements on technology transfer. Thus, *it is not a legal instrument which contains a system of incentives to support national technological research*. Nor does it constitute a mechanism which contributes to the *formation of a national policy on technology acquisition*. *It does not establish*, for instance, regulation of sectoral priorities for technology import". [B. Sepulveda, quoted by Alvarez (1982),p.1117].

The law has had some success in bringing down the level of TNCs' technological abuses, at least in those areas easier to control. For instance, between 1973 and 1975, the National Registry of Transfer of Technology (NRTT) rejected 856 licencing agreements which included different restrictive clauses. The most common restrictive clause was the excessive or unjustified price of the technology found in more than 80% of the cases [Nadal(1977a),Campos(1975)]. Other clauses appeared much less frequently and varying percentages. Such pattern, however, did not imply the TNCs were less fond of indulging in other restrictive practices. Rather, it reflected both the emphasis which the law gave to the volume of payments for technology and "the fact that MNC do not have to use a technology agreement to impose certain restrictions" (Nadal,1977,p.225). For instance, in relation to TNCs subsidiaries, which, actually account for most of the royalty and technical assistance payments,

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"dumping" to remind Mexico who is in control" (Barkin,1975,p.72).



"...the transnational enterprise need not resort to restrictive clauses in its contracts in order to constrain a subsidiary to follow its instructions. The parent company can limit exports, force a subsidiary to acquire inputs only from other companies in the group, over-invoice or under-invoice these transactions, etc., without leaving a single trace of these restrictions in its contracts" (Nadal,1977a,p.152).

On the quantitative side, it has been estimated that, between 1973 and 1975, the NRTT's control of technology agreements brought about a saving of 26% of the payments which would have occurred in absence of the law (ibid.). Most importantly, the annual rate of growth of payments for technology transfer was reduced from 15% for the period 1953-68 to only 6% for the period 1970-1976 (Correa,1983). For most analysts of the law, however, this quantitative success is far from even touching the fundamental problems involved in the search for Mexico's technological autonomy. In Leff's words, "although it is possible to regulate and improve the purchasing conditions of our technological imports, this does not entail the creation of the basis necessary for a reduction of our dependency on this matter" (Leff,1983,p.279). In effect, given that, according to the law, the NRTT can only intervene once the industrial projects have been negotiated (63), it is clear that such fundamental issues as the choice of imported technology are simply out of the government control (64). Furthermore, even where the law allows for some intervention, for instance, regarding the content of the technology transferred, in practice, this intervention has been negligible. From the 856 licencing agreements rejected between 1973 and 1975, only 0.58% of the cases were based on the fact that the imported technology was wholly or partially available in the country so that its import was not justified (Correa,1983). Likewise, according to an ex-director of NRTT, there are scores of instances of agreements and large payments for unnecessary technologies such as cosmetic formula, foreign models for the garment industry, administrative services in the soft-drink industry, etc. (65). For all this, when in 1981 the government decided to review the 1972

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(63) "...as a regulating instrument, the NRTT has the disadvantage of scrutinizing contracts only once the industrial projects have been conceived and negotiated. The conditions of financing have already been established, the sources of inputs, the technology supplier, the location of the plant, etc., are all parameters already established when the Registry receives the contract. Therefore, the fundamental technological decisions have already been taken (including the decision on the goods to be produced) and the NRTT only intervenes *ex post factum* in some of its formal conditions" (Nadal,1977a,p.158).

(64) "The law neither affects the process of choice of technologies, nor does it favour a disaggregation of technological packages with the end of increasing both the technological level of the internal industrial process and the gradual substitution of technological goods. Nor does it promote an improvement in the level of technical capabilities for the process of assimilation of imported technologies" (Leff,1983,p.279).

Law on the Registration of Transfer of Technology, such a revision was already long-overdue. Thus, for Alvarez (1982), the government decision to review the 1972 law was justified by "the need to advance to a different phase in technology policy that overcomes the "defensive" stage limited to the "control" of technology imports" (Alvarez,1982,p.1117). In this new phase, Alvarez argues for a more aggressive promotion of the internal technological development in accord with the country's productive structure. Indeed, the writers of the new law themselves (66) seem to have been aware of this demand when they wrote that the new project sought "to transcend a regime which was exclusively regulatory, in favour of a basic mechanism ensuring commitment to an effective and optimal transfer of technology, for the benefit of the country" (Quoted by Alvarez,1982,p.1117). As the same analyst concludes, however, aside from changes legally *adjusting* the 1972 law, the new document did not show any difference regarding the fundamental issues of Mexico's technological dependence, "it completely overlooked these aspects, thus wasting the opportunity to improve substantially the conditions of the process of technology transfer and hence, to increase the latter's contribution to the country's development" (ibid.,p.1118). In this respect, our argument is that this was not actually a wasted opportunity from the point of view of something that should have been done and it was not done. Rather the new law, as the old, simply reflected the limits imposed by the Mexican government by its participation within a contradictory social constituency of interests. The law reflected the relative weight and the specific interests of each of the constituents under given historical circumstances. For this reason, when Alvarez (1982) warns that the next opportunity should not be missed, we much better look at the situation of the "triple alliance" to anticipate the answer. Our opinion is that, as long as the high relative weight of transnational capital within the current social constituency of Mexico's industrialization remains in force, hardly the Mexican legislation can become a tool for appropriating TNCs' technological capabilities which, after all, constitute the roots of the latter force's power within the constituency. An action of this kind would entail touching deeply the interests of transnational capital, thus almost certainly giving rise to a crisis of interests within the social constituency. Since there is no indication that the government has the political will to risk such a crisis, then there is no reason for the legislation to reflect a conflict of interests which in practice has not arisen (67).

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(65) Jaime Alvarez's statement referred to by Correa (1983).

(66) The Direccion General de Inversiones Extranjeras y Transferencia de Tecnologia.

(67) The situation thus far is summarized by Cockcroft (1983). The Mexican bureaucratic

Recognizing its own political unwillingness, therefore, and faced with the technological might of a social constituent whose interests do not spontaneously entail the development of Mexico's technological autonomy, the government has sought, for some years now, to promote the only credible non-conflictual path towards decreasing Mexico's technological dependence. This is the strengthening of the country's own scientific and technological capabilities through a concerted plan of national action which would lead towards the overcoming of the present underdeveloped state of such capabilities. This was the aim of the first national plan for science and technology launched in 1976 and spearheaded by the formation of the National Council for Science and Technology (CONACYT) in 1970. Both the CONACYT and the first plan represented the first serious and systematic effort to actually face the enormous problems affecting Mexico's science and technology system (S & T system). Below, we shall examine them in greater detail as we come to discuss the characteristics of Mexico's R & D system, given the crucial importance of such a system for the existence of an indigenous microelectronics capability. For the time being, we turn our attention to the following question, to what extent has the process of dependent capitalist accumulation led towards the realization of the ultimate goals of the Mexican nation as exposed in the present national development plan ? In short, to what extent has this process led to freedom and justice for all Mexicans ?

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bourgeoisie "to the extent that it is integrated with Mexican and foreign private capital, it shares the general direction of capitalism and official politics - moved, and strongly so, by the forces of monopoly capital. This is not to deny the many policy conflicts that the representative of the state and of monopoly capital have to grapple with, including conflicts among themselves; but such conflicts rarely becomes antagonistic, since the evolution of the corporatist political system has tended to unite, more than to divide, the interest of the state bureaucracy and those of the Mexican bourgeoisie and foreign capital" (Cockcroft,p.218).

### 4.1.3. The Social Issues of Mexico's Process of Dependent Capitalist Accumulation

"The egalitarian society is an original demand of the Mexican Revolution. The struggle for greater equality has been a constant element in the history of Mexico and a principal motivation of the country's great popular movement" (Poder Ejecutivo Federal,1983,p.90).

In this way the current national development plan opens its section Social Policy. The Revolution took place in the 1910s, more than 60 years later not even the government would suggest that Mexico is in anyway near to this goal. Certainly, there have been advances as the development plan well describes:

"...the national population has increased fivefold since the beginning of the century; nevertheless, at the same time, it has been possible to decrease the absolute number of families without access to minimum levels of welfare. Life expectancy has increased from 36.8 years for men and 38.2 for women in 1930, to an average of 64 in 1980; illiteracy has been reduced from 50% to 15% of the population in the same years, and the coverage of social security services has come to reach nearly half of the total population, whereas basic health services now assist almost the entire population" (Poder Ejecutivo Federal,1983,p.91).

Yet, as the same document acknowledges, "acute social inequalities exists between social groups, between the city and the countryside and between the regions of the country" (ibid.). In effect, despite the advances mentioned above, the fact is that in relation to the actual and potential wealth of the country, Mexico's social conditions show a very high level of sharp inequalities and human deprivation for millions of Mexicans. In a country where underemployment is put at over 40% of the economically active population (68), the ideals of the Revolution, the ultimate development purposes set out in the National Plan, are reduced to empty rhetoric in the face of the unjust distribution of wealth and basic resources such as housing, education, health and social welfare. Table 4.15 gives the official estimates regarding Mexico's pattern of income distribution for the years 1968 and 1977. As we can see, the lower 20% of inhabitants shared only 4.2% of the national income in 1977 and almost 10 years later, in 1977, this share had actually fallen to less than 3%. In the same ten years, the upper 20% had kept its share between 55% and 54% of the income. The reality, therefore, seems to be that far from approaching its

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(68) "In 1980, of an estimated economically active population of about 20 million, 9.6 million were underemployed, and 1.8 million were unemployed. ...[In addition A.M.]...the government must provide (or encourage others to provide) one million new jobs each year" (Velasco,1983,p.2).

Inhabitants (%)	1968	1977
20	4.2	2.9
30	14.1	13.3
30	26.6	29.4
15	27.5	30.5
5	27.7	23.9

**Table 4.15.- Distribution of Income, 1968,1977.**

**Source.- SPP/INEGI (1983b).**

ultimate development goals the Mexican society is in fact developing into an increasingly unequal society. This conclusion has been confirmed by the findings of various studies (Goulet,1983). For instance, a World Bank report,

"...found that in 1975 the poorest 10 percent of Mexico's population received only 0.62 percent of total income, whereas the richest 10 percent obtained 30.57 percent of the total. The richest 30 percent of the country enjoyed 60.18 percent of income, while the poorest 30 percent received but 4.71 percent. Comparative figures for 1963 are revealing: the poorest 10 percent got 3.3 percent of income whereas the top 10 percent had as its share 25.69 percent of the total. The bottom 30 percent received 11.05 percent as against 51.41 percent for the top 30 percent. In short, disparities grew wider" (Goulet,1983,p.29) (69).

From a different angle, it has been estimated that, in 1958, the income of the richest 5% of families was 22 times greater than that of the poorest 10% ; in 1970 it was 39 times greater and in 1977 had gone up to 47 times greater (Gonzalez Casanova(1980),Cockcroft(1983)]. As expected, this very unequal income distribution is reflected in housing, education, health and, ultimately, life itself. In effect, as table 4.16 shows, at the bottom of the life-expectancy league, agricultural wage earners can expect to live around 54.2 years. that is, over 14 years less than the so-called new petty bourgeoisie who have a life expectancy of 68.8 years. According to Narro et al (1984), for the former group, mortality is now at the level of the national average in the 1950s. Thus, taking due consideration of time factors affecting the figures, they conclude that "...if the degree of "backwardness" in the health conditions of the more marginalized classes were susceptible to measurement in chronological terms, the gap which would separate them from the most "advanced" classes would be 40 years" (Narro et al,p.639).

A closer look at the distribution of basic resources and social services will help us to understand why this is so. Table 4.17 shows the characteristics of housing in Mexico. Clearly, there has been a relative improvement from the figures of 1970s (70). In 1980, however, considering that there was an average of 5.5 people per dwelling, millions of dwellings had no electric energy, no piped water of any kind (i.e., not even access to a public tap), no sewage

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(69) For social figures for the 1950s and prior to the Mexican Revolution, see Gonzalez Casanova (1970). Reflecting about the social achievements of the Mexican Revolution, Gonzalez Casanova echoes the question in the mind of many people "Did it not fail the Mexican Revolution ?, Was for this that a million people died ?" (ibid.,p.416).

(70) As the population has grown faster, the improvement in percentages does not necessarily mean a reduction in the absolute number of people affected by bad housing conditions.



Category	Age
National Average	62.4
Non-Agricultural Population	
New petty bourgeoisie	68.8
Bourgeoisie	67.9
Traditional petty bourgeoisie	65.7
Proletariat	62.3
Non-typical proletariat	63.1
Typical proletariat	61.6
"Free" unwaged labour force	58.3
Agricultural Population	
Middle and well-off peasants	60.0
Poor and semiproletarian peasants	56.9
Agricultural wage earners	54.2

**Table 4.16.- Mexico: Life Expectancy at Birth  
by Social Classes, 1977.**

**Source.- J. Narro et al (1984), p.38.**

Category	1970		1980	
	No. of Dwellings	%	No. of Dwellings	%
Total	8,286,369	100.0	12,216,462	100.0
Inhabitants per Dwelling	5.8		5.5	
Without Electric Energy	3,409,624	41.1	2,661,719	21.8
Without Piped Water	3,230,202	39.0	3,391,827	27.8
Without Sewage System	4,845,903	58.5	5,035,177	41.2
With Bare Earth Flooring	3,403,066	41.1	3,405,938	27.9
With Piped Water	5,056,167	61.0	8,701,146	71.2
Inside the dwelling	3,210,795	38.8	6,097,999	49.9
Not inside the dwelling but in the building or neighborhood				
Not inside the dwelling but access to a public tap	881,067	10.6	1,986,751	16.3
	964,305	11.6	616,396	5.0

Table 4.17.- Characteristics of Housing in Mexico, 1970 and 1980.

Source.- SPP/INEGI (1983b).

system and only bare-earth flooring. This meant that, from a population of 69 million in 1980, 18.5 million Mexicans were living without access to piped water and 27.5 million had no sewage system in their homes. In addition, there was an acute housing shortage with estimates varying from a 4 million deficit to a 7.8 million deficit (Schteingart,1984) (71). Whatever the figures, the important fact is all too clear. There are millions of Mexicans for whom the "benefits" of capital accumulation has meant very little or, simply, a miserable life. Effectively, from the viewpoint of poverty, insufficient diet, lack of education, etc., the pattern is roughly the same. For instance, a recent essay on poverty in Latin America (Serrano,1984a) provided the following picture for Mexico. In 1970, a national average of 34% of households were under the poverty line (72); this included 49% of households in the rural sector and 20% in the urban sector. In extreme poverty or destitution, there were 12% of Mexican households involving 18% of the households in the rural sector and 6% in the urban sector. In absolute numbers, this means that a total of 17.4 million Mexicans were under the poverty line in 1970, figure that reached 20.2 million in 1980 and is expected to reach 24.3 million for the year 2000 (ibid.). Other scholars suggest an even worse situation, "...Some 18 million underprivileged people in rural areas live in extreme misery; 40 million Mexicans have a nutritionally inadequate diet, and 30 percent of the population consumes 10 percent of the food produced while the 15 percent with the most buying power consumes 50 percent" (Gonzalez Casanova,1980,p.162). A similar diagnosis is made by Chavez (1983) who points out that various studies, including those by the National Institute of Nutrition, suggest that two-thirds of the country's population has an insufficient diet. Moreover Chavez (1983) estimates that "...From the 3 million children who are born annually, at least two and a half million do so in an ecological environment propitious to malnutrition and infection, and, therefore, cannot develop all their human capacities" (Chavez,p.226).

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(71) "There is a housing shortage of 6 million units, and 40 percent of the existing "homes" consist of only one room with primitive roofing. A million families are homeless, and about half the population lacks sewage services, toilets, potable drinking water, floors other than dirt, social security, adequate footwear, or an income of more than \$0.25 (U.S.) per person per day" (Cockcroft,1983,p.3).

(72) In this essay, "poor families" are defined as "those whose pattern of expenditure in food and other consumer products (clothing, etc.) does not enable them to satisfy their minimum nutritional needs". A complementary definition is that of "destitute families" as those "which would not satisfy their minimum nutritional needs even in the case of assigning the totality of their resources to the purchase of food" (Serrano,1984a,p.757).

It is not surprising, therefore, that infant mortality is still very high in Mexico. For instance, between 1971 and 1972, deaths of less than five year old children amounted to 43% of total deaths, while for the same category and years, the figures in Cuba, Canada and the US were 18%, 4.6% and 4.2%, respectively (Lopez,1980). Officially, the death rate for less than 1 year old children was 48.9 per 1000 registered births. More realistic estimates, however, put the figure as high as 73.3 deaths, with great disparities for different areas of the country. In one particularly deprived area, death rates of 227 per 1000 births are estimated. In 1978, Mexico was among the 10 American countries with the highest infant mortality rate. It had a rate 3 times greater than Cuba, and 15 and 14 times greater than Canada and the US, respectively. Among the most common causes of infant deaths were infectious diseases accounting for 50% while nutritional deficiencies occupied the seventh place. With regard to general mortality, again Mexico was high in the American ranking. It occupied the eighth place in mortality due to infectious diseases and enteritis; fourth place in mortality due to influenza and pneumonia; and fifth place in mortality due to tuberculosis [Lopez(1980),Narro et al(1984)]. All these causes of death have a much lower incidence in other countries such as Cuba, Canada and the US. Just consider tuberculosis, a disease which causes 2.2, 0.8 and 0.7 annual deaths per 100.000 in Cuba, Canada and the US, respectively. In Mexico the same statistics is 16.5 persons (Lopez,1980).

It seems pretty clear that, as a social phenomenon, deaths in Mexico follow the general pattern of social inequality. As Almada (1982) has put it,

*" The avoidable character of a significant number of these deaths cannot be ignored, given that causes of deaths which have been controlled or eliminated in other countries, take in Mexico a heavy toll of lives...[In addition A.M.]... The distribution of deaths, diseases and disabilities does not follow an arbitrary path, instead it affects predominantly the sector of the population which lacks potable water, sewage, adequate housing, balanced and sufficient diet..."(Almada,pp.33-34).*

It is primarily the task of the state to tackle the roots of the unfair distribution of life and death in Mexico. A look at table 4.18, however, shows that the proportion of the total population protected by some form of social security institution is still less than 50%. In effect, although between 1970 and 1979 there was an important increment in the number of people covered by some form of social security, the fact is that in 1979 almost 60% of the population, that is, some 40 million people, were not part of any institution. In contrast, the military, and important state enterprises like PEMEX and FF.CC

Category	1970		1979	
	\$	Index	\$	Index
Total Population Protected by Social Security Institutions	24.1	100.0	41.5	225.9
Instituto Mexicano del Seguro Social (IMSS) (1)	19.5	100.0	31.1	212.1
Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado (ISSSTE)	2.7	100.0	7.9	394.2
Secretaría de la Defensa Nacional	0.5	100.0	0.5	78.6
Secretaría de la Marina	0.2	100.0	0.2	167.1
PEMEX	0.7	100.0	1.0	197.6
PP.CC	0.5	100.0	0.8	188.5

Table 4.18.- Coverage and Structure of Social Security in Mexico, 1970 and 1979.

Source.- SPP/INEGI (1983b)

(1) The IMSS had 80% of the protected population in 1970 and 75.1% in 1979. Behind in importance came the ISSSTE with 10.9% in 1970 and 19% in 1979.

(Railways) had their own systems. The health needs of the 40 million inhabitants out of the social security system was thus left to the Ministry of Health and Assistance and hence, to the facilities this institution could provide. In 1976, these facilities meant a "capacity of hospitals, assistance centres and services which could cover between 15 and 18 million persons. That is to say, between 20 and 25 million of Mexicans lack permanently of any health service" (Lopez,1980,p.196).

Finally, to bring our excursion into the social conditions of the Mexican society to an end, table 4.19 provides a quantitative picture of the educational situation in the country. Again, we see advances between 1970 and 1980. Yet in 1980 almost 9 million from a total of 55.8 million people over 6 years old were illiterate. In addition, for the majority of Mexicans the level of education hardly goes beyond the primary level. Thus, in 1980, from a total of 47.6 million people over 10 years old, more than 30 million, or 64.4%, found themselves in this category. For the case of people over 40 years old, the situation was even worse: from a total of 12.5 million, 71.6% or approximately 9 million never went beyond the primary level. In fact, 3 million people alone had no instruction at all. The number of persons with some post-primary instruction was less than a quarter of the population of over 10 years old, although the actual level of education reached was not clear. At any rate, university education has benefited only a tiny minority, since in 1970 only 3% of those over 24 years old held some university degree (Fuentes,1983). In terms of geographical distribution, all these inequalities became even worse. For instance, the rate of illiteracy for the states of Chiapas, Oaxaca and Guerrero was over 35% in each one of them, while for the Federal District (Mexico City) and Baja California the rate was 5.9% and 6.6% respectively. Likewise, there is a marked sexual discrimination insofar as illiteracy affects more the women than the men population (Islas,1984).

All in all, it is abundantly clear that Mexico's path of dependent capital accumulation has led to nothing like the freedom, equality and justice proclaimed as the ideals of the Mexican Revolution and the ultimate goals of the country's development process. The mass of the people has benefited little from the accumulated wealth which has accrued primarily to those social sectors involved in the control and stability of the prevailing power structure. There is certainly nothing inevitable about the widespread conditions of poverty and



Category	1970	%	1980	%
Population Between 6 and 14 years	12,431,880	100.0	17,499,932	100.0
Illiterates	4,162,981	33.5	3,120,791	17.8
Population of 15 years or more	25,938,558	100.0	38,324,335	100.0
Illiterates	6,693,706	25.8	5,750,934	15.0
Population of 6 years or more	36,370,438	100.0	55,824,267	100.0
Illiterates	10,856,687	28.3	8,871,725	15.9
Population of 10 years or more	--	--	47,622,962	100.0
Illiterates	--	--	5,667,132	11.9
Primary instruction:1st to 3rd year	--	--	9,810,330	20.6
Primary instruction:4th to 6th year	--	--	15,191,724	31.9
With some post-primary instruction	--	--	11,334,264	23.8
No specified	--	--	5,619,509	11.8
Population of 40 years or more	--	--	12,527,815	100.0
Without instruction	--	--	3,006,676	24.0
Primary instruction:1st to 3rd year	--	--	3,094,370	24.7
Primary instruction:4th to 6th year	--	--	2,868,870	22.9
Some post-primary instruction	--	--	1,365,532	10.9
No specified	--	--	2,192,368	17.5

Table 4.19.- Selected Data Regarding Levels of Education of the Mexican Population, 1970 and 1980.

Source.- SPP/INEGI (1983b).

inequality within the Mexican society. Rather, it has been the result of a definite social choice primarily exercised by those social forces who control and benefit most from the particular process of Mexican capital accumulation. As Purcell (1981) has put it,

"The problem for Mexican society as a whole, which can be seen most clearly in the rural areas, is not simply the lack of sufficient material resources, nor, as some think, a matter of bringing "traditional" or "backward" peasants, whose culture makes them inefficient producers, into the modern world. Rather, it is a problem inherent in the social, economic, and political structure of Mexico" (Purcell,p.46).

This judgement can be repeated in relation to each one of the social indicators reviewed above: housing, health, etc. For instance, for Eckstein (1977), the extremely non-egalitarian distribution of wealth "can be traced to a variety of factors, among them regressive fiscal policies, protection of oligopolistic enterprises, spotty enforcement of the existing tax laws, and inflationary government policies" (Eckstein,p.23). Likewise, in relation to malnutrition, Chavez (1983) argues that an improvement in the present situation is something that can be achieved by the present society. "The real cause of malnutrition is not the shortage of food but its distribution... The poor die because they lack food while the rich die from metabolic and cardiac problems because they have plenty of food" (Chavez,pp.227 and 229). In the same vein, for Lopez (1980), "...Health and disease are social phenomena insofar as there exists a social and political structure which allows that "man is affected by diseases whose mastering is at the reach of its hand when he organizes, in a more just social manner" (Lopez, p.219). The problem is that, in Mexico, that more just social manner will hardly grow out of the present form of capitalistic industrial development. The social priorities are simply not there. Look, for instance, at table 4.20 where the pattern of government's investments are given. The major relative decline suffered by the category of social welfare during the 1970s -a drop of more than 10%- is in fact clear indication that it is simply not in the overriding interest of the postwar social constituency made up by the state, transnational capital and private national capital, to lead the way towards a substantial social change. After all, is it not true that the present state of affairs is primarily the result of the domination of Mexico's development process by these same forces? Or as Cockcroft (1983) has put it in a more detailed questioning referring to the distribution of the benefits of the oil wealth.

"Why doesn't the oil benefit the poor ? Why can't the money pay for medical care, housing, and education ? It has that potential. But how

Category	1970	1972	1974	1976	1978	1980
Public Sector Investment	29,205	33,298	64,817	108,611	217,382	486,178
Industrial Sector	38.0	34.5	36.0	46.0	48.0	45.6
Social Welfare	27.1	23.1	20.8	14.5	16.0	16.6
Transport and Communi- cations	19.9	23.7	24.0	19.2	14.5	12.1
Agriculture, Fishing and Rural Development (1)	13.4	14.8	16.9	14.8	19.4	18.7
Tourism	--	0.4	0.6	1.3	0.4	0.6
Administration and Defense	1.6	3.5	1.7	4.2	1.7	3.2
Coordination Exclusive Agreements (2)	--	--	--	--	--	3.2

Table 4.20.- Structure of Public Sector Investment by Sector of Activity, 1970-1980.

Source.- SPP/INEGI (1983b).

{1} Starting in 1976. It includes Commerce,

{2} Started only in 1979.

can it go for the people's needs if the bureaucrats and capitalists spend it on wine, women and song ? How can capital investment increase or profits be maintained without a low wage scale, and how can this be guarantee unless under- and unemployment in turn guarantee a reserve army of unemployed ? This is the dilemma of the capitalist state" (Cockcroft,p.4).

For our purposes the important fact is that it is the same capitalist state and process of development which provide the framework for the problem of indigenous microelectronics capability. Hence, as we shall corroborate later on, IMC for development purposes in Mexico actually means the development of a capitalist IMC. The fundamental question thus arises. Is a Mexican IMC a viable proposition given both the findings of Chapters 3 and 4 and the internal context we have just examined ? To this we now turn our attention by looking first at the state of development of Mexico's R & D capabilities and then at the country's electronics capabilities.

## 4.2. Science and Technology and the R & D System in Mexico

The intrinsic science-based nature of microtechnology makes the possession of an R & D capability an inescapable requisite for an indigenous microelectronics capability. In Chapter III, we discussed this fact and showed that, in principle, science was the only social force which could be considered as intrinsic to the dominant social constituency of an IMC. Consequently, we discussed the postwar evolution of the US's R & D system and the workings of the corporate capital-government-military-science social complex of power which has effectively been its dominant social constituency in contemporary US. In so doing, however, we discussed the evolution and shaping of an existing and developed system in accordance with the interrelating interests of a complex of social forces involved in its development. In other words, the reality of the US's R & D system and its social constituency was accepted (73) and our concern was its historical evolution. In the Mexican case, the latter is something we cannot afford to do, for such R & D is hardly in existence and its social constituency, as we shall presently see, is yet to involve private capital in a country which is seeking capitalistic forms of development. Likewise, the conspicuous absence of a science constituent from the process of industrialization we discussed in the previous section is but another manifestation of the same reality. In the following, given the importance of a national R & D system for the possession of an IMC, we shall first examine the broad context of Mexico's science and technology, and then, more closely, the characteristics of the Mexican R & D system, its social constituency, and the efforts being made to foster its development.

### 4.2.1. The Science and Technology System in Mexico: Goals and Problems

Nowadays, it has become almost a matter of faith among Mexican policy makers and government that an autonomous development of science and technology is the only way to ensure autonomous development and national self-determination. This view which began to take deep roots in the spheres of government in the early 1970s (74) and only after the process of ISI came into

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(73) This we could do on the basis of our discussion in Appendix III where we examined the origins and early development of the US's R & D system and its social constituency.

(74) In 1971, the National Council for Science and Technology (CONACYT) was established to give shape to Mexico's science and technology policy. In 1976, CONACYT produced the first major policy document in this area; it was the *National Indicative Science and*

crisis with its sequel of technological dependence and balance of payments problems, was given prominence in the current National Development Plan.

"In the international ambit, the differential solution to the crisis of the 1980s will rest partly on the capacity of industrialized countries to generate and apply knowledge. Mexico cannot isolate itself from this dynamics without jeopardizing its development potential or its national independence in the long run. By means of national research and development the aim will be to seek the country's scientific and technological self-determination and to ensure that the external transfer of technology is optimally exploited....Science and technology will seek to offer alternative solutions to the country's social and economic problems, among which the most salient are: those activities in which strategic national interests are involved, the satisfaction of the basic needs of the population, the creation of an internationally competitive industrial sector, and the integration of the national productive structure" (Poder Ejecutivo Federal,1983,p.61).

The national development plan devotes a complete section to outlining a diagnosis and guidelines for action in relation to Mexico's scientific and technological development, all of which was later incorporated in the *National Programme of Technological and Scientific Development, 1984-1988* (Poder Ejecutivo Federal,1984) (75). It is this document which constitutes the official philosophy and policy currently dominating Mexico's search for an autonomous S & T capability. Thus, in line with the national development plan, the T & S programme defines as its two general objectives:

To increase the technological self-determination of the country.

To integrate scientific research to the stock of national resources for the solution of the problems of all sectors of national life.

The T & S programme makes it clear that Mexico is not seeking scientific and technological autarchy but, rather, the gradual transformation of an "excessive dependence into a relation of interdependence with the technologically

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*Technology Plan, 1976-1982* launched in the last year of Echeverria's administration. This plan was practically abandoned by the incoming administration of Lopez Portillo who in 1978 launched his own *National Science and Technology Programme, 1978-1982*. These are the direct precursors of the current S & T plan launched under the administration of Miguel de la Madrid. To a large extent the three documents represents the S & T response of different government to different historical circumstances but they also represent an evolution in the search for an S & T approach which is appropriate to the government interests and needs. Thus, although practical policies and instruments differ from one document to the other there is a basic continuity in the fundamental objective of using S & T to achieve both technological self-determination and the solution of the country's major social problems.

(75) From now on the T & S programme.



advanced countries" (Poder Ejecutivo Federal,1984,p.37). In this context, it specifically defines technological self-determination as,

"...having the capacity to apply scientific knowledge to the solution of national problems without having to resort to external solutions unless it is to complement the national solutions. Technological self-determination includes the capacity to choose technologies which increase the international competitiveness of our productive structure; it also means a tendency to invest more in assimilation, adaptation and local development of technology rather than in its importation" (ibid.p.38) (76).

In the fulfillment of technological self-determination, the T & S programme identifies two crucial aspects which highlight the breath and complexity of the task facing the development of the autonomous Mexican S & T system. First is the possession of a strong scientific capability since " it is no longer possible to conceive a technological development without a development of scientific research" (ibid.). Second is the effective demand by the Mexican productive system since "the scientific flourishing of a country is only possible if it is sustained on the demand for national technology by the economic structure...[This means that A.M.]... The country's scientific and technological development is a task that involves as much the science and technology system as the production system" (ibid.,p.39). In brief, the T & S programme has put in the agenda of Mexican S & T policy the goal of integrating into one cohesive system the activities from science to production. Self-determination will emerge from such a system and, conversely, the latter will be the expression of self-determination.

How this can be achieved within the context of social forces discussed above is an issue that the document is basically not concerned with. Indeed, there is an implicit belief in the capacity of the government to bring about the necessary conditions for the flourishing of an autonomous S & T system in Mexico. Through direct investments, legal incentives and regulatory controls within the context of a correct strategy, the assumption is that the government can redirect the thrust of the Mexican economy towards the development of a national S & T capability. All this without the need to confront transnational

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(76) This idea is basically the same as in the first (1976) national S & T plan. There technological self-determination was defined as the "construction of a domestic capacity that would permit the demand for technology to be oriented progressively...towards local sources of technical knowledge; that would rationalize purchases of foreign technology and help to assimilate and adapt imported know-how, using it as the basis for internal generation of technology" (Wionczek,1979,p.224). Later, the second (1978) S & T plan defined technological self-determination as the capacity to take, independently, those decisions which will define the future development of Mexico (CONACYT,1978).

capital but, merely, of curbing its excessive practices through such legislation as we saw in the previous section. Thus, what seems to matter most in the view of Mexican policy-makers is the unilateral strengthening of the country's own S & T capability through the creation, support and integration of all the institutions and legal instruments considered necessary for this goal to materialize. In this sense, the underlying philosophy seems to be that the technological advantage of transnational capital with its sequel of consequences is not just the result of TNCs' technological strength but, primarily, the result of Mexico's own S & T weakness which does not allow the country to benefit fully from the presence of TNCs. And this is what the T & S programme sets out to change by seeking to integrate "science and technology in the tasks of national development" (ibid.). To what extent this can or is to be accomplished from within the framework of the "triple alliance" is hard to say. But given the previous historical record of the Mexican constituency, one has every reason to doubt the likelihood of any major change in Mexico's technological dependence (77). On the other hand, the extent and deepness of the present crisis in Mexico may be just creating the galvanizing pressures for the emergence of a new path of economic and technological development which may lead towards a more genuine effort for greater autonomy (78). In this respect, however, the recent and renewed drive to rely on foreign capital which we saw in the previous section seems to indicate that such a new path will not come about, and that, if anything, a deepening of the interrelations of the "triple alliance" and its dependent model of capital accumulation is actually taking place. In the latter context, one can only say that the unilateral strengthening of Mexico's

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(77) Discussing the same issue in relation to the first (1976) national S & T plan, Nadal (1977a) wondered if it was really possible "to transform the 'model of technological development' without altering the model of economic development. It is clear that the answer is negative since the latter is the fundamental conditioning factor of the former...there is at present a 'pattern of dependent technological development'...[and]... this state of affairs is a direct *consequence* of the model of socio-economic development" (Nadal, pp.34-35).

(78) Interestingly enough, the T & S programme itself acknowledges not only the failure of regulatory legislation but also the need for galvanizing pressures in order to generate effective change. In reference to the present economic crisis, it somehow welcomes the lack of foreign exchange currently affecting Mexico as a boon for the development of the country's own technological capabilities. "Thus far the cultural and commercial relations with foreign nations have meant for the country a negative balance in technological matters. Despite the legal instruments to regulate its import, embodied and disembodied technology has been acquired in a practically indiscriminate form and without concern for its assimilation. It is expected that in the future the lack of foreign exchange will reduce markedly the possibilities of maintaining this attitude; in these conditions there will have to be a better use of the financial and technical resources available to the country, and the start of an endogenous development based on the diffusion of mature technologies, the assimilation of

own S & T capabilities looks more urgent than ever before. Let us see, therefore, what the current state of development of Mexico's S & T capabilities is, or to put it differently, What are the major structural problems the government will have to solve in order to achieve its advocated goal of technological self-determination ?

As part of their exercise in S & T planning, Mexican policy-makers have carried out an extensive diagnosis of the country's S & T system. The most relevant features transpiring from this diagnosis, which can be found not just in the three official S & T plans (79) but also scattered in a variety of studies through the 1970s and 1980s (80), are basically two: first, the remarkable resilience of the fundamental problems of Mexico's S & T system notwithstanding the support and advances since the 1970s; second, the extensive nature of the problems and interrelations involved which, emerging from the all-pervasive reality of technology itself, has led to an integrated view identifying and linking Mexico's deficiencies from scientific research to production, education and S & T policy itself. Reflecting the latter, the current T & S programme for development has adopted a system view of what it calls the National Science and Technology System (SINCYT) and which defines as the interrelated set of the following set of six subsystems and their corresponding functions:

- "a) *research*, whose function is to generate new scientific and technological knowledge
- b) *research-production linkage*, which must orientate the choice of technologies, apply technological knowledge to the production of goods and services, and translate the needs of national production into specific demands for technology.
- c) *research-education linkage*, whose function is to educate professionals and researchers of the highest level for the productive system
- d) *social communication*, which must diffuse through society information about the nature, functions, problems and products of science and technology
- e) *regulatory and planning*, which must provide political and legal framework for the science and technology system; and establish, monitor and evaluate the national strategies and actions in this area
- f) *coordination*, whose function is to facilitate the interaction of the system components among themselves and with other sectors of society" (Poder Ejecutivo Federal, 1984, p.24).

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new technologies and the innovation and transfer of advanced technologies" (ibid., p.43).

(79) See note 74 above.

(80) See Wionczek (1979), Chavez et al (1974), Schoijet (1979), UNESCO (1978), Marquez (1982), Alvarez et al (1982), Waissbluth and Gutierrez (1982), Ortiz and Torres (1975), Campos (1972).

Clearly this concept of national S & T system fails to recognize the crucial role of specific social interests (81). Nevertheless, it is still useful on at least two accounts. First, because it shows clearly the complexity and the large number of parameters involved in the task of achieving an integrated S & T system in a country such as Mexico; and, second, because it enables the distinction of the major aspects involved in such a system for purposes of diagnosis and analytical treatment (Chavez et al,1974). On the first account, the complexity of the task of achieving an integrated S & T system can be readily seen from the more specific list of institutions involved in such a process. According to Marquez (1982),

"At present day, Mexico's technological and scientific infrastructure is made up of the following elements: practically all the Secretaries of State; a national organism of coordination and promotion (CONACYT); the universities, the technological and higher education institutes; the institutes, research centres and industrial services; the laboratories of certification, quality control and metrology; the specialized technical information centres; the institutions of financial promotion; the engineering and consultancy firms; the research and development units of public and private enterprises; the juridical-legal framework in matters of science and technology (laws, regulations and official dispositions); the human resources qualified in R & D; and, finally, the foundations, academies and related associations" (Marquez,p32).

On the second account, the systemic distinction of the aspects, relations and institutions involved in Mexico's S & T system has made possible the necessary detailed diagnosis, analysis and goal-setting exercise which constitute the foundation of all serious policy-making (82). As a result, the analysts of Mexico's S & T system have generated a pretty detailed picture of the state of development of the system as a whole and of the problems affecting each one of its subsystems. Overall, the picture that emerges is hardly one of an integrated system. In the words of the current T & S programme,

"...the science and technology system is still very deficient because it is small, incomplete and uncoordinated. All the subsystems are insufficiently large in relation to the national context and, although there are some vigorous components, others are very weak or lack certain key elements. The greatest defect of the system is perhaps the scant interconnection between subsystems and between components of each one of them, which is necessary for a greater internal efficiency and for a global efficiency" (Poder Ejecutivo Federal,1984,p.24) (83).

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(81) For a discussion and critique of the systems view of S & T in the UDCs, see Amadeo (1979).

(82) We are not suggesting here that this will ensure the correctness of the resulting plan.

(83) According to Waissbluth (1982), "...The Mexican scientific and technological system currently has five main features: it is small, it has a high rhythm of growth, it is

In a more specific fashion, a study carried out by CONACYT in the 1970s identified, among others, the following problems as hindering the development of Mexico's S & T system,

"...deficient coordination between science and technology and the production of goods and services; absence of effective mechanisms of international cooperation; transfer of inadequate technology; lack of a satisfactory informative infrastructure facilitating decision-making in the choice of technologies; relative lack of human resources qualified to carry out research and experimental development; small proportion of national expenditure devoted to these activities, and difficulty in acquiring and maintaining scientific instrumentation" (Alvarez et al,1982,p.64).

At the level of each subsystem, the picture that emerges from the diagnosis of Mexico's S & T system is also one of deficiency and relative weakness. In the present work, we shall not attempt to review the state of affairs of each one of the subsystems since that is not necessary for our purposes. Instead, we shall focus on the major features of the first two subsystems distinguished above, namely, those of research and research-production linkage since, together, these subsystems more directly constitute the core of the R & D system so crucially important for the possession of an IMC.

#### 4.2.2. Mexico's R & D System: Characteristics and Social Constituency

Quantitatively, Mexico's R & D system is of a very modest size when compared with that of the developed countries, while, qualitatively, it shows the typical problems and imbalances of a dependent and underdeveloped system. Table 4.21 shows the magnitude of the total financial resources Mexico spent in R & D in various years. In 1980, the total expenditure was about \$370 million which amounted to approximately 0.24% of the country's GDP. In per capita terms, this amounted to 5.4 dollars for every Mexican. If we consider that IBM and AT & T alone spend about \$2 billion each on R & D (84), it is possible to realize how modest the Mexican R & D effort is. Table 4.22 gives a comparative picture (85). As we can see in per capita terms and as a

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heterogeneous, it has problems of linkage with users, and, paradoxically, it is non-existent as a formalized system" (Waissbluth,p.118). A similar statement had been made by Chavez et al (1974) almost a decade before, "...The examination of the present conditions of the SCT [scientific-technological system A.M.], reveals that in Mexico there exists no integrated system of generation, diffusion and utilization of scientific and technological knowledge" (Chavez et al,p.270).

(84) See Chapter III.



Year	GDP (millions dollars)	Total R & D Expenditure (thousands dollars)	% of GDP	Per Capita R & D Expenditure (dollars)
1973	54,536 <sup>(1)</sup>	102,209	0.2	1.8
1977	81,930 <sup>(2)</sup>	161,210	0.2	2.5
1980	154,892	371,739	0.24	5.4

Table 4.21.- Data Relating to R & D in Mexico, 1973, 1977 and 1980.

Source.- UNESCO (1978,1979), F Sagasti et al (1984).

{1} This figure relates to GNP.

{2} Calculated from figures in Mexican pesos. Rate of exchange for 1977, 1 = 22.57



Country	Total R & D Expenditure (thousand dollars)	% of GNP	R & D Expenditure per Capita (dollars)	Expenditure per R & D Scientist or Engineer (dollars)
U.S.A. (1976)	40,113,400	2.7	186.5	74,133
F.R.G. (1975)	9,358,719	2.3	151.4	90,130
France (1975)	6,121,568	2.0	116.0	93,280
UK (1972) (1)	3,227,693	2.0	58.7	42,490
Italy (1975)	1,787,198	1.1	32.0	47,106
Sweden (1975)(1)	1,239,462	2.0	151.3	82,644
Japan (1975)	10,024,310	2.1	89.8	25,057
USSR (1976)	23,399,400	4.9	91.2	18,633
Mexico (1980)	371,739	0.24(2)	5.4	17,182(3)

Table 4.22.- R & D Expenditure for Different Countries.

Source.- UNESCO (1979).

(1) Not including data for Social Sciences and Humanities.

(2) Data relates to GDP.

(3) Data for 1973.

percentage of national income, Mexico's R & D expenditure is well behind that of the most advanced countries (86). Such a situation is mirrored, for instance, in the fact that Mexico counted in 1984 with only 6,000 researchers having some kind of postgraduate study, which means a relation of less than 0.8 per 10,000 inhabitants as compared with figures of between 20 and 45 for the most industrialized countries (Poder Ejecutivo Federal,1984). However, a slightly better picture emerges as we consider the total expenditure for science and technology, which includes expenditure in formation human resources and social diffusion of information (87). Figure 4.1 illustrates the evolution of the volume of S & T expenditure in current and constant prices for the 1970s. Whereas figure 4.2 illustrates the evolution of this expenditure as a percentage of the country's GDP for the same period. Clearly, in real terms, S & T expenditure has reflected the ups and downs of the Mexican economy with the biggest jump taking place in the late 1970s as a result of the impact of the oil boom. On the whole, in 1981 Mexico was spending 4 times more than it did in 1971. This amounted to an annual growth rate of 11.5% through the decade (Marquez,1982). As a percentage of GDP, however, the increase from 0.39 in 1971 to 0.47 in 1981 was not impressive. Indeed, if we consider that the national S & T programme 1978-1982 put 1% of GDP as a goal to be achieved by 1982 (CONACYT,1978), we can see not only how modest was the actual performance but also how disparate the goals in official plans may be. The current T & S programme brings a new figure of 0.54% for 1982 (88), but this does not alter things very much since it is clear that the economic crisis that began to bite the same year must have had a negative effect once again. In the words of the director of CONACYT at the time,

"During 1982, we have had to decrease the size of the editions of our journals, suspend granting new scholarships, and stop financing new research, infrastructure projects, and important international cooperation programs. The decision has been difficult since we are fully aware that it will have long-term repercussions on the development of a scientific effort that was growing and creating gratifying perspectives"

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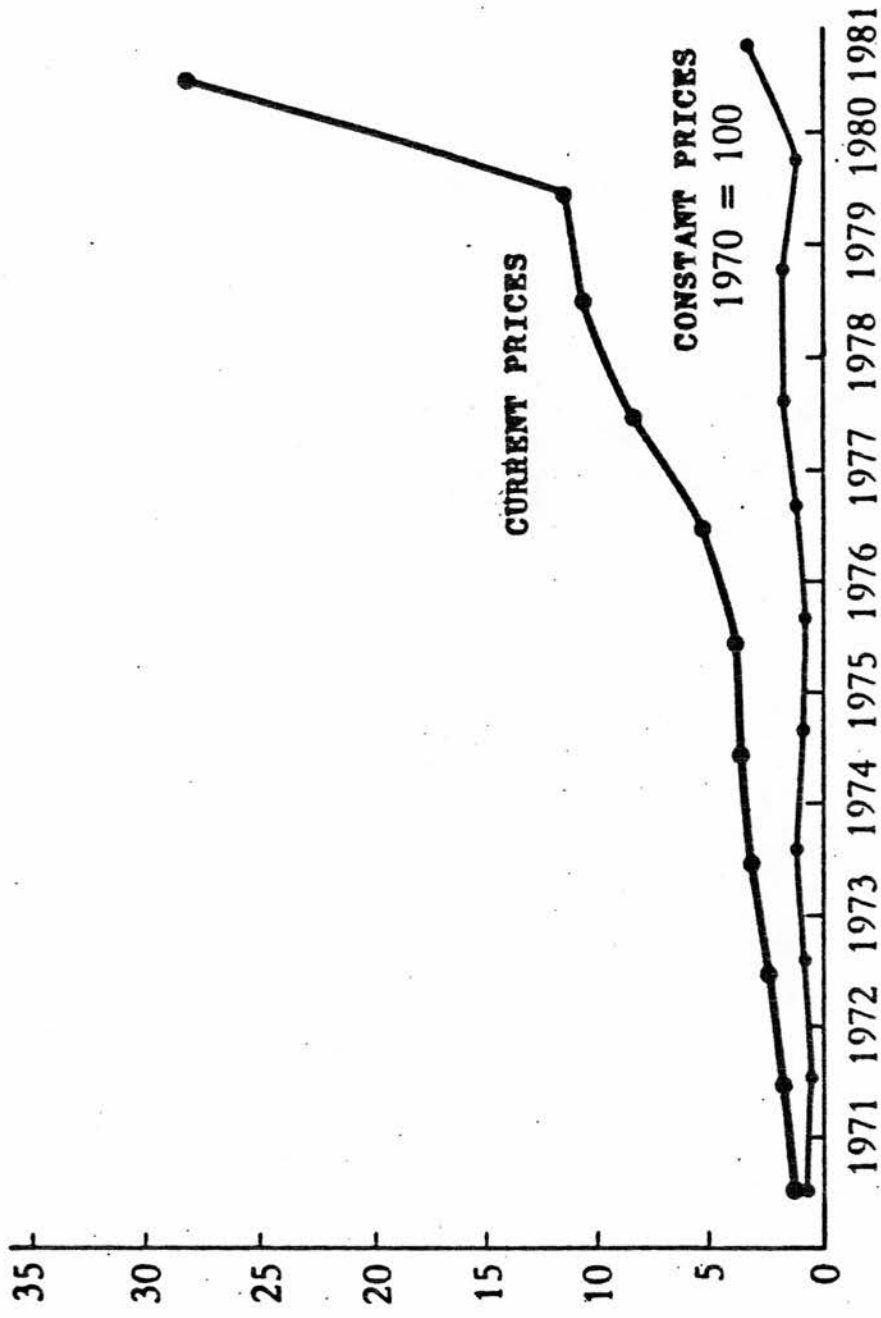
(85) Note that for Mexico the figures are for 1980 while for the other countries they are mostly for the mid-1970s.

(86) One has to take into account that the level of R & D expenditure before the 1970s was very low indeed. Spaey (1970) gives figures of 0.1% of GNP for the mid-1960s, while Nadal (1977) gives a figure of 0.06% for the same period. Spaey (1970) also gives a per capita figure of 0.5 dollars. See also Soberon and Poveda (1973).

(87) For instance, "...according to a study carried out in 1975 by the Exchequer and CONACYT, the public sector devoted 50.5% of its science and technology expenditure to R & D activities, and the remainder 49.5% to education, diffusion and support activities" (Marquez,1982,p.52).

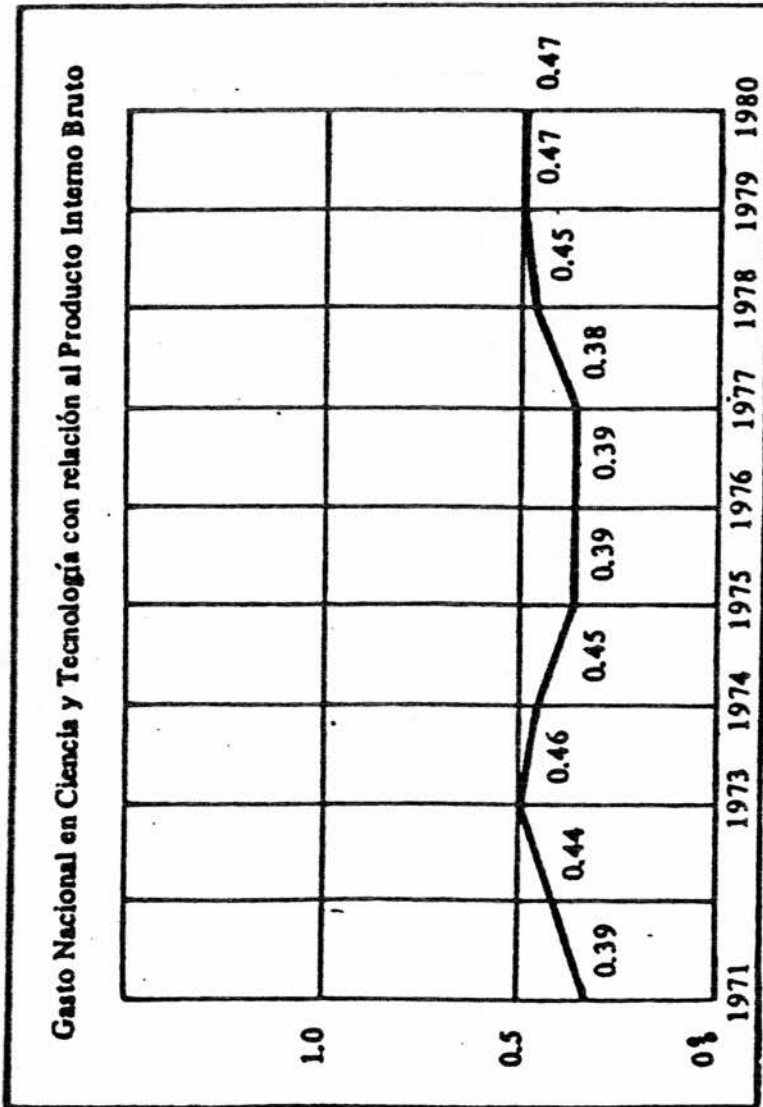
(88) Flores (1983) gives a figure of 0.6% for 1982, but this is in relation to Mexico's GNP.

BILLIONS OF PESOS



**Figure 4.1.- Evolution of Mexico's Expenditure on Science and Technology, 1971-1981.**

**Source.- E. Flores (1982), p. 111.**



**Figure 4.2.- Mexico's Expenditure on Science and Technology as a Percentage of the Gross National Product, 1971-1980.**

**Source.- E. Alvarez et al (1982), p.62.**

(Flores,1983,p.1401).

As it has been indicated earlier, it is not only the size of the Mexican R & D system that constitutes a problem. Undoubtedly of greater significance are the qualitative unbalances typical of a dependent and underdeveloped system which will not be solved simply by raising the level of financial resources. Among the most prominent of these unbalances, the following have been identified (89).

a) Mexico depends to an exaggerated degree on the development of science and technology in more advanced countries, thus limiting its output in many cases to purely imitative quasi-research activities in fields in which serious local R & D is badly needed.

b) It is estimated that the proportion of human resources devoted to the activities of basic research, applied research and technological development is 40%, 55% and 5% respectively. In contrast, in developed countries, the relative weight of basic research tends to range between 12% and 20% while that of technological development ranges between 48% and 65%. This shows how little R & D in Mexico is actually concerned with technological advance. In addition, the functional distribution of R & D expenditures is equally deficient. Almost 70% of financial resources is spent on salaries and wages, while less than 15% is available for the purchase of equipment indispensable for serious research.

c) National scientific equipment and materials are expensive and scarce; and specialized workshops for their maintenance are insufficient and in some places non-existent. This means that numerous projects must be delayed or interrupted due to lack of equipment and materials at the appropriate time. On the other hand, there are cases of overequipped laboratories, where the equipment may become obsolete even before it has been put into use.

d) Most R & D institutions face a critical lack of researchers. Less than 10% of the total existing research entities employ more than 20 people each, the minimum needed for relevant research in most fields. Those research centres with more than 100 researchers amounted to 10 in 1979, and between the 53 main research centres, together they employed 5,000 researchers and technicians. Compare this with the 17,000 professional staff employed by Bell Labs in the

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(89) See Poder Ejecutivo Federal (1984), CONACYT (1978), Wionczek (1979), Chavez et al (1974), Schoijet (1979), Alvarez et al (1982), Marquez (1982).

late 1970s (Braun and MacDonald,1978). In addition, there is a relatively wide dispersion of scarce resources as the latter are shared among too many projects. Table 4.23 shows that the rate of project per researcher was 1.22 in 1973 and that the funding per project was less than 12,000 dollars (90).

e) The ratio of research workers to auxiliary technicians is much higher in Mexico than in developed countries. It has been estimated at about 6:1 in Mexico against 1:2 in the UK and 1:1 in West Germany. This means that often researchers have to devote themselves to tasks other than research, thus affecting the productivity and the quality of the research.

f) Overall the scientific and technological productivity in Mexico is quite low as it is shown by the various indexes given in table 4.24. For instance, the proportion of researchers who published their work was only 0.08 by the mid-1970s. In relation to patenting, productivity was equally low with an index of just 0.02 patents registered by resident researchers. Thus, it is not surprising to find that from a total of 2,552 patents granted in 1982, 93.2% corresponded to non-resident applicants (Sagasti,1984). In addition, most of the patents granted to Mexicans have related to improvements on equipment, processes or materials.

g) Geographic and institutional concentration is enormous. Research institutions located in Mexico City account for 80% to 90% of all researchers, and more than 40% of the researchers belong to just 5 institutions.

h) The development of science and technology is highly unbalanced sectorally and by disciplines, with consequent neglect of important areas of research. There are research groups relatively vigorous and developed, specially in disciplines such as agricultural sciences, biomedicine, physics and some areas of engineering and social sciences. On the other hand, it is remarkable the disparity between Mexico's needs and the lack of strong groups in earth sciences research, meteorology, marine sciences, biology, economy and chemistry. Furthermore,

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(90) Years later, this situation seems to have changed little as it is illustrated by the case of IMEC (Mexican Institute of Research in Metal-Mechanic Manufacturing), a research institute established in 1976 to offer technological assistance to the engineering industries and develop projects of applied technology and technological development in relation to the concrete needs of these industries. Initial government plans were for a large institution to support the development of this crucial sector of the capital goods industry. However, in 1982, IMEC employed only 40 persons, of which 8 were engineers and the rest were employees, workers and technicians of a workshop. In spite of its limited resources IMEC had initiated 31 projects during its 6 years of operation (Lorentzen,1984).



Number of R & D Projects	9,287 <sup>(1)</sup>
Number of Researchers	
Individuals	7,582
Full-time equivalent	6,084
Financial Resources for R & D (thousands dollars)	107,763 <sup>(2)</sup>
Average Size of Projects (thousand dollars)	11.6
Project per Researchers	
Individuals	1.22
Full-time equivalent	1.53
R & D Expenditure as Percentage of GDP	0.22 <sup>(3)</sup>

Table 4.23.— Projects, Researchers and Financial Resources for R & D in Mexico (1974).

Source.— F. Sagasti et al (1984), p.1174.

(1) Comprises projects between December 1973, and October 1974.

(2) Figures for 1973.

(3) Percentage with respect to 1973 GDP.

Authors per projects	0.07 <sup>(1)</sup>
Authors per No. of researchers	0.08 <sup>(1)</sup>
Patents registered by residents per projects	0.02 <sup>(2)</sup>
Patents registered by residents per No. of researchers	0.02 <sup>(2)</sup>

Table 4.24.- Selected Indexes of Scientific and Technological Productivity in Mexico, 1974.

Source.- F. Sagasti et al (1984), p.1175.

- (1) Figure for authors is for 1976.
- (2) Figure for patents (residents) is for 1980.

search for technological knowledge is neglected in such areas of importance as subsistence agriculture, non-renewable resources, capital goods, transport and communications, and urban development and housing.

i) The links between the R & D effort and the educational and productive systems are very weak. The weakness of technical diffusion and extension services obstruct the transmission of knowledge to the productive system, specially in non-commercial agriculture and consumer goods industry.

These and a host of other less obvious problems (91) are part of the basic structural characteristics of the R & D system in Mexico. As it is possible to observe, the country is still far from the R & D reality of developed countries. Indeed the more so, if we consider the characteristics of the social constituency which is necessary to advance the development of the system in accordance with its overriding interests. In effect, in Mexico there is nothing like the powerful social complex of interests advancing and shaping the development of the US' R & D system for instance. To start with, the relative weight of Mexico's intrinsic science constituent is quite reduced, given not only all the problems and limitations we have just described, but perhaps of greater importance, the lack of immediate importance of the product of the science constituent for the overriding interests of other social forces commanding, for instance, the necessary financial resources to advance the interests of science. In the US, as we saw in Chapter III, galvanizing economic and politico-military forces have made science a fundamental element for the fulfillment of the overriding interests of capital, government and the military. In consequence, the science constituent has obtained huge resources to grow and fulfill its social purpose in exchange for shaping the product of its activity in accordance with the interests of the other social forces. In the Mexican context, however, this is hardly the case, for, in practice, apart from the government, there is no other force seeking to advance its own interests through the advance of Mexican science. This statement is clearly supported by the situation depicted in table 4.25, where the distribution of researchers and R & D financial resources is given. As it is possible to

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(91) For some organizational and cultural problems affecting research work in the most important Mexican university (UNAM), see Lomnitz (1977,1979). For instance, an interesting feature is that "the prevailing structure within the university (as in the country at large) places great rewards on administrative positions, since such positions are awarded as a form of recognition and represent practically the only available kind of promotion. Hence the well-known paradox, where advancement in the research profession requires abandoning one's research work" (Lomnitz,1977,p.324).

Sector	Number of Researchers (1980) (1)		Financial Resources (1978) (2)	
	Individuals	% of Total	Thousands Dollars	% of Total
Universities	3,832	36.8	67,851	24.7
Public Sector	5,685	54.6	169,216	61.6
Government agencies			166,194	60.5
State enterprises			3,022	1.1
Private Sector	718	6.9	23,350	8.5
Others	177	1.7	14,284	5.2
Total	10,412	100.0	274,701	100.0

**Table 4.25.- Distribution and Percentage Structure of Researchers and R & D Financial Resources in Mexico by Performance Sector.**

**Source.-** F. Sagasti et al (1984), p.1172.

(1) Estimated on the basis of percentage structure of 1974.

(2) Estimated on the basis of percentage structure of 1973.

observe, between the public sector and universities, they account for 91.4% and 86.3% of researchers and financial resources respectively. Private capital's share of researchers and financial resources is a meagre 6.9% and 8.5% respectively. In contrast to the case of the US, therefore, in Mexico not only the military plays a negligible role in the unfolding of the country's R & D system (92), but, most significantly, the fundamental force of capitalist development, namely, capital itself, plays almost no role when compared with the US where, currently, capital is the most important social constituent of the R & D system in terms of both source of funds and performance (93).

In more specific terms, the weak relative weight of capital in Mexico's R & D system means that private national capital and foreign capital alike are little interested in funding, demanding and shaping the products of Mexican science for purposes of their own specific interests. On the part of TNCs, they simply do not need to resort to such products nor they are truly willing to carry out R & D activity to generate them in Mexico. This is consistent with what we have found regarding the role of TNCs in the process of Mexican industrialization. Thus, in Schoijet's words, "...A nearly total lack of interest of multinational enterprises in local research and development is evident in Mexico. The pharmaceutical industry, a typically multinational industry, spends a lot on research in its central laboratories in the advanced countries but in Mexico it spends 26 times more in advertising than in research" (Schoijet,1979,p.409). In fact, studies carried out in Mexico in the 1970s showed that the source of the

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(92) Although Mexico's military expenditure has been increasing quite markedly in recent years -the joint army and air force budget increased by 55% in 1980- overall spending has been rather low by Latin American standards. for instance, Cuba with a population of 10 million has armed forces twice as large as Mexico with its 70 million inhabitants. Likewise, in 1980, Mexico's military expenditure (\$563 million) was almost half that of Cuba (\$1,907 million) and less than a third that of Brazil (\$1,907 million). See Goldblat and Millan (1982) and Tullberg and Millan (1983). In addition, it has also been noted that, as a share of GDP, Mexico has one of the smallest defense budgets in the world, only about 0.5% (Davidson,1986). Traditionally, the Mexican military have been very much out of the political realm. Some observers, however, have seen in the increased expenditures and other political concessions to the armed forces, a possible trend towards the alteration of this situation (Granados,1982).

(93) In the US, in 1982/1983, capital contributed 51.2% of all the funds for R & D; 68% of all the funds for industrial R & D; and performed an equivalent of 74.3% of all the funds for R & D (see tables 3.3 and 3.4 in Chapter III). In contrast, as the current National Development Plan acknowledges, in Mexico the contribution "of enterprises to national technological development is very limited; some industries have groups devoted to solving their own problems, but the scale of such activity is of little significance; in general, small and medium-scale industry shows no interest in research, whereas large industry pays excessive explicit royalties for imported technology or implicit royalties in the equipment which buys. This is true as much for private enterprise as for public ones" (Poder Ejecutivo

technology used by foreign firms operating in Mexico was chiefly the corporation or parent company [Nadal(1977),Wionczek(1973)]; and when they have relations with local scientific and technological institutions, these are basically for services such as troubleshooting, tests and quality control (94). On the part of private national capital, as Alvarez (1982) has put it, "...As a general rule, Mexican private enterprise has had neither the tradition nor the interest to support research and experimental development" (Alvarez,p.68). For some commentators the reason for this situation lies in the infrastructural weakness of Mexico's S & T capabilities and industry itself. Thus, "...Conditions are unfavourable for indigenous private enterprises to create important laboratories, because of the small size and poor managerial and technical skills available in such enterprises" (Schoijet,1979,p.409) (95). The current national T & S programme follows a similar line. It argues that the inability of the small and medium industry to develop new products is due to the following factors: lack of skills from its technicians, engineers and administrators; inadequate infrastructure for the development of technologies; obsolete equipment; lack of access to test laboratories and lack of capital (Poder Ejecutivo Federal,1984). Along with these factors, some scholars have also pointed to the Mexican entrepreneur and the lack of profit-making incentives or pressures existing in the Mexican economy. According to Campos (1972), Mexico has not had an innovative and risk-taking entrepreneur. Instead, thanks to a captive market, the entrepreneur has not only been able to afford inefficiency while obtaining large profits, but has been quite oblivious of the fact that production at low cost and high quality is one of the condition for successful competition in the international market. In specific terms, Campos (1972) identifies the following reasons for the lack of R & D capabilities in Mexican companies. Firstly, they have lacked the main incentive for research, that is, the presence of efficient competitor-enterprises. Second, the small size of the internal market in which most of the enterprises concentrate

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Federal,1983,p.164).

(94) "Out of 27 firms that were visited, twelve stated that they had no relations at all with local scientific and technological institutions. The other fifteen firms used local facilities for quality control activities (10), manpower training (6), technical troubleshooting (2), minor adaptations (1) and for process development (1). This last case is that of a firm which has strong ties with the Mexican Petroleum Institute in order to develop a suitable process for one of its by-products" (Nadal,1977,p.244).

(95) The relevance of the skills of existing human resources is another factor. For instance, while in the US 29% of all physicists worked in industry in the late 1970s, in Mexico there seemed to be no physicist employed as such in industry. The reason "is not only because industry could not use them or because it has never heard of them, but also because of the fact that until quite recently very few Mexican physicists were trained in fields which are most pertinent to industry" (Schoijet,1979,p.386).



their operations makes it difficult to afford research. Thirdly, research activities characterize themselves by their high degree of uncertainty while there are abroad proved technologies, involving no risk for the users (96). Hence, as the 1978-82 S & T plan acknowledged, "...Foreign technology continues to be for the Mexican entrepreneur the most expeditious and efficient option in order to make industry grow and to improve the quality of its products" (CONACYT,1978,p.1529) (97).

Thus far, therefore, it is plain that we have very little in the shape of a social constituency of Mexico's R & D system. On the one hand, the intrinsic science constituent has a very weak relative weight and, on the other, the fundamental constituent of its capitalist development, namely, capital, does not incorporate such R & D system as a crucial factor for the fulfillment of its overriding interests. This means that the government alone is effectively left as the dominant social constituent of the R & D system insofar as the latter has come to be perceived, increasingly, as an important factor in the process of economic growth and political stability that sustain its political power. Historically, however, this commitment to R & D by the government is rather recent. As we indicated at the beginning of the present discussion, it only goes back to the early 1970s to the establishment of CONACYT and the generation of the first national S & T plan in 1976 (98). Consequently, there is no long-

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(96) Wionczek (1973) also identifies similar problems along with the weakness of Mexico's S & T infrastructure and the major technological role of foreign private investment. He mentions "the high level of protection enjoyed by industrial activities in Mexico and the control of supply by a relatively small group of large enterprises in proportion to the magnitude of the national market. These factors explain the passive attitude of industrial enterprises in relation to costs, quality and adaptability of imported technology since, in the final analysis, it is the national consumer who pays the cost of inadequate technologies and of the subsequent inefficiency of the industrial process" (Wionczek,pp.245-246).

(97) A clear illustration of the behaviour of Mexican entrepreneurs is furnished by the pattern of investments in the capital goods sector in the context of Mexican policies of industrialization. "For the national investor the capital goods productive sector has been less attractive than those of intermediate and consumer goods, mainly because in the former sector there are no protectionist policies, but also because it is technologically more complex, thus requiring highly qualified personnel and a sustained R & D effort...The promotion of industrialization implied facilities for the import of capital goods; for the national producer, private or public, foreign equipment was cheaper, offered under better financial conditions, and of better quality..."(Poder Ejecutivo Federal,1984,p.15).

(98) Before CONACYT, there had been in Mexico national organizations dealing with the promotion and coordination of science, but none of them had any significance on the generation of a R & D system as such. Thus, in 1935, president Cardenas established the National Council of Higher Education and Scientific Research which operated until 1938; then the Scientific Research Promoting and Coordinating Commission was created in 1942, followed by the National Institute of Scientific Research in 1950. The latter organization was reformed in 1961. [Amadeo(1979),Marquez(1982)]. See also Soberon and Poveda (1973).

term experience to make a more definitive judgement about the true extent and depth of the government's commitment and, above all, of its ability to actually make possible the development of an autonomous R & D system. Even so, the fundamental approach implicit in the planning exercises and subsequent developments to the 1976 plan suggest a picture that casts serious doubts about the attainment of the latter possibility. In effect, at a fundamental level, since the government is committed to a model of development and social alliance of which it itself is a major social constituent, all the S & T planning simply ignores the fact that the present state of affairs is largely the result of the general model of development which has dominated Mexico since the postwar. As Leff put it in relation to the 1976 national plan,

"...[it]...establishes as its fundamental objectives scientific development, cultural autonomy and technological self-determination... But it avoids the analysis of the economic and political structure that produces...[the]...blocking effects, veiling capitalist dependence in the mist of nationalism, autonomy, liberty, etc. It is stated that scientific-technological policy must be integrated to the country's general development policy, but it is not made clear that the country's scientific-technological policy...has always been and will be the articulated outcome of a global policy of development" (Leff,1980,p.276).

Ultimately, what the government fails to recognize is that the present model of dependent capitalist development is based on a social constituency whose interests not only do not lead spontaneously to the development of an autonomous R & D system but, also, at least in the case of transnational capital, tends strongly to contradict such a development. In other words, what it fails to recognize is that within the context of the present process of capitalist development, the dominant social constituency of such a process is at the same time the social constituency of what we may call Mexico's R & D incapability. Of course, being itself part of the complex of interests of such social constituency, one can hardly expect the forces in control of the government to accept such a proposition. After all, the present state of Mexico's R & D system is also the result of many explicit and implicit government policies which for long neglected the search for its autonomous development. In this sense, it is possible to say that there is nothing permanent in the current interest of the Mexican government for the R & D system and, indeed, one may even doubt about the future of this interest too. To a large extent, all will depend upon the existence of societal pressures which put and keep S & T as an important goal in the strategy to fulfill the government's overriding interests. Past events clearly bear out the validity of this statement. For instance, the very creation

of CONACYT is said to have been prompted for economic as well as political pressures threatening the stability of the country (99). On the economic front, according to Wionczek (1973),

"...the preoccupation of the state for the cost, quality and adaptability of the technology available in the country has emerged only at the moment in which the saturation of the internal market and the difficulties of the balance of payments have faced Mexico with the need to change its industrialization policies passing from import substitution to others more effective which tend to promote the export of part of industrial production. It was at this moment that the inconveniences of the country's almost complete dependence upon imported technologies began to be discovered...Hence the creation, by the Executive's initiative in the late 1970s, of the National Council for Science and Technology (CONACYT)" (Wionczek,p.246).

On the political front, Lazcano (1982) points to the role of the political unrest in universities in 1968 which ended up in the Plaza de Tlatelolco massacre where scores of students were killed (100). In this connection, the foundation of the CONACYT also fulfilled the political need to channel resources to the R & D community as a means to both healing the wounds of 1968 and keeping a closer control on the activities of the academic community. This view was acknowledged by CONACYT itself in the 5th edition of its national S & T programme (1978-1982). There it is stated that,

"The CONACYT was born not only because there was awareness of the country's scientific and technological backwardness...but also as a probable solution to an acute political need detected as a result of the events of 1968, when the State realized that the conflict had been to a large extent exacerbated due to the lack of channels of institutional communication with the university scientific and technological community, that is, students and lecturers" (Quoted by Lazcano,1982,p.346).

As we saw in figure 4.1, it was in the early 1970s that the expenditure in S & T began to rise. Since then, the Mexican R & D community has received

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(99) There are two other exogenous factors which are often mentioned. First, the influence of the developed countries' S & T planning policies and the enormous growth of the R & D budgets in these countries with the consequent effect on the productive sectors. Second, the emergence of the "planning" fashion in Latin America which was stimulated by the US policy of Alliance for Progress and officially began in 1967 with the Conference of Latin American presidents at Punta del Este, Uruguay. With the Alliance for Progress -which was itself the US response to the alternative open by the Cuban Revolution- the US offered a new model for the granting of financial aid, which demanded from the receiving nations a clear definition of their needs, specified in time and by projects, that is, planning. Thus, it was at Punta del Este where for the first time the need was stated for the generation of national S & T policies that supported the economic and social development of Latin American countries. See Amadeo (1979), Leff (1980).

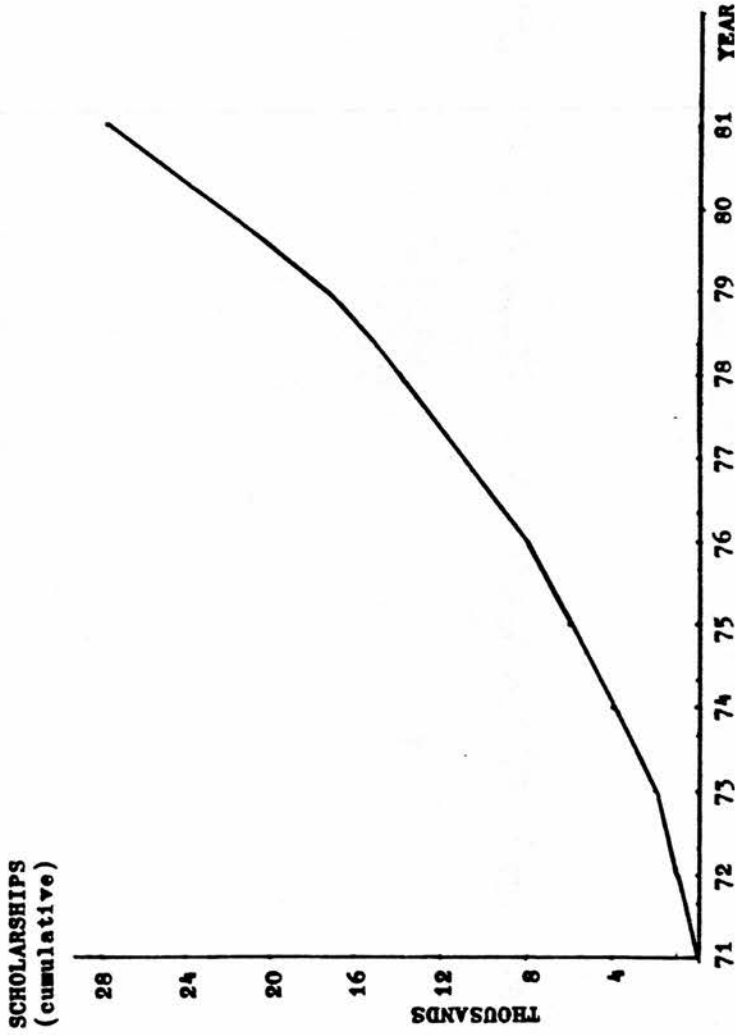
(100) See note 18 above.

important benefits through CONACYT's major S & T programmes. For instance, as figure 4.3 illustrates, the number of scholarships granted by the council reached a cumulative level of 28,000 during the decade 1971-1981. Members of the scientific community have also participated in the S & T planning exercises headed by the council and have benefited from the policy of promotion of scientific and technological international cooperation. Likewise, CONACYT's programme of research centres also involves the participation of institutions of higher learning along with state governments, industrial groups and other agencies. Through CONACYT, therefore, the government has attempted to give the R & D community an institutional channel for closer incorporation into the political system (101), thus diffusing a political tension which might have had threatening consequences for the stability of the system. At the same time, in response to economic pressures, CONACYT has become the spearhead of the strategy to strengthen Mexico's S & T capabilities in pursuit of the goal of technological self-determination.

As we have seen from figure 4.2, however, the political and economic pressures of the 1970s were not strong enough as to ensure that total S & T expenditure reached the advocated goal of 1%. In fact, the real levels achieved seem to have been enough for political stability, but it is quite clear that they fell far short from the requirements implied in a committed effort to attain technological self-determination. Of course, we already know that, during this period, the pressure of economic forces did in no way altered the fundamentals

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(101) President Echeverria, who set up CONACYT, was at pains to emphasize that this organization truly represented the interests of the scientific community above all others. "The council is a decentralized organ, with an independent status, and under its own control. Its sole point of contact with the government is a secretary of state, the Secretary of Communications and Transport, who was named its director-general by me, since the legal authority is vested in the President. He is a member of the scientific community, is considered by them to be one of theirs, and in this post he is well placed to provide them with economic assistance, mobility and contacts" (Echeverria, 1972, p.46). Some members of the scientific community, however, have strongly criticized what they see as the mediatization of Mexican science by an enormous bureaucratic apparatus that seeks to control its development. Perez Tamayo (1982) criticizes CONACYT as political organism whose directors are appointed more in response to political interests than technical interests. He sees bureaucracy growing to intimidating levels and argues that there is more interest in the promotion of CONACYT itself rather than S & T for the country. He proposes the dismantling of CONACYT and its replacement by a small agency directed by members of the scientific community instead of politicians. Bellinghausen (1982) and Lazcano (1982) basically agree with Perez Tamayo although they have little hope that CONACYT will be dismantled. One of the reasons, according to Lazcano (1982), is that "bureaucrats, unlike the rest of matter and energy existing in the Universe, do not obey at all the First Law of Thermodynamics, that is, bureaucracy never destroy itself, it only creates and transform itself" (Lazcano, p.345). Of course, from our viewpoint, this is true for all interest groups, including science itself.



**Figure 4.3.-** Cumulative Number of Scholarships Awarded by CONACYT, 1971-1981.

**Source.-** R & D Mexico (1982), p.38.



of the model of dependent capital accumulation dominated by the "triple alliance" of government, private national capital and foreign transnational capital. If anything, it became stronger by the late 1970s when the flood of imports clearly had the effect of increasing technological dependence, thus making a mockery of the technological self-determination efforts based on both legislative controls to curb the excesses of transnational capital and the national S & T planning promoted by CONACYT. Perhaps the clearest illustration of the fragility of any long-term government interest in, or commitment to, Mexico's S & T autonomy in the context of the "triple alliance" was the demise of the first national S & T plan of 1976, abandoned in the wake of the change of administration and a serious economic and political crisis in the country. As Wionczek (1979) explains,

"Under this conditions, the scientific and technological problems lost importance relative to the many other pressing problems that the government and public sector had to face, particularly because its authors insisted on the long-term nature of any effort in the field, and were unable to offer politically attractive solutions to the country's short-run problems" (Wionczek,p.230) (102).

It seems, therefore, that although S & T capabilities have come to be perceived as important for the realization of government interests, in practice, such importance is dampened by the long-term nature of the problem and, above all, by the permanency of a model of development whose social constituents not only do not advance spontaneously but, indeed, contradict the development of an autonomous R & D system in Mexico.

Nowadays, we are in the face of a new national S & T programme and the worst postwar economic crisis Mexico has ever suffered. Again S & T is talked about as a fundamental factor for the future of the Mexican nation and a detailed set of objectives, strategies and tasks, both general and specific, have been elaborated. Underlying it all, however, is the unquestioned permanence of the model of dependent capitalist accumulation and of the social complex of interests associated with it. The hope of the government is that, this time, due to the major restrictions created by the current crisis, particularly in foreign exchange, capital will be forced to decrease its dependence on foreign technology, thus searching for, using and developing national capabilities. Through

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(102) According to Schoijet (1979), there was no organized protest of any kind against the shelving of the plan "which shows both the fragile nature of the concensus achieved and the lack of coherence of the Mexican scientific community" (Schoijet,p.411). In other words, this shows the non-existence of an effective social constituency and the fact that the government



infrastructural support, incentives and controls, the government expects to reinforce this process to bring about the crucial integration between the R & D institutions and the productive sector. In the view of the programme,

"...the challenge facing the country in this respect is technological development at the level of productive plant, since in spite of the fact that in the last decade there have been notable advances in the endowment of infrastructure and formation of human resources highly qualified in research and development, an effective scheme of technological development at the industrial plant level has not been achieved" (Poder Ejecutivo Federal,1984,p.121).

Ultimately, under the galvanizing pressures of the present critical context and through a mammoth techno-bureaucratic effort, what the government is attempting is to stimulate and manage a process of reorientation of practices within the social constituency of Mexico's dependent capitalist accumulation in order to gradually transform a pattern of technological dependence into one of self-determination (103). In practice, this would amount to little less than creating from above the capitalist social constituency of Mexico's R & D system or, even more exacting, transforming what has effectively been the social constituency of Mexico's R & D incapability into that of Mexico's R & D capability. It would be in the latter constituency where finally the interests of government, capital and science would integrate each other in the manner we have seen in the most developed capitalist countries.

However, given the historical record and context that has predominated for several decades, the above goals seem hardly realistic. Instead, it seems much more realistic to expect that in a few years time we shall again be faced with a new national plan, the fourth, but very much in the same situation as far as the social constituency of Mexico's R & D system is concerned. Let us turn our attention to Mexico's electronics capabilities since we now have all the necessary elements to put into its proper societal perspective the analysis of the problem of indigenous microelectronics capabilities in a country such as Mexico.

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is the completely dominant social constituent. See also Amadeo (1979).

(103) One of the challenges the national plan poses to the country is "...The need to transform substantially the strategy of industrialization, replacing the pattern of technological dependence"...so as to divert..."present and future demand towards local sources of technological supply and, in this way, gradually and progressively to achieve self-determination" (Poder Ejecutivo Federal,1984,p.120).

### **4.3. Indigenous Microelectronics Capability in Mexico: Characteristics of the Electronics Infrastructure and Its Social Constituency**

The development of the electronics infrastructure in Mexico constitutes a particular manifestation of the processes and tendencies we have discussed in relation to the country's industrial and R & D capabilities. As such, it contains the essential sociotechnical features characterizing the development of the latter capabilities at the same time that those pertaining to the specific nature of the electronics infrastructure itself. In this respect, we shall see for instance that this is a technology whose dominant constituency not only brings together the same social forces of Mexico's industrialization process but it brings them together in a particular form of interrelations where the conspicuous fact is the large relative weight of transnational capital (104).

#### **4.3.1. The Electronics Infrastructure in Mexico: Goals in a Path of Capitalistic Development**

For the Mexican government electronics technology has assumed increasing importance as the realization deepens that its impact is bound to have strategic repercussions in the development efforts of the country. Very much in the same way as science and technology have been identified as crucial factors in the process of breaking with Mexico's dependence, thus electronics has begun to be perceived as particularly crucial for the future success of this strategic objective. As the current national development plan puts it,

"Because of its ever closer incorporation into the capital goods industry, because of the radical transformation which it induces in the production of certain services such as communications, health and education, because of the growing importance that its products have in final consumption, the electronics industry, and its associates such as optical technology, play a central role in the evolution of the organized production of goods and services, increments in productivity and the pattern of private and social consumption...By changing the relative productivity of factors, the introduction of electronics and its associated technologies in productive processes change the structure of comparative advantages at the international scale, the relative profitability of economic activities and enables the cheapening of the costs of services while increasing their efficiency. The unplanned development of these industries might be a cause of serious upheavals in the national economy, above all, if there is not an adequate choice of products and services to support the priority activities of the

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(104) This is a situation that we would not find in Mexico's oil industry, for instance.

country" (Poder Ejecutivo Federal,1983,pp.143-144).

With such a perception, it is not surprising that the Mexican government should consider electronics as a high priority industry for the development of the country. In practice, however, such priority began to take root within government spheres only by the early 1980s when the first major policies for partial sectors were produced (105). Until then Mexico had had no formal policy on the matter, let alone a strategy to deal with the increasingly integrated development of the electronics infrastructure. The latter concern is something that one begins to find only in the current National Programme for Technological and Scientific Research, 1984-1988, where, among the 11 technological R & D programmes related to national priorities, a complete programme is devoted to the development of the Mexican electronics capabilities. In the latter document, the present government exposes the reasons and establishes the guidelines and goals for the development of technological capabilities in various electronics areas which, taken together, would lead Mexico a long way towards the build up of an indigenous microelectronics capability. The areas identified are: materials used in the electronics industry, manufacturing of electronics components, development and application of instrumentation and automation, development of integrated digital networks in services, computer-aided design of integrated circuits, software, and personal microcomputers. In all these areas some definite achievements are envisaged during the present administration (1982-1988) and the ultimate goal is Mexico's appropriation of these particular technologies in fulfillment of the country's search for electronics self-determination. For instance, in relation to materials, the programme makes it clear that "...As long as Mexico is unable to process the materials required by the electronics industry, it will not be possible to break with the external dependence of this industry, even if the country were to count on the technological capability to produce components and equipments" (Poder Ejecutivo Federal,1984,p.317) (106). In this perspective, among the explicit technological objectives of the programme, one finds: development of technological capabilities to manufacture electronics in the country. In the short term, the fabrication of

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(105) In 1981, Mexico produced its Development Programme for the manufacture of Electronic Computing Systems, Central Units and Peripheral Equipment. Its aim was "to accelerate the objective of producing computer electronic systems, their central units and peripheral equipment, locally, so as to increase the internal level of self-determination in a branch of fundamental importance for development" (SEPAFIN,1981,p.4).

(106) Similar concepts are contained in the computer programme of 1981 in relation with the importance of possessing a computer capability. "Technological development in this sector is seen as an aspect of major importance which must contribute to increasing the capacity of

discrete semiconductor components is envisaged; these include diodes, transistors and circuits with a small number of elements. In the medium- and long-terms the country will develop the technological capability to produce LSI and VLSI integrated circuits and other components of major importance. A related objective here is the development of national technological capabilities for computer-aided design of ICs, including the equipment and testing technology of such ICs. In instrumentation and automation, one of the objectives is to implement advanced systems of instrumentation, data acquisition and automatic control in the productive and service sectors, and also to develop the area of industrial robotics. In telecommunications, a major aim is to promote the technological capability to modernize and expand the present digital network of the country and to develop components -particularly for optical communications- equipment and basic programmes. In software the aim is to develop technological capabilities to produce systems of computer programs in the areas of basic programs, advanced programming techniques and application systems. Finally, in the field of computers, the explicit objective is to develop the technological capability to specify, design and produce a low-price personal microcomputer along with its programs and peripheral equipment. Such microcomputer capability is conceived as a focal point for the development and integration of the country's other electronics capabilities, and its evolution is envisaged to reflect the rapid pace of advances characteristic of the electronics sector. For this reason, the programme states that,

"...it will be necessary to promote the country's technological capability in microelectronics, development of systems of programs, computer-aided design and computer-aided manufacturing techniques (CAD/CAM), design of peripherals such as keyboards, floppy disks, mass storage, low cost printers, digital graphic equipment, etc. Some of these aspects are considered in other focal objectives and their implementation and results will have to be incorporated into this microcomputer programme" (Poder Ejecutivo Federal, 1984,p.336).

There is little doubt that were Mexico to achieve the abovementioned electronics capabilities, the country would have taken an important step towards the development of an IMC. However, as we have argued in the present work, the actual possession of such capabilities is not something that can be judged in relation to technological facts alone, abstracted from the country's socioeconomic reality and particularly from the specific development purposes such technological capabilities are suppose to contribute to. Indeed, were we to refer to technical facts alone, it is quite conceivable that all the capabilities abovementioned might

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be acquired, for instance, at the level of laboratory or prototype without having any true and widespread impact, say, in the market place, the welfare of the population or whatever development goal has informed the search for their acquisition in the first place.

Of course, we have discussed Mexico's ultimate development goals before, and we have also seen that such goals are far from being fulfilled as the country treads the path of dependent state monopoly capitalism under the aegis of the state-transnational capital-national private capital social complex of power. In practice, this means that for purposes of the present discussion it is not the ultimate goals but the goals emanating from the latter complex of power which truly furnish the framework of reference dominating the purpose and hence, the very nature of Mexico's IMC. In this connection, it is necessary to remember the most crucial finding of our general discussion on Mexico's R & D capabilities, namely, that in Mexico the social constituents of the capitalist power complex have clearly contradictory interests regarding the autonomy of the country's industrial and technological capabilities, in such a way that it is overwhelmingly the government interests which constitute the driving force of the efforts to achieve such technological self-determination. Furthermore, to the extent that such government commitment is itself constrained by its very participation in the social complex of power and a deeper commitment to a model of dependent capitalist industrialization, it has been the logical consequence of such a context that the very concept of self-determination has been basically understood within the parameters of capitalistic forms of development. In the case of electronics, this has been explicitly reflected in the government policies for the build up of an IMC in Mexico which clearly have posited the particular capitalistic form of IMC as the long-term objective of the government interests. In effect, with little regard for the way in which the pursuit of such microelectronics capability will effectively bring Mexico closer to its ultimate development goals, government planners in the field of electronics have argued for the need to follow the pattern of electronics development dictated by the international market. As a document describing the present administration's strategy for the electronics sector has made it clear,

"The present administration has decided to act energetically, designing and applying an integral and selective strategy which will help to restructure the existing sectors of industry and promote the generation of those sectors in which we do not yet participate. The strategy

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self-determination and to reducing the factors of external dependence" (SEPAFIN,1981,p.5).



pursues four main objectives: international competitiveness, exports, national integration and technological development" (SECOFI,1985,p.1) (107).

In particular, in relation to international competitiveness the goal is for the national electronics industry to supply products having the quality, price, technology, delivery times, and servicing up to international standards. Unless these conditions are fulfilled, it is argued, "in the medium term we shall see that we cannot participate in new sectors and that those sectors we now have are in danger of extinction" (ibid.). This is all the more important given that the second main objective is exports which are envisaged as a springboard for a number of processes: to generate the foreign exchange necessary to acquire those inputs which are not produced in the country; to increase the volume of production and make national production more efficient; and to diminish dependence upon the fluctuations of the internal market. International competitiveness up to the standards of developed countries, therefore, is what specifically guides Mexico's electronics strategy as conceived by the interests of the government social constituent. Put in a different perspective, the government social constituent has chosen, as a means towards self-determination, an IMC development path which not only will engage Mexico's resources for years to come (108) but, most importantly, whose content and dynamics will be effectively shaped by the interests of the dominant social constituents of the developed countries' (mainly US's) IMC. Thus, it is primarily an exogenously-determined strategy which, in the light of past experience, offers little evidence that it will lead to the goal of self-determination and, above all, to the solution of some of the most pressing problems affecting the country's fast growing population. In the latter respect, it seems that, limited by the requirements of its own model of TNCs-dependent capitalist accumulation, the government is just being guided by both fears and hopes into following the electronics development patterns of advanced capitalist countries. For instance, a clear illustration of this fact is found in the current national T & S programme where the need to

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(107) Similar concepts were used in the 1981 computer plan. "The industrial sector of electronic computer systems, central units and peripheral equipment must be oriented not only to import substitution but fundamentally to the penetration of international markets. It must be highly competitive internationally and must promote national technological development" (SEPAFIN,1981,p.5).

(108) As president de la Madrid warned the country recently, "...Several years are required to establish a stable and solid export platform, taking into account a maturation period for projects, learning curves, organization of technology transfer, assimilation and development efforts as well as the formation and qualification of human resources. It may seem a long-time, but it is the only viable path and it is necessary that we should follow this direction immediately" (de la Madrid,1985,p.1187).



introduce automation is argued as follows.

"The purpose of this strategy is not merely the implantation of a technological pattern imitating that of developed countries, but rather to prevent low productivity affecting in the medium term the production and supply of basic goods for a growing population and translating itself as reduced purchasing power, worse income distribution, and loss of competitiveness in international markets; this would increase the country's vulnerability in the face of world economic phenomena" (Poder Ejecutivo Federal, 1984, p.123).

All this for a country which has more than 40% of underemployment with high levels of social deprivation and as if such social malaise were to be a problem of productivity alone. In fact, we have already seen that for all the increments in industrial productivity since the 1950s, Mexico's income distribution has actually got worse during the years. Nevertheless, with very little study about the likely impact of automation in Mexico's social structure, government's hopes for its application are running high. As the T & S programme has argued in relation to R & D in instrumentation and automation,

"In industrial sectors it will help to improve productivity, quality of products and safety and working conditions, thus enabling a better use of capital investment and available manpower. It will strengthen some branches which are still weak in the productive sector, and thus will have an impact on the durable and capital goods industry. In the service sector, it will be possible to achieve savings and improvements and, most importantly, the size of some of the systems in this sector (power network, potable water and sewage, etc.) makes their operation already practically impossible without the incorporation of automatic devices for instrumentation, data acquisition and control. The private and public sectors will be able to co-participate in the programme as generators of technology, as sources of problems, as sources of funds and as direct users and recipients of research and development results...The programme will contribute with scientific and technological inputs to promote the creation, or strengthening, of mixed capital enterprises. Also, it will increase the country's industrial sector competitiveness in the international market, both because of possible improvements in quality and productivity...and because of the development of patentable and tradable technologies at an international level. It is envisaged that this will be achieved in the medium-term and, in certain cases, even in the short-term" (ibid., pp.323-324).

All in all, therefore, the process of building up an IMC in Mexico clearly reflects the fundamental tenets of the country's global development strategy. Thus, the government's role in such an IMC process is being fundamentally determined by its deeper commitment to the global development strategy and its dominant social constituency. The result is that the advocated goals of self-determination and the very development purposes of an IMC can only be conceived within the limits imposed by the interplay of interests of all the

social constituents in the circumstances of particular historical conjunctures. As we shall presently see, in the past such interplay of interests has meant little for Mexico's electronics capabilities. Whether government promotion and the new historical pressures created by the crisis will be enough to radically alter the prevailing situation is something that remains to be seen. In the present work, however, an informed judgement will be attempted on the basis of a detailed examination of Mexico's present state of electronics development, the particular characteristics of its social constituency and the way the government constituent expects to influence the entire social constituency into advancing the cause of an IMC in Mexico. Before doing so, however, a few words are necessary about the Mexican in-bond or "maquiladora" electronics industry given that in the sections that follow we shall not be dwelling upon this sector notwithstanding its important magnitude within the Mexican electronics scene. The reason for this decision is that, qualitatively, such "maquiladora" industry is practically a foreign enclave with little relation to the Mexican industrial structure. In this sense, Rivas' conclusion for the "maquiladora" industry as a whole is also valid for the particular case of electronics. "There is no association with the industrial activity of the country. They are virtually isolated operations which provide work to an important number of workers but possess no link with the industrial base" (Rivas,1985,p.1079). A brief quantitative description of the electronics "maquiladora" industry has been given by Warman (1984). "The electronics sector represents 36% of the total number of "maquiladora" enterprises and 30% of their social capital, but 60% of their employed personnel and 61% of the total value of production of the "maquiladora" industry...The electronics "maquiladora" industry is oriented towards those areas of less technological content and greater labour content...the electronics "maquiladora" industry generates 65,000 jobs, 30% more than the national electronics industry, and in 1979 it exported 30 times more" (Warman,p.73) (109). To a certain extent, the latter comparison already suggests an idea of what may be the degree of development and magnitude of the national electronics industry. But let us not jump to conclusions without the necessary detailed examination to which we now turn our concern.

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(109) For other works touching upon the Mexican electronics "maquiladora" industry, see Grunwald (1985), UNCTD (1983), Minian (1981), US Department of Commerce (1979), UNCTAD (1975).

### 4.3.2. Present State of Development of Mexico's Electronics Infrastructure

The state of development of Mexico's electronics infrastructure has been the subject of serious studies only since the late 1970s. Until then little statistical analysis had been made of the separate electronics sectors with the result that quantitative data may vary for different studies depending upon the sources and criteria used for their calculation (110). This fact, however, does not affect the fundamental agreement that exists regarding the basic features and tendencies characterizing the development of the electronics infrastructure in Mexico. In this respect, whatever disagreement we may find, it will be more the result of perceptions and perspectives regarding the concept of IMC than the result of any actual qualitative problem.

In effect, from the view point of Mexico's IMC, there are some analysts who typically focus their attention on the technological fact of existing local capabilities and resources, normally at university or R & D level, but with little regard for the social context mediating the uprooting of those capabilities in the development of the techno-productive base of society. For instance, two of such analysts, after surveying the microelectronics situation in four Latin American countries (i.e., Argentina, Brazil, Mexico and Venezuela) concluded that,

"There already exists in Latin America an installed microelectronics capacity both at the governmental level and in the industrial sector as such. This potential varies from country to country, but all the countries visited possess the necessary assets for rapid expansion in the microelectronics area" (Fernandez and Octavio,1985,p.1).

Such optimistic view, however, is hardly found in those studies which have dealt with the Mexican electronics infrastructure in greater detail (111). Rather, the picture that emerges simply reproduces, most of the time in a magnified form, all the structural problems we have seen in relation to Mexico's industrial and S & T development. This is particularly the case for the crucial electronics sectors of semiconductors, computers, telecommunications, and measuring and control systems, given that Mexico's electronics base has been basically oriented

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(110) This means that in the present analysis we shall use statistics more as an indication of characteristics and tendencies than as any exact quantification of reality.

(111) Discussion on the characteristics of Mexico's electronics infrastructure can be found in various documents, particularly, government documents. See, for instance, Poder Ejecutivo Federal (1984), NAFINSA/ONUDI (1979), SPP (1980), SECOFI (1985), Moreno (1982), Calderon (1982), Warman (1982,1984), Marquez (1982), Nochteff (1985), Briceno and Rivera (1981), Villela (1981).

to consumer electronics goods (112). In relation to the former sectors -which form the core of what Mexican literature refers as professional electronics (113)- all diagnosis coincide in that Mexico's electronics base possesses the following characteristics: a) high dependence on foreign technology and capital; b) low R & D effort and lack of integration between R & D institutions and the productive sector; c) high costs of production and low productivity and heterogeneous levels of quality. For instance, the wide-ranging NAFINSA/ONUDI study of the professional electronics industry in Mexico provided the following account regarding the structure of this industry in the late 1970s.

"...the Mexican professional electronics industry is chiefly an assembly industry. Most of the main companies are the partial or total property of foreign companies, upon which they depend for the technology and design of their product. Those companies which are completely Mexican, generally have technological agreements or manufacture their products under licence from foreign companies and only a few, mostly small companies are completely independent...The dependence of local industry on foreign technology means that there is neither design nor development of national products. Due to the fact that Mexican electronics firms are subsidiaries of foreign companies, their production and commercialization policies are, to an important extent, determined by the parent companies and there are no incentives to develop products locally...The Mexican electronics industry faces a number of problems which enterprises in other countries do not have: high costs, insufficient quality and erratic delivery of raw materials and parts, lack of availability of electronic components, restrictions and long waiting-time for imports, etc... the greater product efficiency and quality is found in subsidiaries of foreign companies, which are organized and managed according to the pattern of the parent company abroad" (NAFINSA/ONUDI, pp.81-82).

The overall development of Mexico's professional electronics industry, therefore, is pretty weak and subject to major barriers. Certainly, in Mexico one finds no indication of what our analysis in Chapter II identified as one of the fundamental technical characteristics of an IMC, namely, the systemic and synergistic nature of the development process of microtechnology (114). Instead, as we shall see below, in Mexico complete sectors are virtually missing as far as national capabilities is concerned. In this sense, the fact that microelectronic

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(112) In the view of the 1978 S & T plan, "...Technological adaptation and development in electronics have been oriented about 90% towards industrial goods such as radios, televisions, toys, etc., and have not supported in an efficient manner the development of instruments for production and research" (CONACYT, 1978, p.1537).

(113) Professional electronics includes telecommunications equipment, measuring and testing instruments, process control instruments, computers and calculators, biomedical equipment, and electronic components and parts.

(114) As an example, Calderon (1982) notes that in Mexico only one of every 20 computers installed is used or interconnected via telephone lines, with the result that computer

components are not produced nationally cannot be taken as solely the result of lack of technology but, also, the result of the lack of fertile ground due to the minimal national production of microtechnology. In effect, the internal market is relatively small and mostly supplied by foreign companies whereas the international market is a far away possibility and whenever exports take place, these are done by foreign companies. In these conditions, Mexican market oriented technology cannot flourish and the synergy intrinsic to the development of microtechnology is structurally distorted or crippled as far as the build up of a Mexican IMC is concerned.

the analysis of Mexico's electronics industry sector by sector will reveal clearly the extent and depth of its structural weakness and dependence upon foreign capital. Table 4.26 provides a comparison between the structures of the Mexican and the US electronics markets. It shows not only that the total market for electronics products is about 90 times smaller than that of the US, but also that there are significant structural differences in terms of the electronics sectors dominating the development of the industry. Thus, unlike in the US, in Mexico it is the consumer electronics sector which clearly constitute the dominant market. The immediate consequence of such a situation is that most individual companies operating in Mexico have geared their activities towards this particular sector. Table 4.27 shows that from a total of 443 companies operating in Mexico in 1980 (115), more than 50% of them were oriented towards the consumer electronics market (116). Such concentration in the latter market, however does not mean that Mexico is self-sufficient in consumer electronics, nor that it has achieved anything like the technological standards of developed countries. Indeed, as Warman (1984) states, "the consumer sector which has developed in Mexico is that of less technological content" (Warman,p.72). Traditionally, this sector has been highly protected which, compounded to the effect of a relatively small market, has meant little pressure or incentive to invest in technology and produce high quality products at internationally competitive costs (117). For this reason, Mexico still imports

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networks have had a slow development in the country.

(115) The figure of 508 for the total number of enterprises which appear in the table is explained by the fact that some companies operated in more than one sector of the market.

(116) Warman (1984) has estimated that more than 75% of electronics enterprises in Mexico are oriented towards the consumer electronics market. This estimate, however, assumes that enterprises in parts and components supply almost exclusively the consumer electronics sector.

(117) "Clearly, the minimal investment in technology and Mexico's high costs of production are salient features. The former aspect results in the production and sale of obsolete models



Sector	U.S. Market	Mexican Market (1)		Relation
	Market Value (billions dollars) \$	Market Value (billions dollars) \$	Market Value (billions dollars) \$	
Components	10.9	10	0.1	1:109
Semiconductors	7.6	7	0.035	1:217
Data Processing	35.9	33	0.2	1:180
Telecommunications	5.45	5	0.25	1:22
Consumer Electronics	13.0	12	0.47	1:28
Others	36.1	33	0.145	1:249
<b>TOTAL MARKET</b>	109	100	1.2	1:91

**Table 4.26.- Comparison Between Mexico's and U.S.'s Electronics Markets by Sector, 1981.**

**Source.-** J. Warman (1984), p.72.

(1) In Mexico there are no statistics whose break down in different categories is strictly comparable to those categories accepted internationally. For this reason, the figures for Mexico must be taken as elements of comparison and not as precise estimates of the market.



Products	Number of Enterprises	\$
Professional Electronics	175	34.45
Telecommunications equipment	60	11.81
Test and measuring instruments	19	3.74
Instruments for process control	49	9.65
Computers and calculators	38	7.48
Biomedical equipment	9	1.77
Consumer Electronics	171	33.66
Audio	92	18.11
Video	48	9.44
Education	12	2.36
Entertainment	19	3.74
Parts and Consumers	162	31.89
Professional	66	12.99
Consumer	96	18.90
TOTAL	508	100.00

**Table 4.27.- Structure of the Electronics Industry in Mexico, 1980.**

**Source.-** L. Briceno and J. Rivera (1981), p.18.

a significant part of its consumer goods despite the existence of protectionist measures. Figures from the National Confederation of Electronics Industries put imports of consumer goods at 9% of total electronics imports in 1979. These figure, however, seriously underestimate the true level of consumer goods imports given that in Mexico smuggling plays quite an important role. Indeed, "diverse estimates indicate that from 30 to 50 percent of the national market is supplied with illegal imports" (Warman,1984,p.72) (118).

We see, therefore, that the strongest sector of Mexican electronics industry is in fact far behind the high standards demanded by international competitiveness. This means that we can hardly expect a better performance from Mexico's professional electronics sector. Tables 4.28 and 4.29 provide the quantitative picture of the evolution of this sector from 1973 to 1978. Starting from 1978, however, the trends implicit in the data from 1973 to 1978 were substantially altered as a result of the oil boom and subsequent crisis began in 1981 and which is still affecting the Mexican economy. Nevertheless, the 1973-1978 data are still useful because they provide an overall relative picture between production, imports, exports and consumption for the main professional electronics subsectors of finished products and components. This will enable us to gain a global and sectoral insight of the structural characteristics of the crucial professional electronics industry in Mexico, in the knowledge, later to be corroborated, that the oil-boom period brought about a major upsurge in electronics imports (119) and consumption followed by a marked decline of production and imports during the crisis.

From table 4.28, among the most salient structural features of professional electronics in Mexico, it is possible to distinguish the following. The market as a whole was heavily dependent on imports as total national production of finished

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which cannot be exported; the latter aspect is largely due to the lack of scale economies which results from the production of mass consumer goods for a relatively small market. The expenditure in technology is seldom directed towards innovation and, as a general rule, is devoted to the adaptation of obsolete models in order to make them adequate to the national conditions of production and commercialization" (Warman,1984,p.72).

(118) Smuggling is not just confined to consumer electronics. In 1981, there were also reports of serious distortions of the Mexican microcomputer market due to smuggling. "Ruben Tovar, whose firm, *Electronica M y M*, distributes Radio Shack microcomputers, reckons to have sold no more than 300 during the three years he has been in business, and his competitors may have sold the same, but there could be between 2,000 and 3,000 TRS-80 in the Federal District" (*Latin America Weekly Report*, 1981,p.10).

(119) The upsurge in electronics imports was merely part of the general rise in imports of all sorts of goods and, particularly, capital goods which, as we discussed earlier, took place during the oil-boom period.

Category	1973	1974	1975	1976	1977	1978 <sup>(1)</sup>
<b>Total Finished Products</b>						
Production	47.01	61.65	70.20	88.42	98.64	117.70
Imports	158.88	168.24	197.13	219.42	235.79	264.34
Exports	5.65	7.00	9.10	10.50	12.50	14.60
Consumption	200.24	222.89	258.23	297.34	321.93	367.44
<b>Telecommunications Equipment</b>						
Production	33.65	45.30	50.90	63.70	68.69	81.58
Imports	78.52	79.44	94.75	92.84	102.24	113.02
Exports	3.40	4.00	4.70	5.40	6.20	7.07
Consumption	108.77	120.74	140.95	151.14	164.73	187.53
<b>Test and Measuring Instruments</b>						
Production	-	-	-	-	-	0.10
Imports	6.40	6.80	7.00	9.30	10.10	11.04
Exports	-	-	-	-	-	-
Consumption	6.40	6.80	7.00	9.30	10.10	11.14
<b>Instruments for Process Control</b>						
Production	8.90	11.40	13.60	16.70	19.90	23.70
Imports	17.10	23.10	31.40	43.00	49.60	57.00
Exports	0.25	0.30	0.40	0.30	0.50	0.50
Consumption	25.75	34.20	44.60	59.40	69.00	80.20
<b>Computers and Calculators</b>						
Production	4.46	4.95	5.70	8.02	10.05	12.32
Imports	36.60	41.15	38.90	46.55	45.65	51.98
Exports	2.00	2.70	4.00	4.80	5.80	7.03
Consumption	39.06	43.40	40.60	49.77	49.90	57.27
<b>Biomedical Equipment</b>						
Production	-	-	-	-	-	-
Imports	20.26	17.75	25.08	27.73	28.20	31.30
Exports	-	-	-	-	-	-
Consumption	20.26	17.75	25.08	27.73	28.20	31.30

**Table 4.28.- Professional Electronics in Mexico. Summary of the Market for Finished Products, 1973-1978. (million dollars)**

**Source.-** NAFINSA/ONUUDI (1979).

(1) Estimated figure.

Category	1973	1974	1975	1976	1977	1978(1)
<b>Total Components and Parts</b>						
Production	160.50	186.50	207.65	219.70	227.00	241.30
Imports	28.76	31.63	28.57	26.98	25.53	24.34
Exports	2.50	5.60	11.01	13.05	14.48	18.70
Consumption	186.76	212.53	225.21	233.63	238.05	246.94
<b>Vacuum Tubes</b>						
Production	45.50	59.00	62.00	70.00	73.00	77.45
Imports	4.26	3.82	2.90	2.41	2.20	2.00
Exports	1.50	2.80	7.47	8.45	9.90	11.50
Consumption	48.26	60.02	57.43	63.96	65.30	70.71
<b>Semiconductors</b>						
Production	7.60	12.50	15.65	16.70	18.00	22.05
Imports	3.50	4.10	4.33	3.57	2.85	2.50
Exports	0.60	2.00	2.44	3.52	3.48	6.00
Consumption	10.50	14.60	17.54	16.75	17.37	18.55
<b>Passive Components and Parts</b>						
Production	107.40	115.00	130.00	133.00	136.00	141.80
Imports	21.00	23.71	21.34	21.00	20.48	19.84
Exports	0.40	0.80	1.10	1.08	1.10	1.20
Consumption	128.00	137.91	150.24	152.92	155.38	160.44

**Table 4.29.- Structure of the Electronic Components and Parts Market in Mexico, 1973-1978. (million dollars).**

**Source.- NAFINSA/ONUDI (1979).**

**(1) Estimated figure.**

products covered less than one third of total consumption with imports covering about 70%. At the same time, exports constituted a small fraction of total production, about 12%, meaning that Mexico's professional electronics industry contributed heavily to the country's foreign trade deficit. Indeed, NAFINSA/ONUDI (1979), following the trends implicit in the data of table 4.28, had expected a deficit of \$279 and \$313 million for 1979 and 1980 respectively. In practice, as table 4.30 shows, such deficit was considerably higher as Mexico began to experience the effect of the oil-based economic boom. Admittedly, the latter data includes consumer goods imports but, to the extent that in 1979 these were only about 9% of total reported imports, it is clear that the bulk of the total volume of imports corresponded to professional equipment and components.

The overall picture for the professional electronics industry, however, hides major differences between each one of the sectors. Thus, while in both test and measuring equipment and biomedical equipment Mexico was totally dependent with none or insignificant levels of local production, in other sectors, namely, telecommunications, computers, control and components things appeared to be somewhat more favourable. Let us examine more closely the situation in each one of the latter sectors, starting with control and components and then telecommunications and computers. The reason for this sequence is that global figures for the first two sectors actually hide a situation of profound weakness when it comes to electronics control and semiconductor components. In contrast, telecommunications is the strongest sector in the country's electronics infrastructure while the computer sector offers the first major government effort in wide-ranging policy-making aimed at developing the country's electronics capabilities.

#### **4.3.2.1. State of Development of the Area of Control Systems in Mexico**

The detailed statistical picture for the field of process control is given in table 4.31. As it is possible to see, the largest proportion of local production corresponded to non-electric controls and control valves. The production of electronics control systems and analytical instruments was minimal and the latter markets were satisfied almost completely with imports, particularly from the US. In addition, the control sector as a whole was widely dominated by transnational capital since all the most important companies (13 out of 53

YEAR	IMPORTS	EXPORTS	DEFICIT <sup>(1)</sup>
1979	861.1	50.3	810.8
1980	1364	163.7	1200.3

**Table 4.30.- Trade Balance on the Mexican Electronics Industry.**

**Source.- H. Nochteff (1985), p.26.**

**(1) Excludes the "maquiladora" industry.**



Category	1973	1974	1975	1976	1977	1978 <sup>(1)</sup>
<b>Total</b>						
Production	8.90	11.40	13.60	16.70	19.90	23.70
Imports	17.10	23.10	31.40	43.00	49.60	57.00
Exports	0.25	0.30	0.40	0.30	0.50	0.50
Consumption	25.75	34.20	44.60	59.40	69.00	80.20
<b>Electronic Control</b>						
Production	-	0.10	0.20	0.40	0.90	1.80
Imports	6.05	8.85	13.20	20.20	24.60	29.40
Exports	-	-	-	-	-	-
Consumption	6.05	8.95	13.40	20.60	25.50	31.20
<b>Non Electric Control</b>						
Production	4.90	6.25	7.10	7.20	8.40	9.60
Imports	2.75	3.36	4.30	5.78	6.00	6.20
Exports	0.25	0.30	0.40	0.30	0.50	0.50
Consumption	7.40	9.31	11.00	12.68	13.90	15.30
<b>Analytical Instruments</b>						
Production	-	-	-	0.10	0.20	0.30
Imports	1.30	1.70	2.20	2.90	3.20	3.70
Exports	-	-	-	-	-	-
Consumption	1.30	1.70	2.20	3.00	3.40	4.00
<b>Control Valves</b>						
Production	4.00	5.05	6.30	9.00	10.40	12.00
Imports	7.00	9.19	11.70	14.12	15.80	17.70
Exports	-	-	-	-	-	-
Consumption	11.00	14.24	18.00	23.12	26.20	29.70

**Table 4.31.- Structure of the Instruments for Process Control Market in Mexico, 1973-1978. (million dollars)**

**Source.- NAFINSA/ONUDI (1979).**

**(1) Estimated figure.**

companies) were subsidiaries of US companies (NAFINSA/ONUUDI,1979). By the late 1970s, numerical control and computers for continuous process control had only a limited application in Mexico, so that the production of these crucial components of microtechnology was seen as only a long-term possibility (ibid.). By and large, the situation for the early part of the 1980s remained substantially the same (120) despite the important expansion of the control market due to the oil-based economic boom. It was estimated that in 1982 the consumption of instruments for process control had reached \$140 million. Imports accounted for 70% of this market and for almost the totality of the demand for electronic sensors, transducers and actuators (Poder Ejecutivo Federal,1984).

#### 4.3.2.2. State of Development of Electronic Components in Mexico

The detailed structural picture of the electronic components and parts sector is contained in table 4.29 and tables 4.32a and 4.32b. From table 4.29 the impression may be gained that Mexico is nearly self-sufficient in all areas of electronic components. In particular, in the crucial area of semiconductors, total production was greater than consumption in 1977 and exports clearly outperformed imports in the same year. In addition, projections for the period 1978-1982 suggested that this favourable situation would continue deepening so that semiconductors exports would more than double the amount of imports in 1982 NAFINSA/ONUUDI (1979). Closer examination of Mexico's semiconductor sector, however, reveals a much less optimistic pattern of fundamental weaknesses. In effect, if we look at the structure of the semiconductor market for 1976 given in table 4.32a, we can see that three-quarters of semiconductor consumption in Mexico was accounted for by discrete semiconductors. Integrated circuits accounted for the remaining quarter but, of these, less than 10% (i.e., around \$1.7 million) actually corresponded to digital circuits, the technology at the center of the microrevolution. Yet more important for Mexico's microtechnological capabilities, the level of local production of ICs -as table 4.32b shows- was just 20% of the total consumption, which means that only \$0.34 million worth of digital components was being produced in Mexico by the

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(120) In this connection, the current national T & S programme reports that "...From the computers installed in the country, only 8 percent are used in tasks of industrial automation (1 percent in real-time control, 2 percent in machine tools, 4 percent in programming of administration and production and 1 percent in other industrial applications)" (Poder Ejecutivo Federal,1984,p.325).

Product	Share of the Market (%)
<b>Total</b>	100.0
<b>Discrete Semiconductors</b>	75.6
Power transistors, plastic capsules	10.6
Power transistors, metallic capsules	14.3
Small signal transistors	15.7
Thyristors	4.1
Germanium devices	9.6
Diodes	
Zener	4.0
Rectifiers	17.3
<b>Integrated Circuits</b>	24.4
Lineal integrated circuits	15.0
Digital integrated circuits	4.4
MOS and CMOS	5.0

**Table 4.32a.- Structure of Semiconductor Market in Mexico, 1976.**

**Source.-** NAPINSA/ONUDI (1979).

Product	Percentage of the Market
Total of Semiconductors	78.7
Power transistors	65.0
Small signal transistors	20.0
Thyristors	20.0
Rectifiers	100.0
Diodes	75.0
Other discrete elements	90.0
Integrated circuits	20.0

Table 4.32b.- Sectors of the Mexican Semiconductor Market which are Locally Supplied, 1976.

Source.- NAFINSA/ONUUDI (1979).

mid-1970s.

Furthermore, in terms of the production process of those semiconductor components being produced in Mexico, the country possessed none of the most crucial capabilities (e.g., design), being limited to the performance of the simpler and more labour-intensive stages of the whole process of production. As NAFINSA/ONUDI (1979) described, "...In most cases the finished semiconductor wafers are imported and only cutting, splitting, mounting and encapsulating is performed upon them" (NAFINSA/ONUDI,p.66). In other words, Mexico's semiconductor industry was basically an assembly industry of products designed and partially manufactured abroad, which leads us to another of the major weaknesses of Mexico's semiconductor capabilities, namely, that most of the companies in the field are subsidiaries of transnational capital producing in Mexico in pursuit of their own strategies of capital accumulation (121). In practice, therefore, it is possible to say that there is no national semiconductor capability in Mexico, and, as Moreno (1982) described it, the main characteristics of the existing group of semiconductor companies is that "it is a 'maquila' group" (Moreno,p.34). For the same analyst, this situation leads to the paradox that "the national market is supplied almost entirely by the "national" industry but the latter has not generated any technological-scientific contribution to the country" (ibid.).

Given the above context, it was only inevitable that, towards the latter 1970s, the impact of the oil-based boom which pervaded the entire Mexican economy coupled with the fast-growing demand for quality components, were to combine themselves to sharply alter the mid-1970s development of Mexico's semiconductor sector. The result was that, as table 4.33 reveals, imports largely exceeded the previously estimated levels (see table 4.29) reaching a peak for integrated circuits and other semiconductor components in 1980. In particular, imports for ICs grew fast to reach \$27.1 million from the US alone in 1980; an increase of more than 130% over the level of the previous year (122) before

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(121) For instance, the "product lines that are manufactured in Mexico are those which have been gradually displaced within the parent companies, not because they are obsolete, but because the large multinational manufacturers are changing to a completely automated production, in which the minimum economically acceptable production is greater than the demand for some specific products" (NAFINSA/ONUDI,1979,p.67).

(122) This increase in imports affected the components sector as a whole. Thus, "...The imports of electronic components have reached very high levels in the last years (21.8 million dollars in 1978 and 397.5 million in 1981). The average annual rate of growth of such imports in the period 1978-1982 was around 26 percent" (Poder Ejecutivo Federal,1984,p.321).

Year	Integrated Circuits	Other Semiconductors	Parts for Semiconductors (1)
1979	11.6	15.1	128.0
1980	27.1	25.0	153.5
1981	20.7	22.1	175.0

**Table 4.33.- Mexico's Imports of Semiconductors Components and Parts from the U.S., 1979-1981.**

**Source.- Poder Ejecutivo Federal (1984), p.321.**

**(1) Not included in the figures for components.**



falling in 1981 to \$20.7 million, probably, due to the worldwide recession that affected the semiconductor industry during that year. The late-1970s surge in ICs and other semiconductors demand, however, had finally brought into the open the fundamental weakness and dependence of Mexico's semiconductor sector upon the technology and products of transnational capital. Such a situation is not expected to change as the current national T & S programme makes it plain,

"Imports of semiconductors, in general, and of integrated circuits, in particular, show particularly high growth rates and without doubt in the future they will be the most important items, given the industry's tendencies towards a greater level of integration in semiconductor circuits" (Poder Ejecutivo Federal,1984,p.321).

#### 4.3.2.3. State of Development of Telecommunications in Mexico

Clearly, the most important sector of Mexico's professional electronics industry is the telecommunications equipment sector. In 1978, it represented the largest market of finished products (i.e., excluding components) accounting for more than 50% of total consumption and was estimated at \$286 million in 1985 (Hobday,1985) (123). The importance of the telecommunications market is reflected in the very high share of national production of finished products accounted by local production of telecommunications equipment. This was approximately 70% as compared with around 18% and 10% for process control and computers/calculators respectively. The telecommunications sector, therefore, is by far the strongest Mexican professional electronics sector and that where one should expect the greatest development of national technological capabilities. The latter is particularly the case since, as we shall presently see, in Mexico the state effectively controls the telecommunications market. On closer examination, however, and as the current national development plan itself acknowledges, the situation is far from satisfactory.

"The evolution of communications is associated with an accelerated technological advance, closely linked to the development of electronics. This situation has led to a great external dependence and loss of foreign exchange due to the growing and disorganized importation of materials and equipment, not coordinated with the promotion of the

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(123) NAFINSA/ONUDI (1979) had projected a figure of \$320 million for telecommunications equipment sales in 1982. The fact that this figure is more than the one estimated above for 1985 seems to reflect mainly the impact of the economic crisis which between 1983-1984 severely depressed the level of government purchases. For instance, SECOFI (1985) reports of a 50% reduction in the personnel employed by the industry due to the combined effect of the crisis and the technological displacements brought about by the changes from electromechanical to digital technologies.

incipient national electronics industry. Technological research and development in telecommunications in Mexico is small; the lack of qualified personnel constitutes the main limitation, made worse by the deficient coordination between the efforts of the educational sector, research centres, industry and the service-suppliers" (Poder Ejecutivo Federal,1983,p.167).

Obviously, the telecommunications sector has not escaped the general malaise affecting the development of Mexico's industry and R & D system. And it is not just the quantitative fact that the R & D effort has been small or that imports still account for a larger share of consumption than local production. It is, above all, the qualitative realities which underly such quantities and which, as we have argued, involve a sociotechnical process whereby specific technologies and social interests interpenetrate each other deeply. In Mexico's telecommunication sector this is quite clear as its development has reflected the fundamental tenets of the country's dependent model of capital accumulation which brings together the interests of the state, foreign and private national capital. The major partners, however, are the state which possesses almost total control of the market, on one hand, and transnational capital which possesses overwhelming control of the production of telecommunications equipment, on the other hand.

The government control of the market is exercised mostly through its ownership of Mexico's telecommunications network where the most important company is Telefonos de Mexico. Originally created by foreign companies, the Swedish L.M. Ericsson and the North American ITT, the telephone system was taken over by the government in 1947, giving rise to Telefonos de Mexico which currently owns 96% of the country's telephone system and has 51% of government participation with the remaining 49% in hands of Mexican private capital (NAFINSA/ONUDI,1979). On its part, transnational capital's control of the production of telecommunications equipment is exercised through its possession of key telecommunications capabilities which the government has been content to depend upon, in line with its global industrialization strategy. Thus, most of the important telecommunications TNCs have established themselves in Mexico (124) with the aim of supplying the market either through imports or through local assembly and production. From these, Teleindustria Ericsson S.A. (60% Ericsson capital and 40% national capital) and Industria de Telecomunicacion S.A. (INDETEL) (40% ITT capital and 60% Mexican capital)

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(124) AT & T does not figure in the Mexican market for until the recent 1983 divestiture agreement, this company was not allowed to operate internationally.

have the greatest share of the market since, for historical reasons, these two companies have been the only suppliers (90%) of telephone equipment (e.g., switching systems for local and long-distance public exchange, PBXs, multiplex equipment, etc.) to Telefonos de Mexico. As a result, other TNCs have operated in other sectors of the market. For instance, the third largest telecommunications company in Mexico, Siemens Telecomunicaciones, has concentrated in telex, telegraphic equipment and teleprinters where it practically monopolizes the market. After, it comes GTE whose activities include operators' equipment and public and private subscription systems. Many other names such as Philips, NEC, Thomson, and Motorola also figure in Mexico's list of foreign companies active in the country (125), covering a variety of areas such as PCM, microwave, FM and radiocommunications equipment.

All in all, it can be said that Mexico's telecommunications industry is largely dominated by transnational capital which control most of the technology and supply most of the equipment. The role of the Mexican producers is small and they devote themselves mostly to activities of low technological complexity. For Mexico, the result of such heavy dependence upon transnational capital has been quite momentous. It has meant that, in spite of the sector accounting for more than 70% of the value of the country's total professional electronics production, most of the telecommunications equipment consumed in Mexico is actually imported from abroad. In effect, as table 4.28 shows, around 60% of such equipment was covered by imports. Furthermore, closer examination of the type of equipment produced in Mexico (table 4.34) reveals that "...Only in the area of telephone and telegraphic equipment local participation is important, and here the national industry is well established due to the fact that most of the equipment is less complicated" (NAFINSA/ONUUDI,1979,p.25). Thus, in Mexico, the production of sophisticated equipment such as transmission, microwave and data-communication equipment is insignificant, meaning that transnational capital is not actually in the business of developing Mexico's telecommunications capabilities beyond what is necessary for the benefit of its own process of capital accumulation.

Some analysts have looked at the behaviour of some telecommunications TNCs in Mexico and have found relevant variations in their import/export and

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(125) "There are about 150 subsidiaries and sale agents of this [telecommunications A.M.] equipment in Mexico, but there are only a few major suppliers" (NAFINSA/ONUUDI,1979,p.26).

Category	1973	1974	1975	1976	1977	1978 <sup>(1)</sup>
<b>Total</b>						
Production	33.65	45.30	50.90	63.70	68.69	81.58
Imports	78.52	79.44	94.75	92.84	102.24	113.02
Exports	3.40	4.00	4.70	5.40	6.20	7.07
Consumption	108.77	120.74	140.95	151.14	164.73	187.53
<b>Telegraphic and Tele- phonic Equipment</b>						
Production	33.32	44.92	50.30	63.02	67.95	80.78
Imports	49.85	57.68	61.94	56.30	59.64	65.50
Exports	3.40	4.00	4.70	5.40	6.20	7.07
Consumption	79.77	98.60	107.63	113.92	121.39	139.21
<b>Radiocommunications and Microwaves</b>						
Production	-	-	0.10	0.12	0.14	0.16
Imports	22.25	14.81	24.46	27.38	33.86	38.14
Exports	-	-	-	-	-	-
Consumption	22.25	14.81	24.56	27.50	34.00	38.30
<b>Data Communication Equipment</b>						
Production	0.33	0.38	0.40	0.53	0.56	0.60
Imports	2.12	2.50	3.35	3.62	3.97	4.48
Exports	-	-	-	-	-	-
Consumption	2.45	2.88	3.75	4.15	4.53	5.08
<b>Transmission Equipment</b>						
Production	-	-	0.01	0.03	0.04	0.04
Imports	4.00	4.45	5.00	5.54	4.77	4.90
Exports	-	-	-	-	-	-
Consumption	4.00	4.45	5.01	5.57	4.81	4.94

**Table 4.34.- Structure of the Telecommunications Equipment Market in Mexico, 1973-1978. (million dollars)**

**Source.-** NAFINSA/ONUDI (1979).

(1) Estimated figure.

technological strategies. Siemens Telecomunicaciones, for example, is the main exporter and the only major company having a foreign trade surplus (Unger,1985) (126). Its strategy follows specialization in exports of finished products for the regional market, in particular telex equipment and teleprinters, which in the 1970s enjoyed preferential duty treatment under the provision of the Latin American Free Trade Association (LAFTA) (127) [Jenkins(1979),Unger(1985)]. As a result, Siemens Telecomunicaciones exported about 80% of its production to other Latin American countries and, more recently, to the US market where some 35% to 40% of its exports are currently directed. In the case of its teleprinters the company's productive and technological strategy has been to produce exact copies of the machine manufactured by the parent company in Germany. Until the late-1970s the machine produced was electromechanical having a fairly high level of national content (60%) (128). As the technology changed from electromechanical to fully electronics, however, a substantial drop in the level of the national content of the teleprinters was expected, since the labour content of the new electronics model was only 25% of the old one and Mexico's electronics capabilities cannot provide anything like its mechanical capabilities could in relation to the previous model. This may be seen as a typical case of loss of comparative advantages due to technological innovation.

The strategy of the main telecommunications companies, Teleindustria Ericsson and INDETEL, has been quite different from that of Siemens in that they are the main suppliers of the internal market. Thus, imports by these companies have by far exceeded their exports with data for 1975 showing a relation of around 10 to 1 (Unger,1985) (129). In terms of their contribution to Mexico's technological capabilities, however, there has been some important differences between Ericsson and INDETEL, reflecting the policies of their parent companies. According to Hobday (1985), Ericsson has far less local technological

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(126) Siemens, however, has another subsidiary in Mexico -Siemens S.A.- which produces mainly for the internal market importing more than the external surplus of Siemens Telecomunicaciones. This produces an overall deficit for Mexico.

(127) LAFTA ceased to operate in 1981 and it was replaced by a new organization, the Asociacion Latinoamericana de Integracion (ALADI).

(128) Most of the precision mechanical parts were produced in Mexico with some electronic components and raw materials coming from abroad.

(129) Most of Mexico's imports and exports in electronics are carried out by a few TNCs which include Ericsson and INDETEL. "Siemens Telecomunicaciones, IBM, Teleindustria Ericsson, RCA and Industria de Telecomunicaciones carried out 93% of exports and 70% of imports in 1975. These five companies and Control Data, National, IEM and NCR, accumulated 94% of the sector's total imports; the rest was accounted for by other 22



capacity, specially in the area of fully digital technology. All system design and adaptation is carried out almost exclusively in the parent company in Sweden, and local engineering capacity is confined to very low level digital products and electromechanical crossbar technology. On the other hand, ITT's activities seem to have contributed more effectively to the building up of technological capacity in Mexico. As we shall see later on, even a telecommunications R & D centre, INDETELEC, has been organized as a joint effort between INDETEL and the government. For Hobday (1985) this may reflect the global profit-making strategies of the two TNCs. "Unlike Ericsson, ITT has a strictly decentralized profit cost centre (PCC) strategy which means that each plant must be independently profitable. All inputs, including technology, have to be paid for by local subsidiaries and this has led to the building up of local technological capacity in Mexico" (Hobday,p.32).

Company by company, therefore, there are some relevant differences of strategy which the government constituent of Mexico's telecommunications capability may be able to exploit, particularly, since it exercises a virtual monopsonistic control of the market. On the whole, it is the transnational social constituent which control the technologies at the heart of telecommunications capabilities and through them it is able to exercise an oligopolistic control of the Mexican market, producing, importing and exporting very much in accordance with the needs of its global process of capital accumulation. For Mexico, the result has been a telecommunications sector -the strongest of its electronics industry- fundamentally dependent upon foreign technology and one which, in spite of its importance, we can hardly see as making an effective contribution to the building up of Mexico's IMC. For the latter to have any possibility at all, it seems clear that the government constituent should take a much more direct and positive role in the development of such capabilities. As we shall see below, there is evidence that the government is taking some positive steps in relation to telecommunications R & D , although, as it has been its policy with R & D capabilities in general, this is being done very much within the limits of its strategic dependence upon foreign capital and as a way of strengthening its own relative position within the social constituency rather than directly weakening that of transnational capital.

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relatively small companies" (Unger,1985,p.440).



#### 4.3.2.4. Development of the Computer Sector in Mexico

In the area of computers, the development of Mexico's capabilities has been rudimentary, with transnational capital playing an almost completely dominant role within the technology's social constituency. In fact, until quite recently, the government social constituent had been content with letting foreign capital shape not just the development process of computers in Mexico but, literally, the country's computer policy as well. Indeed, as a government study stated, "...Until 1977, the subsidiaries of transnational companies controlled government policies regarding the development of data-processing ['informatica' (130) A.M.] in Mexico, above all in the aspects of imports of goods and acceptance of new suppliers in the national market" (SPP,1980,p.59). Such a control by transnational capital reflected the almost complete lack of national computer capabilities in the country, on one hand, and the general government development strategy of dependence upon foreign capital, on the other. These two aspects acted to reinforce each other leaving transnational capital reaping the benefits of the country's computer market and Mexico in an utter condition of dependence and disorganic structural development. Soriano and Lemaitre (1985), who have studied Mexico's first decade of computing development since the first computer was installed at the National Autonomous University in 1958 (131), have described in the following terms the situation of the 1960s,

"As regards advances in electronics sciences, it can be said that Mexico in particular is characterized by a weak (or null) scientific and technological infrastructure, which along with private foreign investment, created a Mexico more ignorant every day: Mexico imported technology and did not create it" (Soriano and Lemaitre,p.140).

Admittedly, there is one sense in which it could be said that foreign computer companies helped to develop local technological capabilities. This is the generation of human resources able to run and manage the equipment they provided. In effect, since without this personnel computer companies could hardly expect a rapid commercialization of their products, courses soon were organized to fulfill this need. Thus, in Mexico, "...At the beginning, most of the

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(130) The Spanish term 'informatica' has no direct equivalent in English language, and its meaning broadly encompassing human resources, equipment and software for use, application and production of computers seems to be best expressed by the English terms data-processing or computing.

(131) SPP (1980) put 1956 as the year of the beginning of electronics data-processing in Mexico. In that year, the Federal Commission of Electricity bought and installed an UNIVAC 60/120. The computer installed in the university was an IBM-650.

professional and training courses were organized by the manufacturers, often in their own premises" (SPP,1980,p.78). The disadvantage of such a situation was that structural rigidities were created since the courses, by pursuing primarily a profitable purpose, were not oriented to the needs of the users but mostly towards the products and equipment offered by the manufacturers (ibid.). In 1977 a survey carried out by the government (SPP) revealed that the main source of education for computing personnel in Mexico had been the suppliers of computing equipment (85%) and, particularly, IBM which had given courses to 67% of this personnel (132). The structural rigidities resulting from this particular situation were further exacerbated by the aggressive commercial policies of computer companies which generated a proliferation of models totally disproportionate to the number of users and size of the Mexican market. For instance, from a total of 235 models of general purpose computers -most of them incompatible with each other- in the market in 1979, more than 140 were sold in Mexico (SPP,1980). The result has been the existence of small groups of users organized around the 140 models; fact which has conspired in a number of ways against the efficient use, let alone, the development of computers in Mexico. For instance, some of the most important effect which have been identified include lack of incentives for the organization of specialized computer courses other than those prepared by the parent companies; market fragmentation preventing adequate development even in sectors where there are greater opportunities such as software and terminals; impossibility of developing an independent capability for maintenance of computer equipment; and serious problems of under-utilization of the equipment reaching, in some cases, up to 45%-55% of idle capacity [SPP(1980),Lahera and Nochteff(1982)].

Given the above pattern of TNCs-controlled diffusion of computing technology in Mexico (133), it is not surprising to find that the country's

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(132) Commercial private schools came after in importance with a participation of 23% and university institutions with 20%. The total percentage is more than 100% because many of the people had received education in different centres. In terms of educational facilities provided by TNCs, the importance of the Mexican computer market is reflected in the fact that IBM has here one of the two Regional Education Centres in Latin America. The other is in Brazil. In addition, as part of its image of "corporate responsibility", IBM has a Scientific Centre in Mexico which in the mid-1970s was engaged in research in the areas of air pollution, agricultural models, and the application of terminal-oriented APL (Automatic Programming Language) in education. Other Scientific Centre was due to be created in Brazil (Bennett,1975). Clearly, this reflected the fact that Mexico and Brazil have been the most important Latin American import markets as a study of the 50 world's top markets has showed. In 1978, Brazil ranked 16th in the world with near \$200 million worth of imports and Mexico ranked 20th with \$160 million worth of imports (Szuprowicz,1981).

(133) In the 1970s, the active role of the government was limited primarily to such

computer technological and productive capabilities have undergone little advance. In table 4.28 an overview of the volume and supply of the Mexican market for computers and calculators is given. As it is possible to see, in 1977, more than 90% of the market was supplied with imports, mostly from the US, the country where some 90% of all the computers installed in Mexico had come from. At the same time, there was a rather significant volume of production and exports equivalent to 20% and 12% of the value of the total market respectively. On closer examination, however, as table 4.35 reveals, most of the value of production and exports was actually explained by calculators and a small contribution from peripheral equipment. The production of computers as such was insignificant in 1977 and there were no exports. In fact, all there was in terms of local production was two companies assembling minicomputers and which had sold only ten units and two companies producing computer terminals with some 40% of national content (NAFINSA,1979). A subsequent study carried out by the government (SPP,1980) found that in 1979 there were in Mexico 8 companies which "may be considered as national suppliers of some importance" (SPP,p.65). Of these, 5 were completely Mexican and independent (134) while the other 3 had close connection to transnational capital. Thus, one of the latter companies Micromputadora S.A., although Mexican was closely linked to its source of technology: Digital Equipment. The other two were subsidiaries of TNCs manufacturing in Mexico: GTE (General de Telecomunicaciones S.A.) and NCR de Mexico S.A. All of the 8 companies were operating in small niches of the market, primarily, in the area of data-transmission systems where the acquisition and installation of such equipment were under direct control of the government. The latter, therefore, offered a protected market without the competition of large computer TNCs and this acted to stimulate the development of local production. This is corroborated by the fact that, in 1979, sales of data-transmission equipment accounted for 90% of the total sales of these companies with the remaining 10% being accounted for by sales of microcomputers. In terms of productive capacity, due to their concentration in small segments of the market these companies counted on small economies of scale so that even the oldest and most productive of them, Sistemas y

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quantitative measures as establishing import quotas in response to conjunctural economic pressures. In 1975, for instance, such quotas were established with a consequent slow down in the growth of the market. Towards the late 1970s, however, as the economic pressures subsided due to the oil bonanza, such restrictions were lifted producing a major surge in imports.

(134) The companies were Sistemas y Componentes S.A., Transdata S.A., Informatica y Telecomunicaciones S.A., Sistemas Computacionales Avanzados S.A., and Industrias Digitales S.A.

Category	1973	1974	1975	1976	1977	1978 <sup>(1)</sup>
<b>Total</b>						
Production	4.46	4.95	5.70	8.02	10.05	12.32
Imports	36.60	41.15	38.90	46.55	45.65	51.98
Exports	2.00	2.70	4.00	4.80	5.80	7.03
Consumption	39.06	43.40	40.60	49.77	49.90	57.27
<b>Microcomputers</b>						
Production	-	-	-	0.20	0.36	0.46
Imports	2.60	2.92	3.28	5.95	7.11	8.87
Exports	-	-	-	-	-	-
Consumption	2.60	2.92	3.28	6.15	7.46	9.33
<b>Small, Medium and Large Computers</b>						
Production	-	-	-	-	-	-
Imports	29.60	32.52	31.78	35.22	33.14	35.33
Exports	-	-	-	-	-	-
Consumption	29.60	32.52	31.78	35.22	33.14	35.33
<b>Peripheral Equipment</b>						
Production	0.10	0.15	0.20	0.42	0.80	1.00
Imports	3.40	4.41	2.42	4.28	4.10	6.30
Exports	-	-	0.10	0.20	0.20	0.25
Consumption	3.50	4.56	2.52	4.50	4.70	7.05
<b>Calculators</b>						
Production	4.36	4.80	5.50	7.40	8.90	10.86
Imports	1.00	1.30	1.50	1.10	1.30	1.48
Exports	2.00	2.70	3.90	4.60	5.60	6.78
Consumption	3.36	3.40	3.10	3.90	4.60	5.56

**Table 4.35.- Structure of the Computer and Calculator Market in Mexico, 1973-1978. (million dollars)**

**Source.- NAFINSA/ONUUDI (1979).**

**(1) Estimated figure.**

Componentes S.A., produced only 1,000 modems per year, which means a rate of productivity of around 3 modems daily.

Obviously, this is hardly a base to build up indigenous microelectronics capabilities, in particular, as the main markets were virtually closed to national producers due to the overwhelming presence of imports by the large US computer companies. According to Lahera and Nochteff (1982), six of the latter enterprises controlled the Mexican market and one of them, IBM, has a 55% share of the total market (135), followed by Honeywell with a share of 15%. In Mexico, all the main computer TNCs have operating companies and these were either completely owned by the parent company or had 51% of national capital ("Mexicanized") if they had been established after the Law on Foreign Investment (136). For all of them, however, the main activity has been that of imports and sales of the parent company's equipment (137) although, as we shall now see, this situation has begun to change due to the conditions created by the late-1970s oil boom and the subsequent economic crisis which prompted the government to play a more active role in shaping the development of computers in the country.

In effect, although NAFINSA/ONUDI (1979) had expected growth rates of between 10% and 24% for the imports of diverse computer equipment for the years 1978-1982, in practice, such rates did not include the effects of the oil boom which resulted in a very fast increase in the computer market followed by an equally fast increase in imports as the government brought to an end the mid-1970s import restrictions. The restrictions were lifted in 1979 and between this year and 1980 "imports grew in 175% keeping the same level in 1981" (SECOFI,1985,p.2). According to Grapa (1984), the computer market as a whole grew by 280% since 1977 until 1982, and the microcomputer market, in particular, grew by 400% during that period (138). In these circumstances,

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(135) Other estimates put IBM's share of the Mexican market at 45% (*Business Week*, 17 May 1982), and at 44% (Jacobsen,1983).

(136) See discussion on Mexico's legislation on foreign investment above.

(137) Until recently, IBM's subsidiary in Mexico produced only electric typewriters of three different kinds (Standard, Executive and Selectric) typewriter ribbons made of high density polyethylene and polyethylene rolls. Most of these products were exported and the greatest part of the company's exports consisted of electric typewriters. On the other hand, the IBM strategy of a worldwide division of labour within the company meant that the Mexican subsidiary imported all the data processing equipment that the company sold in Mexico. As a result, although a significant part of the company's production was exported, exports represented less than 10% of the company's total sales" (Jenkins,1979,p.163).

(138) Figures provided by Nochteff (1985) estimate in 186% the growth of the computer market for the period 1977-1982. In that period, the microcomputer market would have



computer TNCs were reaping large benefits as the industry's sales kept growing at high annual rates of about 25% to 30% (*Business Week*, 14 November 1983). In 1982, a report estimated that 16,000 computers had been installed in Mexico although, as the report put it "about a third of these are "illegal immigrants", smuggled across the border by purchasers to avoid import licences and quotas" (*Business Week*, 17 May 1982,p.50).

#### 4.3.3. Impact of the First National Computer Plan and Recent Computer Policies

Prompted by the fast growth of computers and its increasing impact in the country's balance of payments, in 1981 the Mexican government began its first serious attempt to stimulate local production of computers by launching its Development Programme for the Manufacture of Electronic Computing Systems, Central Units and Peripheral Equipment. In fundamentals, this programme purported to promote the "generation of a wide and efficient national supply of electronic computing systems" (SEPAFIN,1981,p.7) very much in the Mexican government tradition of using incentives and controls to direct foreign capital into local productive and technological activities, preferably in alliance with private national capital. The rationale behind the programme was well exposed by J. Warman, then director of Electronics Industry at SEPAFIN.

"The definition of the role of foreign or national investment in the development of the electronics industry must take into account the following points:

In diverse areas of electronics, the national technological backwardness makes autonomous development impossible in the short term...The penetration of the international market in several areas (for instance, mainframes) is complex and it is not possible to consider it realistically in the short term...The magnitude of the national market may not be enough in many instances to justify an industry which, because of its scale economies, will need to export...Foreign investment involves technological dependence and may inhibit national development in technology...

In this way, the combination of these mechanisms leads us to the following objectives:

Penetration of the international market through association with the large companies which dominate it, seeking the best possible conditions of technology transfer...Development of national technology in those areas in which it is feasible, in the short- and medium-term, to aim for a degree of technological self-determination" (Warman,1981,p.10).

In pursuit of the above objectives, therefore, the first national computer

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grown by 300%.



programme combined mechanisms such as tariff protection, tax reliefs, preferential prices for inputs and preferential purchases from the state, with a control system of import quotas which progressively reduced both the permitted level of imports by local distributors vis-a-vis those by local manufacturers and the permitted level of imports vis-a-vis local production for companies producing in Mexico. In addition, specific requirements in terms of both national content of the products manufactured and R & D expenditures were also introduced by the programme in an effort to advance the development of local technological capabilities. Overall, the explicit productive goals of the programme were to be achieved in a period of 5 years so that "the national supply of electronics computer systems is satisfied in 70% by national production" (SEPAFIN,1981,p.8). This was not an across-the-board target, however, and, as we can see from table 4.36, targets and requirements for foreign companies wishing to set up facilities in Mexico varied depending upon the type of computing equipment to be assembled. Mainframes, for instance, were not expected to be manufactured in the short-term so that a rationalization of imports was basically proposed. On the other hand, microcomputers, minicomputers and peripheral equipment had to be assembled locally with varying but clear targets in terms of national content of the final product, import/export ratio and minimum level of R & D expenditure. In the area of microcomputers, for instance, where the market has been growing the fastest, manufacturers were expected to achieve between 45% to 60% of national content in three years; to balance their imports with exports by 70% in five years; and to spend a minimum of 6% of their total sales in R & D. In exchange, they were to receive the highest tariff protection (30%) apart from their entitlement to the other incentives introduced by the programme. On their part, minicomputer assemblers faced less demanding requirements in terms of national content and R & D expenditures but they were expected to balance imports with exports within four years of starting assembling.

In terms of ownership, the programme demanded a minimum participation of 51% for national capital except for those companies already established in Mexico with majority foreign ownership. The latter, of course, was in agreement with the Law on Foreign Investment and this had to be reflected in the framework established by the computer programme. In practice, however, the issue of 51% ownership was clearly no longer a high priority -at least at the present stage- in the minds of the Mexican planners as it was restricted mainly to microcomputer manufacturers. For those foreign companies assembling

Product	Degree of National Integration or Content to be Achieved by the 3rd Year	Export/Import Relation	Minimum R & D Expenditure as Percentage of Total Sales
Microcomputers Central unit	45% to 60%	70% by the 5th year	6%
Minicomputers (1) Central unit	50% to 60%	100% by the 4th year	5%
Mainframes	35% to 50%		
	30% to 35%		
	To encourage minicomputer manufacturers to generate the physical, human and technological infrastructure for the eventual production of mainframes in Mexico		
Peripheral Equipment		70% by the 4th year	3%
Modems (300 to 1200 bps)	75% to 90%		
Modems (1201 to 4800 bps)	70% to 80%		
Intelligent VDUs	35% to 50%		
Non-Intelligent VDUs	65% to 80%		
Printers (Impact)	50% to 60%		

**Table 4.36.- Foreign Companies' Targets as Required by the Mexican Computer Plan of 1981.**

**Source.-** Arranged from data given in NAFINSA (1981).

(1) For the case of "maquiladora" companies, the import/export relation must be 3:1 from the start and the minimum R & D expenditure must be 3%.

exclusively minicomputers and more powerful computers, majority foreign ownership was offered in line with the new policy of priority areas for foreign investment (139). Also the latter companies had the option to register themselves under the provisions for the "maquiladora" industry if no less than 75% of their production was to be exported (i.e., a minimum export/import ratio of 3 to 1 from the start) and commitments were made in terms of national integration and R & D expenditure. The latter was fixed at a minimum of 5% of total sales.

The above provisions for the computer sector in Mexico became official policy in August 1981. By May 1982, driven by the attraction of the fast growing Mexican market and the threat of being left out of it, some 45 US companies had applied to assemble computers and peripherals in Mexico (*Business Week*, 17 May 1982). Hewlett-Packard had been the first to be granted permission to manufacture its major commercial minicomputer, the H-P 3000, under 100% ownership of its plant. Table 4.37 shows some of the major US computer makers which had or were setting up manufacturing facilities in Mexico by 1984. Most of the companies appearing in the table are operating in the minicomputer field with the exception of Apple which has set up personal computer facilities. Tandy Corp., which before the regulations had some 20% of its Latin American market of microcomputers in Mexico, has decided not to produce locally under the conditions imposed by the legislation (*Business Week*, 14 November 1983). The reaction of TNCs, however, has been variegated very much in response to the changing economic environment in Mexico (140).

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(139) See above pp.355-356.

(140) Jacobsen (1983) has assessed the reaction of US computer companies to the Mexican computer programme in the following way, "...The response of these companies to the Computer Decree and to its performance requirements has been very quiet...This industry acquiescence, though at first surprising, is understandable. First, U.S. computer firms already doing business in Mexico prefer to negotiate individually with the Mexican government. In many cases, they have negotiated such arrangements. Indeed, the Computer Decree allows for negotiation; performance requirements generally are administered with great flexibility. Second, companies have not complained openly about the Computer Decree probably because they fear retribution. The agreements already negotiated probably are less than secure and are subject to change at any moment. Because the agreements are tenuous, most companies would not want to be identified publicly with any criticism of the Mexican government. Third, the Computer Decree, standing alone, is not significantly injurious to the individual computer firms. For example, the decree offers tax credits, energy subsidies, and tariff protection. These benefits may counterbalance the negative effects of the obligatory requirements. In addition, to the extent that the Computer Decree discourages investment, the few companies willing to make the investment will dominate a very profitable, protected market. Finally, the Computer Decree is most harmful to those companies, especially the smaller ones, not yet doing business in Mexico. Because these firms do not have an established interest in the Mexican computer market, they have little incentive to complain about the new performance requirements. The new rules will be just one of many factors that they must consider if, and when, they decide to invest overseas" (Jacobsen, pp.1181-1183).

	Status		
	Currently Manufacturing Locally	Currently Selling Locally Manufactured Equipment	Expected to Begin Local Manufacturing within Two Years
IBM	Yes	No	N/A
Burroughs	Yes	No	N/A
NCR	Yes	Yes	N/A
Wang Labs	No	No	Yes
Apple	Yes	No	N/A
Hewlett-Packard	Yes	Yes	N/A
Mohawk Data	Yes	Yes	N/A
Basic 4 Info. Sys.	No	No	Yes
Prime Computer	No	No	Yes
Tandy Corp.	No	No	No

**Table 4.37.- Selected U.S. Computer Companies and Their Manufacturing Status in Mexico.**

**Source.- M. Salehizadeh and J. Garza-Adame (1984), p.100.**

Minicomputer makers, for instance, have been able to keep 100% ownership and, as the crisis has brought severe foreign exchange restrictions on the country (141), most of them seem to have little choice but to pay attention to Mexican needs for exports. This is not at all contradictory to their interests. Rather, it represents an accommodation to the new conjuncture since they can still sell in the Mexican market which has remained strong despite of the crisis (142), while using production facilities in Mexico to attack the Latin American market. Interestingly enough, in the new critical conditions, the Mexican government has been willing to relax the 51% national ownership rule even in the field of microcomputers. However, Apple, the company involved in such an offer, preferred to seek the safety of minority ownership (49%) given the present conditions. Thus, for an investment of only \$600,000, Apple expected to begin assembly of 5,000 personal computers in 1984, and double that number in the next year (143). For a company with the huge resources of IBM, however, such need for Mexican partners does not arise. Thus, when the company decided that they wanted to established production facilities for microcomputers in Mexico, it made clear that this would be under 100% IBM's ownership. This led to a showdown with the government, eventually settled by the sheer weight of IBM's resources (144), which raised its proposed investment from \$6 million

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(141) At the height of the 1982 crisis, complete lack of foreign exchange forced some companies to turn to barter for their import/export transactions. As a report put it at the time, "...Barter is specially appealing to multinationals laden with large inventories already targeted for export to Mexico. A major supplier to Telefonos de Mexico has already gone the barter route, and the major U.S. automobile companies are scrambling to balance imports with exports" (*Business Week*, 4 October 1982,p.56).

(142) "Although overall computer sells in Mexico plunged 40% in 1982, to \$300 million, and a further 5% so far in 1983, minicomputer sales have remained strong" (*Business Week*, 14 November 1984,p.64).

(143) "For Apple, the joint-venture formula will have many advantages. In addition to sharing the risks, its well-connected Mexican partners are expected to give Apple de Mexico an edge in selling to the government and state-run companies such as Petroleos Mexicanos" (*Business Week*, 12 March 1984,p.30).

(144) In January 1985, the National Commission on Foreign Investment rejected IBM's application arguing that the project did not meet the aims of the federal government's economic objectives and would displace national capital, besides the fact that there were already some companies, such as Hewlett-Packard and Apple, manufacturing the same line of products (*Comercio Exterior*, February 1985). In July 1985, the Commission finally authorized IBM to manufacture its System/51 microcomputer, after the company had presented a new plan offering important new financial and technological concessions. As it was reported, "IBM finally got what it wanted: 100% ownership of new microcomputer manufacturing facilities in Mexico. But it had to give up more than it planned to win approval of Mexican officials. It agreed to sharply increase its capital investment to \$91 million over five years... It further agreed that new technology it developed will be exported quickly to its Mexican operation...Further, it will set up programs for developing local suppliers, as well as provide a center for semiconductor development and the production of IBM software and its distribution to Latin American countries" (*Electronics*,

to \$91 million over a five-year period and committed itself to exporting 92% of its production ( *Comercio Exterior*, Agosto 1985).

Under the galvanizing pressures of the economic crisis, therefore, and stimulated by the size of the Mexican market and a host of legal incentives and requirements, the Mexican government seems to have succeeded in bringing transnationals to produce computers within the country. The latter, however, have done so in pursuit of their own interests and in accord with their global strategies of capital accumulation which take into account the new conditions arising in every country of operation. Whether the new place of Mexico in the TNCs' strategies coincide with the government's long-term objectives for the computer industry, is something doubtful given the past experience of Mexico's industrialization. For the time being, however, some contradictory developments have taken place. On the one hand, the dynamics of computer imports and exports has undergone a major change since the heavy-imports days of 1979-1981. Thus, between 1981 and 1983 imports actually declined by 65% while exports grew sharply by 500%. In addition, the Mexican computer market has become more competitive as some 80 national manufacturers of microcomputers, peripheral and components were reported to have been successfully established in 1985 (Fernandez and Octavio,1985). This has brought about a reduction in prices and also employment has increased as the new plants have created jobs that were not there before. Horizontal integration of the national electronics industry has also been helped as the growth of the professional electronics sector has stimulated growth in the production of components and printed circuits. Consequently, improvements in the quality and technology of these sectors is envisaged for the near future. In addition, some five projects for the manufacture of subassemblies have been initiated to further the process of integration. Finally, some R & D projects have also been reported (SECOFI,1985a). On the other hand, apart from the impact of the crisis which seriously curtailed the start of various projects during 1982 and 1983, it is clear that transnational companies have not welcomed the programme and some have actually attacked it (145), thus contributing to a climate of uncertainty which

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29 July 1985,p.14).

(145) Also, some US analysts of the Mexican computer programme have called for concerted action on the part of the US government, since US computer companies operating in Mexico prefer to negotiate individually and hence, may tend not to voice openly their opposition to the programme because of fear of retribution. In this respect, Jacobsen (1983) has argued that..."It is important that the United States respond to the Mexican Computer Decree because its performance requirements distort the international flow of trade and capital and directly affect U.S. imports and exports" (Jacobsen,p.1188).



has all but left Mexican private capital out of the current developments in the computer sector. In effect, according to SECOFI (1985a) despite all the incentives provided by the government, there had been no significant response on the part of Mexican entrepreneurs. Thus, they seem to have adopted an attitude of wait and see, until it becomes clear what there is in the computer sector for them. In this respect, the reservation of the microcomputer market for national companies has been seen very much as a crucial mechanism to gain the Mexican entrepreneurs' confidence. The terms of the argument have been well summarized by Grapa (1984).

"...transnational companies will apply pressure to open the microcomputer market to companies which are one hundred percent foreign; their importance in the market and the political pressures of these companies will test the solidity of current policy. The struggle is not simple, but if the government surrenders the microcomputer market in the face of pressure and the promise of short-term economic advantages related to export, it will have to be aware that it is giving the market to the transnationals and with it, the opportunity in the medium-term to create a true national industry which will be able to attack the Latin American market at an appropriate time. A denial of the present policy would surely damage irreversibly the confidence of Mexican entrepreneurs in the permanence of any other future policy on this matter" (Grapa,p.20).

In this context, the original rejection of IBM's application was seen as having a positive effect on the confidence of Mexican entrepreneurs (SECOFI,1985a), although it is not clear what has been the effect of the subsequent acceptance of the company's new proposal. It seems, therefore, that, as one commentator put it, "...The near future will tell who has won the battle: either the policy of nationalist integration or the transnationals" (Grapa,1984.p.21).

But there is a related and, perhaps, deeper issue in the involvement of transnational capital in Mexico's computer sector. This is whether or not the transnational producing in Mexico can effectively further the long-term objectives of a competitive and integrated Mexican electronics industry as envisaged by the government. Some analysts question this possibility very strongly. Let us take the issue of competitiveness, for instance. Here, the government's argument is that "the programme ensures competition by never closing the border completely to foreign-made computers. It also says that companies must export from Mexico, guaranteeing the product will be competitive in the international markets" (Salehizadeh and Garza-Adame,1984,p.98). The problem with this argument is the assumption that because TNCs must balance imports with

exports, then, they will be forced to produce in Mexico the best of their products for the international competitive market. The fact is thus ignored that Mexico is only one piece in these companies' worldwide productive and marketing strategies which entails extensive international division of labour and intra-company trade. In these strategies, to gain access to a market like the Mexican and being able to import, TNCs will normally allocate the production of one product, or one model of product, or part-component of product to that country. They will then export this particular product mostly to affiliates in other countries while importing from them different lines of products as well as important components [Jenkins(1979),Unger(1985)] (146). In this way, production and export markets are controlled by TNCs in a strategy which not only takes advantage of the trade agreements between countries (147) but, also, tends to make a nonsense of the idea of international competitiveness for a host country like Mexico. IBM, for instance, exports finished products almost exclusively to affiliates, and "IBM headquarters distributes orders between its subsidiaries according to the work load of each company and the speed with which the products can be delivered. In this context, costs of production are secondary and the price of the final product to the customer is the same irrespective of which IBM subsidiary has produced it" (Jenkins,1979,p.164). Obviously, such degree of freedom in terms of costs of production is something that a truly Mexican industry striving for international competitiveness could not afford. The strategy of other TNCs may not even include the export of

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(146) "The auto industry is also required to balance imports with exports, and most of them are doing just that. But are they exporting automobiles? The answer is no; most of these companies are exporting Mexican-made engines and other parts mainly to their parent companies. It is only recently that Ford announced \$500 million investment in Mexico to produce cars aimed at the U.S. and the Canadian markets" (Salehizadeh and Garza-Adame,1984,p.97). In the 1970s, in order to generate foreign exchange, Volkswagen allocated to its Mexican subsidiary the production of one model to be exported worldwide. The car, however, failed to meet US safety regulations, thus deeply affecting the exports of Volkswagen's finished products from Mexico. Like other motor manufacturers, therefore, the company's exports has consisted mostly of parts and components to its German parent company (Jenkins,1979).

(147) Although the LAFTA agreement has been terminated, the following example of the use of its trade opportunities by TNCs shows the way in which these companies organize their strategy worldwide. "As in the case of IBM...Olivetti is engaged in exchange of different product lines between its various subsidiaries (in this case within Latin America) so that exports only represent about a fifth of the total value of sales in Mexico. Production for the Argentinian, Brazilian and Mexican market is divided between the Olivetti subsidiaries in the three countries, Argentine specializing in manual and electronic calculators, Brazil in electric and standard typewriters and Mexico in portable and semiportable typewriters. Such specialization is facilitated by LAFTA agreements which give preferential treatment to these products. In Mexico imports from other LAFTA countries pay lower duties and do not require import permits" (Jenkins,1979,p.165).

finished products to fulfill the Mexican import/export requirements. Indeed, as in the case of the auto industry ( see note 146), for those companies pursuing the benefits of the protected Mexican market, the choice of exporting part and components to their parent company may well be the most attractive. Thus, "...Computer manufacturers could very well end up exporting keyboards and knobs, thus satisfying that requirement and then enjoying a protected market at the expense of the consumer" (Salehizadeh and Garza-Adame,1984,p.97). It seems clear, therefore, that, on the basis of incentives and regulations only, transnational capital is hardly the social force to be entrusted with the development of a competitive Mexican electronics industry. As things stand at the moment, the most likely development is that these companies will in fact export a number of models of finished products with more or less national content. The heart of the computer technology, however, specifically, sophisticated semiconductors, will remain being imported from abroad, thus defining the character of Mexico's TNCs-based computer industry as essentially one of product assembly. In the latter respect, we can also see, therefore, that, just like the aim of international competitiveness, the government's aim of an integrated Mexican electronics industry is hardly a task that can be entrusted to transnational capital on the basis of incentives and regulations only.

Admittedly, the government itself does not expect transnational capital to contribute to the integration of the Mexican electronics industry in the context of the present legislation and without bringing further pressure upon TNCs. The risk of provoking a strong opposition from the TNCs, however, is something that the government is not prepared to run in the present circumstances when the official policy in response to the crisis has given foreign investment a major role in Mexico's financial revival and technological development. In effect, earlier in this work we have seen how in an effort to entice foreign capital the government has quietly changed the ownership requirements established in the Law on Foreign Investment by declaring various industrial sectors as priority areas for foreign investment. One of these priority areas is computers and related electronics fields where, as we have already seen, 100% foreign-owned plants have become quite common.

As a result of the crisis,therefore, the dependence of the government's model of electronics development upon transnational capital has grown stronger. Thus, although the TNCs' interests in the Mexican market makes them susceptible to make concessions too, it is clear that the government can only

push its demands up to certain limits, mostly defined by the present correlation of government-TNCs forces under the prevailing historical circumstances both at national and international levels. Thus, Mexico's major foreign exchange and debt problems have constituted an irrefutable reality which TNCs having interests in Mexico have had little choice but to acknowledge in defining their production and export strategy for that country (148). Although this implied concessions on the part of computer TNCs, the latter were not prohibitive as the government made simultaneous concessions on ownership, so that, on the whole, it is possible to say that a convergence of interests on new grounds has been possible under the galvanizing pressures of the recent economic crisis. From here to the goal of an internationally competitive and integrated Mexican electronics industry, however, there is a huge gap which is simply not in the interests of transnational capital to bridge. At least this is the conclusion that emerges from all we have seen regarding the role of TNCs in Mexico's process of industrialization and development of the country's R & D system. In this respect, whether the new critical conditions have changed the situation so radically for transnational capital to become an effective agent in the development of an autonomous Mexican electronics industry, is something that not even the government is trying to suggest. Instead, the idea seems to be that, under the present arrangements, Mexico's electronics industry will gradually grow stronger on the shoulders of foreign capital, up to the point where further concessions from the latter will be able to be negotiated. For instance, in a recent interview, a key government official, Guillermo Funes (149), has rejected criticisms in relation to the fact that foreign firms coming to Mexico will continue importing semiconductors, the technology that Mexico really needs for an integrated electronics industry. In his view, Mexico is simply not ready to tackle chip production and there is still room for technology transfer in assembly. Thus, although firms interested in the manufacture of some components are being encouraged to come to Mexico, Funes' idea is quite clear, "...We've lost the main train, and now we have to jump on and find a market niche where we can. In 10 years, we'll be in a position to really negotiate" [Quoted by Layton (1985),p.38).

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(148) An example of international pressures favouring Mexico has been Brazil's exclusion of some TNCs from segments of the internal electronics market. Thus, "...Sperry-Univac, excluded from the Brazilian market, has identified Mexico as its largest potential market in Latin America..." ( *Latin America Weekly Report*, 1981,p.10).

(149) Guillermo Funes is general director of technology transfer and foreign investment in the Ministry of Trade and Industrial Promotion; and also executive secretary of the National Commission on Foreign Investment.

What Mexico will be negotiating in 10 years is hard to envisage. What is clear though, is that for many years to come transnational capital is set to continue as the dominant social constituent in shaping the development of Mexico's electronics industry. In this context, the role of Mexican private capital is bound to remain weak with some presence in less complex fields as microcomputer assembly and peripherals. In turn, the government constituent, committed to its TNCs-based model of electronics capital accumulation, will continue with its basic policy of stimulating and regulating Mexican but, above all, foreign capital into developing Mexico's electronics capabilities. In this framework, direct government involvement in the strengthening of these capabilities will take place, primarily, at the level of R & D activities where industry has traditionally done very little and where the government sees an important way of strengthening its position vis-a-vis transnational capital, without having to risk a serious conflict with the latter constituent which may destabilize their strategic alliance.



#### 4.3.4. Electronics R & D in Mexico

A close look at electronics R & D in Mexico will serve to corroborate the view that the government social constituent considers this particular area of the electronics technical base as very important for the process of building up Mexico's indigenous capabilities and hence, for improving its own position vis-a-vis transnational capital. First, as we have seen, in an effort to stimulate industrial R & D demand, the government is expecting companies to allocate around 5% of total sales for R & D expenditure and priority is being given to projects contracted with independent research institutions with the purpose of multiplying and strengthening the national technological capacity in this field (Fernandez,1985). In the usual fashion, this regulation is supported by a decree that establishes tax incentives to promote R & D and commercialization of national technology. As a result, estimates from the government suggests a substantial investment is expected to be channelled towards R & D in the electronics sector (150). What kind of R & D is to be carried out, is not clear but some R & D groups and activities have been organized at the level of industry. The companies which are reported include Ericsson, INDETEL, IBM, NCR, SISCOM, MEXEL, Micrologica Aplicada and Transdata and Link. In telecommunications, the Instituto de Telecomunicaciones (INDETELEC) has been created in 1981 involving INDETEL, the Mexican government and private capital (151). In the latter case, however, we already see the direct participation of the government in the formation of R & D centres. For INDETELEC is the result of direct promotion by the Ministry of Communications and Transport which has been entrusted, along with Telefonos de Mexico, with the task of developing Mexico's R & D in the telecommunications sector (152). Another ministry which is promoting research in electronics is the Ministry of Energy,

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(150) UNIDO (1982) reports a sum of 500 million dollars. This amount must be a mistake, however, given that the largest electronics market in Mexico, i.e., telecommunications, has been estimated at around 300 million dollars. The figure may well be 500 million pesos which converted to dollars at the time (1981/1982) would give some 20 million dollars.

(151) INDETELEC is the largest of Mexico's electronics R & D centres having approximately 275 employees of which 200 are engineers. Technological activities are shared between adaptations of ITT's digital exchange to suit Mexican telecommunications conditions, and the development of digital transmission and peripheral equipment. Already INDETELEC has developed fairly sophisticated software expertise for the exchange system (Hobday,1985).

(152) For instance, the current national T & S programme states, "...To achieve the technological capacity required for the national development of integrated digital networks in services (RDIS), a coordinated multidisciplinary effort is required. The participation of the Ministry of Commerce and Transport and Telefonos de Mexico in the research and development programme on RDIS will be a factor of great importance. Their role will have to be active and not just limited to that of funding source for some studies" (Poder



Mines and State Industry which,

"...considers electronics...as an essential area in which it is possible to use the purchasing power of the State, and the research and development capacity of the sector, to promote electronics enterprises that could become internationally competitive and could have also a very important effect in the local manufacturing of material and components...The Ministry is basing its programme on the activities of the research institutes within its area of competence, such as in oil, electricity, steel and nuclear research. The electronics activities of these institutes are focused mainly on specific applications" (Fernandez,1985,pp.18-19).

Table 4.38 gives a list of government supported research institutions carrying out electronics R & D in Mexico. As we can see, direct government participation tends to manifest itself through both institutions of higher learning and governmental institutes, with the latter mostly related to particular areas of application. The range of R & D activities touches upon all areas of professional electronics and it is in the higher learning institutions where the widest range of research is performed. In contrast, governmental institutions focus their R & D activities on electronics applications relevant to their respective fields. In addition, most of the institutions share their electronics R & D with other activities which may include, for instance, oceanography (CICESE), molecular biology (CINVESTAV), solar energy (IEE), etc. Indeed, only in the field of telecommunications, the most important Mexican electronics sector, we find R & D institutions dedicated specifically to electronics R & D. Here, INDETELEC is the most important centre with 200 engineers. As far as the number of researchers working in electronics in the other institutions is concerned, this is unlikely to be higher than that of INDETELEC although the data given in table 4.38 are for 1979. From all these data, therefore, it seems that the government has a long way to go in R & D if the latter is ever going to spearhead the strengthening of Mexico's electronics capabilities and hence, the government's own position vis-a-vis transnational capital.

In effect, a closer analysis of the present situation reveals an electronics R & D system which is not only very small in comparison to the standards of advanced capitalist countries but which also suffers from the general underdevelopment problems affecting the Mexican R & D system at large (153). Let us take INDETELEC, for instance, the largest of the electronics centres in the largest of the electronics sectors in Mexico. Its 200 engineers clearly compare

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Ejecutivo Federal,1984,p.329).

(153) See discussion on Mexico's R & D system above.

Research Institution or Groups	Number of Researchers	Activity
National Autonomous University (UNAM) -Engineering Institute	87	biomedical equipment telecommunications, CAD/CAM, process control measuring equipment, data processing
-Instrument Centre -Research Institute on Applied Systems and Services (IMASS) -Physics and Materials Institute <sup>(1)</sup>	59 96+56	data processing semiconductors
National Polytechnical Institute (IPN) -Center for Research and Advanced Studies (CINVESTAV) -Mechanical and Electrical Engineering School	160	telecommunications, process control data processing, semiconductors biomedical equipment and measuring equipment
Metropolitan Autonomous University (UAM)		telecommunications, process control test and measuring equipment
Autonomous University of Puebla		semiconductors
Electrical Research Institute (IEE)	280	telecommunications, process control data processing
The Scientific Research and Higher Education Centre of Ensenada (CICESE)	86	telecommunications
Telecommunications Institute (INDETELEC)	200 <sup>(2)</sup>	telecommunications
Research and Development Centre in Telecommunications (CIDET)		telecommunications
The Telephone Company Research Group (TELMEX)		telecommunications
National Institute of Astrophysics, Optics and Electronics (INADE)	40	semiconductors
Petroleum Institute (IMP)	180	measuring equipment, process control data processing
National Institute for Nuclear Research (ININ)	592	measuring equipment
The Technological and Higher Studies Institute of Monterrey (ITESM)		process control
Regional Technological Institute of Tlalnepantla		NC machine tools
Social Security Institute		biomedical equipment
Cardiology Centre	24	biomedical equipment
Universidad Iberoamericana		
Universidad Anahuac		
Universidad La Salle		

**Table 4.3B.-** Research Institute or Groups Active in Electronics R & D in Mexico.

**Source.-** Data from Fernandez (1985), Marquez (1982), NAFINSA (1979), Moreno (1982), Hobday (1985), Nucimo (1982).

(1) In 1979 the Physics and Materials Institute were separate institutions having 96 and 56 researchers respectively.

(2) INDETELEC was formed in 1981.

badly with the number of researchers employed in transnational companies like Siemens and Ericsson which employ many times over (154). The latter without taking into account that INDETELEC is in fact partly owned by a transnational company (ITT) which means that its R & D policy is bound to reflect the interests of this TNC too. Indeed, we have already seen that INDETELEC's R & D activities have revolved around ITT's technology so that, in practice, the contribution of the institute to Mexico's indigenous telecommunications capabilities is, after all, as the country's industrialization process at large, mediated by the power of transnational capital. In this context, it is hardly surprising to find that, even when official forecasts are predicting a fivefold expansion in Mexico's telecommunications infrastructure by the year 2000, almost no R & D activities in advanced telecommunications technology is currently taking place. As the latest T & S programme has acknowledged,

"In the coming years, technological advances are expected in optoelectronic integrated circuits; in new processes for the fabrication of components such as lasers, fibre and detectors that possess greater reliability and lower production costs; and in systems of larger transmission capacity. In Mexico, the research and development activities in this area are practically non-existent" (Poder Ejecutivo Federal, 1984, pp. 328-329).

For the area of electronics signal systems as a whole, the place to look for R & D activities are the institutions of higher learning. Table 4.38 shows that UNAM and CINVESTAV, for instance, are carrying out R & D activities across most of the areas of electronics technology. The scale, however, is small, even if we assume that the number of researchers may have doubled since 1979. In other words, such a broad range of activities can only mean just a few researchers per project and area of research. In addition, just as we saw with the Mexican R & D system at large, there seems to be very little integration not only between different research projects within the sphere of institutions of higher learning but, also, between the R & D activities of these institutions and the technological activities within the industrial electronics sphere. Thus, on the first aspect, there is very little indication that the systemic and synergistic nature of the development process of the microtechnology is having some impact in the activities of Mexico's R & D institutions. For instance, nothing like the multidisciplinary teams at Rensselaer Polytechnic Institute and Carnegie Mellon University in the US (155) has developed in Mexico, and a CONACYT study in

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(154) "Siemens employ around 2,000 engineers in R & D devoted to exchange systems...Ericsson allocates more than 2,000 scientists, engineers and technicians to develop its exchange and transmission systems" (Goransson, 1984, p. 1230).

the late 1970s showed that there was no coordination in the research work of higher learning institutions in Mexico (NAFinsa/ONUDI,1979) (156). CONACYT itself was to undertake tasks of coordination but mostly to avoid overlapping in the work of different institutions.

With regard to the integration of the educational R & D sector to the industrial sector, the situation simply reproduces the general weaknesses of Mexico's R & D system. As Warman (1984) has stated,

"In Mexico, as in other developing countries, there is an almost total divorce between the productive sector and those capable of doing research and development; the latter sustain themselves by means of public expenditure, and the enterprises acquire their technology from firms whose parent companies are in the developed countries" (Warman,p.76).

Indeed, NAFinsa/ONUDI (1979) found that the R & D performed in technical schools and universities in Mexico had only educational purposes, or was aimed at developing and building electronic equipment and instruments which were needed by the institutions themselves. At present, the study concluded, "there is no link between industry and the academic institutions where electronics development is performed, nor there is a coordinated programme of research that may serve the needs of the industry" (ibid.,p.85). The whole situation was put in a nutshell by Moreno (1982) when he said that R & D in Mexico "is generally rickety" (p.43).

Currently, the *National Programme of Technological and Scientific Development, 1984-1988* has altered the situation somewhat by providing a general programme of R & D for the technological development of the electronics industry. As we saw at the beginning of the present section, the programme sets the goals, justification and even the specific lines of research and technological development which Mexico must pursue, across the entire area of electronics signal systems, in order to advance towards electronics self-determination or, in our terms, the possession of an indigenous microelectronics capability. The goals, sector by sector, have been described earlier, here our concern is simply to draw attention to the problems presented by the facts we

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(155) See note 114, Chapter III.

(156) An interesting example of the lack of integrated and cumulative electronics experience in Mexico is given by Grapa (1984), who argues that Mexico has an opportunity to develop software capabilities for the Spanish language market but that it is running the risk of missing it, among other factors, because of "the absurd over-competition of Mexican technologists (generally, every programmer states that his programs are better than those of

have been recently discussing in relation to the characteristics of Mexico's electronics R & D system and, indeed, the country's R & D system at large. In this respect, it seems pretty clear that, in itself, the T & S programme is merely a first step in the direction of an IMC. The actual achievement of the latter, however, will demand not just huge commitments in human, financial and material resources but, indeed, the very construction of an electronics R & D system truly materializing the basic scientific and systemic nature of the process of development of microtechnology and its industry. Here, the degree of development and structural problems of the present R & D system alone, suggest that the task facing Mexico is truly enormous. Indeed, the construction of a systemic and industrially-integrated electronics R & D system, if achieved at all, is certain to be a long-term process reaching deep into the 21st century. Sector by sector, major advances will have to be made given the very low level of R & D capability existing in most of them. For, it is simply impossible to think of a systemic R & D structure when, as in Mexico, some key R & D activities are virtually missing. Take R & D in materials for instance, only a few educational institutions perform R & D in this area, while, thus far, the "national electronics industry has not sponsored any research in the area of materials" (Poder Ejecutivo Federal,1984,p.318). In instrumentation and control, the situation is similar as the R & D personnel is estimated to be between 100 and 150 persons (50% researchers and 50% support personnel), all of them scattered around more than a dozen groups (ibid.). In telecommunications, we have already mentioned that research in advanced technology such as lasers, optical fibre was practically non-existent in Mexico. The same is the case for the technology of ICs design. Here, activities in the area of CAD are practically null. "In addition, there are no CAD systems in the country, either in the R & D sector or in the educational and industrial sector" (ibid.,p.331). In turn, in the area of electronic components, there is practically no R & D in VLSI technology. Here, the R & D institutions are mostly associated to higher learning, and it has been estimated that their capacity will enable them to develop, in the short-term, technology for the fabrication of discrete semiconductor components. However, "...In general, the research centres are not multidisciplinary, and this limits the range of their work" (ibid.,p.321). In computers, it is estimated that the R & D institutions of the country have the capability to develop without difficulty an industrial prototype of microcomputer (ibid.). More complex hardware, however, is not in the present R & D agenda

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any other person)..." (Grapa,p.20).



of Mexico. Finally, on the software side, where there are various institutions working on R & D, the situation is still precarious. Thus, "...The country's software R & D institutions have a limited capacity for determining requirements, test criteria, quality control, estimates of development time and costs, adequate documentation, etc., all of which...poses severe constraints to the possibilities of commercialization of their products" (ibid.,p.333).

As we can see, therefore, the government social constituent will have to do much more than producing a global electronics R & D programme if it expects to bring about a truly systemic and industrially-integrated R & D system which spearhead not only the build up of Mexico's IMC but, simultaneously the strengthening of its own stand vis-a-vis transnational capital. On this score, the establishment of the government-industry sponsored industrial laboratory in advanced electronics proposed in the current national T & S programme may represent an important step. According to the programme, such laboratory "will be able to contribute significantly to develop the multidisciplinary programmes of oriented research which are required" (ibid.,p.319). In the same line, other commentators have recently written on the growing interest in Mexico for the establishment of an electronics industry support centre which is probably very much related to, if not the same as, the industrial laboratory just mentioned. As it has been described, this support centre would "provide technical support to the electronics industry for electronic circuits design, interaction with silicon foundries and in general for the development and evaluation of electronics equipment. This centre could also improve the collaboration between industry and research institutions, facilitating the industrial application of research results and also the identification of opportunities for new projects" (Fernandez,1985,p.22) (157). In theory, therefore, such a centre would be in itself the seed and the missing link of an industrially-integrated electronics R &

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(157) The idea of a centre specifically dedicated to the generation and sale of electronics technology in Mexico has been consistently put forward by J. Warman, present director of electronics industry, SECOFI, referring, for instance, to the experience of the Korean Institute for Electronics Technology (KIET) and, also, the Mexican Petroleum Institute (IPM) in Mexico itself. According to Warman (1982), the centres of higher learning are not adequate as source of technology for industry; therefore, centres specifically dedicated to that task, "technological enterprises", are necessary. The latter centres must have the following characteristics. They must be in direct and close contact with industry; they must establish their R & D programmes based on the country's existing market for technology; they must be in close contact with the academic centres of higher learning and technology; they can organize educational programmes which serve the specific human resources needs of industry; financially, they could, in the long-term, become partially self-sufficient given the income to be derived from the selling of technology and the training and teaching programmes. See also Warman (1981,1984).



## D system.

In Mexico, however, there are problems. One of them may simply be the size and resources of the proposed centre, given the traditionally low level of expenditure which the country has devoted to R & D activities generally. But even more crucial is the fact that an industrially-integrated R & D system can only materialize through the deep involvement of the electronics industry itself; and this inevitably leads to the social issues in the development of the Mexican electronics industry. That is to say, it leads to the nature of its social constituency as well as the development purposes characterizing its unfolding as, indeed, that of the entire process of industrialization in Mexico. In this respect, we know from our analysis above, that in line with its TNCs-dependent model of industrial capital accumulation, the government social constituent not only has defined international competitiveness in the world market as the development purpose of Mexico's electronics industry but, also, has given transnational capital the task of developing the technological and productive foundations of this electronics industry. Its own role in the process has been self-defined as primarily one of promoter and regulator, while the small role of Mexican private capital has been basically the result of the latter constituent's own structural weakness.

Thus, by a dubious logic, in Mexico's present electronics strategy the main responsibility for materializing the industrial integration of the country's electronics R & D system has effectively fallen on the shoulders of transnational capital, the same social force whose overriding interests in global capital accumulation and hence, global control of the electronics infrastructure, tends to contradict the development of Mexico's autonomous technological capabilities. From another angle, the same social force whose dominance of the electronics world market is based on the power of its technology has the task, in Mexico, to effectively contribute to develop the country's international competitiveness and the technological capabilities sustaining it. Admittedly, it is true that transnationals can help with some technological developments here and there and even make use of Mexico's government-promoted R & D system. But it is a completely different matter to think that, because of some incentives and controls, they may become the fertile ground, the active agents of a systemic and industrially-integrated autonomous R & D system whose materialization can only lead to enhancing Mexico's indigenous microelectronics capability and hence, to simultaneously diminishing the TNCs' own relative weight vis-a-vis that of

the Mexican social constituents. Certainly, from all the evidence we have seen throughout our analysis of the country's long experience with TNCs-based industrial accumulation, there is no indication that the latter could actually happen. The same is still valid under the new historical pressures created by the recent crisis since, if anything, the dependence upon transnational capital and hence, the latter's relative weight within the social constituency of Mexico's industrialization, has increased. It seems, therefore, that as it stands today Mexico's path towards its goal of a capitalist IMC is fundamentally flawed. For, unless the Mexican social constituents are able to increase, gradually and consistently, their relative weight within the social constituency of the development process, such a constituency can only be described as the social constituency of Mexico's indigenous microelectronics incapability.

### 4.3.5. General Discussion

A simple way of starting the present discussion would be to say that Mexico neither has an IMC nor it is in the process of building up one which would materialize the goal of technological self-determination advocated by Mexican policy-makers.

The absence of an IMC in Mexico is a straightforward fact which emerges from the comparison between the characteristics of Mexico's electronics infrastructure and those characteristics which we have identified as intrinsic to an IMC in our discussion in Chapters II and III. In effect, in Chapter II we concluded that the systemic and synergistic convergence of electronic signal systems constituted a feature intrinsic to the development process of microtechnology and hence, of an IMC. In Mexico, however, we have found nothing of the sort in the country's technological base. Indeed, not only there is very little indication of the systemic and synergistic convergence of electronic signal systems but, more dramatically, whole areas of production of such systems have either a rudimentary development or are virtually missing. Consequently, in Mexico neither there is such a thing as the convergence of industries materializing the convergence of technologies taking place in the electronics technical base of society, process which in Chapter III we identified as an intrinsic feature of any IMC too. Finally, at a fundamental level, the science (R & D) constituent, which in Chapter III we also identified as intrinsic to any IMC, actually plays a negligible role in furthering the development of microtechnology in Mexico. In this respect, it is clear that the roots of the problem go deeper and beyond the limits of the electronics case alone, for, in the final analysis, it is the Mexican R & D system as a whole which is small, weak and disarticulated. In the abstract, therefore, the above findings in themselves suggest that the build up of an IMC in Mexico is a truly complex and long-term task which, among other things, passes through the very need to generate the intrinsic science social constituent of microtechnology in Mexico.

An IMC, however, does not exist in the abstract. It can only develop as part of a particular strategy for its build up which is inseparable from the country's general development strategy.. in Mexico, this has translated itself in the pursuit of a particular kind of IMC, namely, a capitalist IMC.

As we have seen in Chapter III, the particular kind of capitalist IMC incorporates the social force of capital as one of its intrinsic social constituents

along with the science social constituent. Moreover, we have also seen that, as the process of electronics development has unfolded, a tendency has developed for governments to also become intrinsic social constituents of microtechnology, mostly due to the fact that the resource-requirements necessary to get into and stay in the struggle for control of the electronics infrastructure have increasingly surpassed the ability of even the largest units of capital. This process has been reinforced by the governments' own perceptions of the crucial role of microtechnology for the realization of their overriding social interests.

In Mexico, however, government and capital alike have hardly acted as social constituents for the build up of a Mexican capitalist IMC. The reason has laid deep in the very nature of the development process pursued by these forces, which has been predominantly a process of industrial capital accumulation based on a high dependence on foreign transnational capital in a context of low development of the national technological base. For Mexico, this process has meant that its electronics development has become inextricably linked to the global struggle for control of the electronics infrastructure being waged by the electronics corporate capital of developed countries. Or to put it in another way, Mexico's capitalist electronics development has become a subordinated part and parcel of one and the same process of electronics capital accumulation at world scale. It is within this context that what we have referred to as the social constituency of Mexico's indigenous microelectronics *uncapability* has actually taken shape. Briefly, the main characteristics of such uncapability can be summarized as follows.

i) *Fundamental weakness of the Mexican social constituents of an IMC, with feeble interrelations and a lack of convergence of specific interests leading to the non-development of a capitalist IMC.* In Mexico, the science constituent is small and basically concentrated in academia, performing R & D activities with little concern for the interests of the electronics industry. On the other hand, Mexican private electronics capital is itself very weak and technologically dependent, seldom contributing to electronics R & D either in terms of its demand or in terms of its production. This means that there has been little material conditions for the convergence of the overriding interests of science and capital as the latter force has neither demanded the fruits of science nor supported its activities. In turn, the government social constituent has not until recently played any major role in the development of an autonomous electronics base in Mexico, and its recent commitment has been mainly indirect in nature, relying

on the promotional power of incentives and regulations but leaving the fundamental decisions on the shaping of electronics development to the unconnected interests of capital and science. In this respect, to the extent that there has been any direct role played by the government, this has been in the establishment of intermediate R & D mechanisms (R & D institutes) for the possible integration of science and capital. Such mechanisms, however, although an important advance in the conditions of general weakness of Mexico's electronics infrastructure, cannot in themselves provide a solution to the lack of dynamism of such electronics infrastructure. Ultimately, the latter is something that depends deeply on the existence of a strong social constituency consistently committed to the autonomous development of a Mexican IMC in such a way that the overriding interests of all the social constituents truly and effectively converge in the realization of such a task. In Mexico such a constituency does not exist and there is no indication that it is in the process of development.

ii) *Dominant relative weight and contradictory role of foreign transnational capital (mainly US) in the social constituency of Mexico's electronics development.* In Mexico, transnational capital, as a result of a TNCs-based development strategy, has acquired the effective control of the country's electronics industry from the beginning. The result has been that, on the whole, the development of such industry has primarily reflected transnational capital's overriding interest in global capital accumulation which, in practice, is always materialized within the limits imposed by its interrelations with national social forces under given historical circumstances. Thus, in this context we have seen that for most of the post-World War II period, Mexico has been primarily a market outlet for the products of electronics TNCs. While, more recently, in response to the conditions brought about by the critical conjuncture facing the Mexican social constituents, transnational capital has begun to contribute modestly to the development of some productive and even R & D facilities in Mexico. This shows that the TNCs' potential for contribution to the development of the electronics technical base of Mexico cannot be overlooked and that it certainly should form part of any strategy pursuing such a development. From here, however, to the likelihood of transnational capital effectively becoming the pivot of a process leading to the development of an autonomous Mexican industry, there is a huge abyss of contradictory interests to breach which, in practice, renders the realization of such a process a completely illusory goal. The participation of transnational capital in the Mexican electronics industry has no other ultimate purpose but the incorporation of this industry in its own strategy

of global capital accumulation. And insofar as this entails the practical control of the Mexican industry by foreign interests in opposition to its national autonomy, it is clear that the dominance of Mexico's electronics industry by transnational capital is intrinsically contradictory to, and represents a negation of, the goal of national autonomy.

Given the characteristics just described, therefore, it is plain to us that while they remain in force within the general context of the country's TNCs-based development strategy, there can be no other conclusion than to state that the social constituency of Mexico's electronics development is the constituency not of an IMC but, indeed, of an indigenous microelectronics *un capability*.

Theoretically, however, from the conclusion that Mexico's goal of a capitalist IMC is being intrinsically negated by its TNCs-dominated social constituency, it does not necessarily follow that it is the goal of a capitalist IMC which is fundamentally flawed. Indeed, from our analysis, we can only say for certain that it is Mexico's particular TNCs-dominated model of capitalist IMC which presents the fundamental flaws. In this respect, the more successful experience of countries such as Brazil and South Korea, who are also pursuing a capitalist IMC, is particularly revealing. In effect, although it is too early to say whether Brazil and Korea will succeed in their long-term strategies, in both cases the development of national electronics capabilities has been more successful than in Mexico. Interestingly enough, in both countries the key to their progress can be said to lie in a strategy of gradual and selective development of national electronics capabilities based on the combination of two factors. On the one hand, the subordination of transnational capital to the needs of national electronics development, sometimes even to the extent of its exclusion from specific electronics sectors. On the other hand, the stronger commitment by the national social constituents, particularly government, to the development of national electronics capabilities. To put it in another way, in both Brazil and Korea, the relative weight of the national social constituents is much greater than in the case of Mexico and, consequently, their role in, and control of the process of national electronics development is much greater too.

In the case of Brazil, for instance, without going into details (158)), we

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(158) For details of the Brazilian strategy in electronics and its achievements and problems, see Tigre (1983), Nochteff (1985), Fernandez (1985), Hobday (1985a,1986), Goransson (1984), Turner (1984), McCrone (1985), Kucinsky (1983), Erber (1985), Wajnberg (1985), Brundenius and Goransson (1986), *Latin America Weekly Report* (1981), *American Machinist*



can characterize its strategy as one of government-driven strengthening and integration of the science and national capital social constituents to the increasing detriment of transnational capital's early dominant control of the country's electronics industry. This strategy which took a definite shape by the mid-1970s with the elaboration of a national plan for electronics development has led to the establishment of a network of national companies and government R & D institutions which has strengthened and tied closer together the interests of government, national private capital and science in the development of a national electronics industry in Brazil. Simultaneously, the government social constituent has sought to reduce directly the relative weight of transnational capital within the social constituency of Brazil's electronics development. More conspicuously, it has done so, first, by "Brazilianization" (i.e., 51% Brazilian ownership), then increasingly by a policy of reserved markets in priority sectors which means the virtual exclusion of transnational capital and its products from the Brazilian market. This latter policy which began in the field of microcomputers has more recently been expanded to include, among others, telecommunications and CAD/CAM products and even some integrated circuits. The reaction of foreign transnational capital has been strong and currently the US government is putting strong pressure with the likelihood of retaliation against Brazil's products imported into the US. This shows that the path of confrontation with TNCs is not easy since the latter are not going to relinquish their control of any market without a battle. At any rate, the greater success of Brazil's strategy of development of a capitalist IMC puts clearly in a relief the intrinsic limitations of the Mexican strategy.

The same is the case with the Korean experience (159), where in a context of much less natural resources and smaller size than Brazil and Mexico, the government and private national capital have since the 1960s worked together in the development of Korea's electronics capabilities and industry. Indeed, already in the five year economic plan of 1962 the government selected electronics as one of Korea's priority industries. In this context, beginning with the development of an import-substitution consumer electronic goods industry, Korea's strategy has consistently emphasized a combination of aspects involving: exports to the world market; protectionism to infant Korean electronics sectors in the national market; promotion of foreign capital investment mainly for the

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(1985).

(159) For details, see UNCTC (1983), Chon (1984), Park (1984), Berney (1985), Berger (1985), Nam (1986), Jung-nam (1984), Parthasarathi (1978), Ahn (1985), Choi (1983),

export sector and particularly successful in the semiconductor sector in the 1970s; upgrading of national electronics technology and production through the generation of an important electronics R & D base involving both large and advanced research institutes supported by government and private capital and the R & D facilities of Korean large electronics companies themselves; transfer of technology and its appropriation mainly through the mechanisms of licencing and joint-ventures between foreign transnational capital (mostly Japanese and US) and Korean corporate capital. In the latter respect, not only many Koreans have gone to study to the US but some large Korean companies have even established subsidiaries in that country to facilitate and expedite the process of transfer of technology. As a result, it can be said that Korea has steadily strengthened a national social constituency of government, capital and science which is strongly committed to the development of national electronics capabilities and which has become more able to control and, more significantly, incorporate the activities of transnational capital into the development process of a Korean electronics industry. On this score, what is most particular in the Korean experience as compared with those of Brazil and Mexico, is the development of large Japanese-style integrated electronics companies such as Samsung and Goldstar which have emerged strongly into the world market, particularly of consumer electronic goods, and have move gradually into different and more complex areas of electronics technology. It has been these companies which have become the nucleus for the Korean appropriation of foreign technology being able to enter in licencing and joint-venture agreements on the basis of a technological capability which effectively enables them to profit from such agreements. No similar companies exist in Mexico with the result that any joint-venture agreement for instance, always involve Mexican companies which are weak electronically and which are thereby neither able to appropriate the foreign technology nor to exercise the role of equal or majority partner in the venture. Thus, if anything can be learned from the Korean experience of development of a capitalist IMC, this particular aspect of promoting the development of integrated electronics companies -which tend to reproduce the integration of electronics technologies taking place in the technical base of society- seems to be one that deserve paramount attention. Sure enough, such companies can only develop out of the strong commitment of the national social constituents for the development of autonomous electronics capabilities. And the latter has not been the strong point of the Mexican case.

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Westphal et al (1984), Kaplinsky (1986).

The fundamental weakness of Mexico's pursuit of a capitalist IMC, therefore, shows even clearer when we compare with the cases of Brazil and South Korea (160). Admittedly, due to the relatively early stage of the latter two countries' electronics development, it remains to be seen whether they will eventually succeed in their endeavours of achieving a capitalist IMC, faced as they are with strong competition and pressures from the countries leading the struggle for the control of the world electronics market. The crucial point for the present discussion, however, is that in the pursuit of a capitalist IMC no universal strategy actually exists and that Mexico's strategy has been one of the less successful, relying as it does on the dominant and contradictory role of the social constituent of foreign transnational capital.

In the Latin American context, the situation just described has important implications for the possibility of effective regional cooperation in the field of microelectronics: one of the alternatives most strongly advocated by those commentators propounding the development of indigenous microelectronics capabilities in Latin America (161). In effect, this alternative sees in the microelectronics challenge a real need and opportunity for Latin American countries to integrate their efforts and resources in pursuit of a collective Latin

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(160) It is relevant to note that, unlike in Mexico, in both Brazil and Korea the military have played a critical and long-term role in the machinery of government of the respective countries. In fact, since the military takeovers of 1961 in Korea and 1964 in Brazil, the military effectively became the government in both countries for at least the next two decades. This means that the military has undoubtedly been a prominent element of the social constituency of the industrial development process and hence, of the electronics development process in both nations. Unlike in Mexico, military pressures have had an important galvanizing role, particularly in South Korea where in the aftermath of the Korean War the country has come to live under an almost permanent state of war preparedness. In Brazil, the pressures arise from the traditional struggle for the hegemony of the South American region which the country dispute with Argentina. In Brazil as much as in Korea, therefore, military interests and the issues of military strength and national security have clearly informed and shaped the development of industry and the search for autonomous electronics capabilities. This can be seen, more generally, in the fact that both countries have developed important military industries and are among the most important Third World producers and exporters of weapons [Lock(1986),Nolan(1986)] and, more specifically, in the fact that the development of an autonomous electronics industry is taken not just as an economic necessity but also as a matter of national security. For instance, in rebuking the US pressures against Brazil for its policies of reserving markets for national companies, the recently-installed first civilian president since 1964, Jose Sarney, has defended Brazil's right to build its electronics industry on the basis of the country's debt problem as well as on the basis of national security (McCrone,1986). Despite the obvious importance of the military social constituent in the electronics build up of Brazil and Korea, no generalization as to their necessity is possible as it is shown by the Chilean experience where the monetarist oriented military government has been responsible for the virtual destruction of that country's nascent electronics industry.

(161) See Galli (1982), Lahera and Nochteff (1982), UNIDO Secretariat (1985a,1985b),

American electronics self-reliance. It is argued that the complexity and magnitude of the technological challenge is such that no single country can easily master it so that cooperation offers the best and, perhaps the only, path to enhance the individual efforts of every country while developing the collective self-reliance of the region at large. It is often noted that Latin America has a tradition of regional cooperation and efforts of integration with many multilateral and bilateral agreements, including industrial and technological agreements such as the Andean Pact where even a common treatment to regulate the activities of transnational capital was involved. In the field of electronics, two regional associations are in existence: the Latin American Association of the Electronics Industry (ALAINEE) and a similar association for the Andean Pact countries (ANDINEE). Currently, a UNIDO programme has made it its goal to establish a Regional System for Microelectronics in Latin America (REMLAC). Such a system, which was due to start as a pilot experience in 1985, is mostly concerned with microelectronics technology and has been conceived as a network of institutions based in different countries and having as its essential function the establishment of effective mechanisms for flows of information and organization of events among its members. This will link together scientific and technological activities between the countries involved; facilitating the preparation and implementation of cooperative activities; and keeping its members informed not only of their own activities but also of the international trends in the microelectronics field (UNIDO,1985a,1985b).

The implementation of the REMLAC concept is certainly a very worthwhile effort, as indeed have been all the previous efforts to implement the variety of mechanisms which have been proposed to advance the cause of Latin American scientific and technological integration (see Campos,1972). In this sense, an idea which seems particularly attractive, given the Japanese and Korean experience, would be to target the creation of multinational Latin American integrated electronics companies which are able to galvanize massive resources and reflect the systemic convergence of electronics technologies in the technical base of society. In a context of planned cooperation, the existence of such an industrial base would incorporate the REMLAC concept providing it with the fertile ground the latter now lacks. Indeed, within the framework of regional cooperation, it is clear that this and many schemes could be devised which are highly desirable, for, in the final analysis, their effective implementation would mean the materialization in practice of the old dream of Latin American unity.

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Whatever the desirability and obvious potential benefits of regional integration schemes, however, it is clear from our analysis that without the existence of a coherent Latin American social constituency which is committed to the development of a Latin American IMC, the likelihood is that international cooperation will continue to play the limited role it has played thus far, hampered by the many contradictions implicit in often divergent development strategies and ready to be sacrificed in the face of any major crisis or political change. Chile's withdrawal from the Andean Pact in the aftermath of the 1973 military coup, for instance, and, quite significantly, the dwindling of the 1970s efforts to generate Latin American multinational enterprises which never actually took off within the subcontinent for all their worth (Raddavero,1985), are just a couple of the many instances where regional integration has shown to be a fragile reality in a societal context which is unable to produce a consistent social constituency for the success of such efforts. It is in this light that the divergence of the Mexican strategy in relation to that of Brazil for instance, augurs little hope for the prospects of the country ever achieving an IMC through the collective path of a Latin American IMC. This means that notwithstanding Mexico's keen involvement in the development of the REMLAC concept since its beginnings, it is unlikely that the latter will have any dramatic impact on the present course of development of the country's electronics capabilities and industry, and will probably follow a similar fate to that of Mexico's various R & D institutions which have been unable to root themselves in the fertile ground of a national industrial base.

Finally, in bringing the present discussion to an end, we return to where we started, namely, Mexico's ultimate development goals and the possible role of microtechnology in bringing them about. Here, the conclusion that emerges from all the issues we have discussed in the course of the present chapter is unavoidably pessimistic: within the context of the present dominant social constituency of power and associated development strategy, all the ideals of national independence and social justice and equality for the Mexican people are bound to continue as little else but the recurrent theme of a rhetorical discourse only mystifying the reality of a process of development which is simply not leading to their fulfillment. Thus, unless some important changes in the fundamental social forces and tenets of Mexico's development strategy actually take place, it is plain that the promises and potential benefits of microtechnology will hardly materialize themselves in the solution of the acute social problems

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affecting the millions of the dispossessed people of the country. The specific ways and exact nature of such changes, however, is not for us to say. For, undoubtedly, this is a task that belong to nobody but the Mexican people alone.

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Fernandez and Octavio (1985), Aguirre and Heredia (1982).



## Chapter V

### By Way of Conclusion: From an IMC Towards a Sociotechnical Theory of Indigenous Technological Capabilities.

As a conclusion to this thesis we could have taken the option of keeping the focus of our analysis strictly related to the theme of an IMC and, basically, bring together under one chapter heading the concepts which we have exposed throughout the present work, particularly, in the general-discussion sections of Chapter II, III and IV. However, since this would have amounted mostly to a repetition of these sections which somehow have as their proper place the end of the respective chapters abovementioned, we have decided to take a somewhat more demanding option, namely, that of trying to contribute to the conceptualization of a more general theory of ITCs as sociotechnical systems using the findings and theoretical underpinnings of previous chapters. Thus, in what follows our aim is clear: to advance the systematization of the general workings of an ITC sociotechnical process, particularly of a large-scale and complex ITC, from its basic components to its international dimension. Obviously, the much broader and systematic analysis involved in such a generalization means that some new ground will have to be covered in the present conclusion given that not all its conceptual elements and argumentation will have been dealt with or used in the course of the previous chapters. Hence, it is necessary to say that while substantial parts of the analysis will indeed find its roots in the various concepts and many processes dealt with above, some other parts will be primarily the result of logical analysis. In addition, since both the field of ITC and a sociotechnical approach to technology do not start with this chapter but have already an important tradition, we have also thought necessary to review some of the most relevant contributions which have been made so far, as a way of putting our own conceptualization into perspective. This chapter, therefore, is divided in three distinct parts. First, a review of ITCs conceptualizations, then, a review of sociotechnical approaches to technology and, finally, our attempt to contribute to a sociotechnical theory of ITCs.

## 5.1. Indigenous Technological Capabilities in UDCs. Technological Self-Reliance

The concepts of indigenous technological capabilities and technological self-reliance are intimately related in that without an ITC there can be no effective technological self-reliance (1). For this reason, when, by the early- to mid-1970s, some scholars, particularly from Latin America (2), began to concern themselves with the issue of scientific and technological (S & T) self-reliance in UDCs, their work tended naturally to focus on the kind of technological capabilities necessary for the materialization of the goal of self-reliance as well as on the problems affecting the development of such capabilities. As it normally happens with all concepts, however, the concept of S & T self-reliance was liable to be interpreted in different ways with the corresponding differences being reflected in the content of the specific capabilities identified as necessary for UDCs. For instance, Sagasti (1976) identified three different interpretations of S & T self-reliance.

"a) *As the capacity for autonomous decision-making in matters of technology...* In this case it is not necessary to possess the technology to meet development needs within the country. Decision autonomy refers to the capacity for defining technology requirements, identifying alternatives available elsewhere...and determining the best way to acquire, incorporate and absorb the technology. This in turn is related to the capacity for obtaining and processing information about technology.

b) *As the combination of decision autonomy and the capacity to generate independently the critical elements of technical knowledge required for a particular product or process...* This capacity is closely linked to the development of engineering design skills and does not necessarily imply that the totality of the 'critical elements' is to be produced within the country. What is required is the capability to design the process or product (and its critical elements in particular), to define standards and specifications for the components to be manufactured and to assemble the components into the complete design.

c) *As the autonomous potential for producing within the country the goods and services considered essential in the development strategy...* In this sense technological self-reliance involves autonomy of decision and the possession of technical knowledge and skills, as well as the capacity to transform them into goods and services. The country would be able to 'rely on its own capabilities' if forced to do so, although under normal conditions it would not attempt to engage in all of the

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(1) It is true that a country may possess a capability in some aspects of a given technological process, for instance, capability to use, without having an indigenous capability in other more complex aspects, for instance, capability to produce a given technology. In this case, as we shall see, we can hardly talk of a country's technological self-reliance, although we may conceivably talk of self-reliance in that particular aspect of the technological process.

(2) For instance, see Sagasti (1975,1976), Herrera (1972,1978), Sabato (1975).

productive activities it is capable of performing" (Sagasti, pp.939-940).

As we can see, therefore, all the goals of self-reliance imply a search for clear degrees of autonomy which only the effective possession of specific combinations of ITCs can materialize. Obviously, specific countries can pursue one or another form of self-reliance and, in principle, they may always progress towards the highest forms of self-reliance given the right set of conditions. Indeed, the latter forms of self-reliance very much constitute the implicit goal assumed by those studies which tend to posit the situation in the developed countries (DCs) as the goal for the UDCs. Sabato (1975), for instance, compares the situation of the R & D infrastructure of UDCs with that of the DCs and points to the importance of the capabilities to take decisions, predict (forecast), adapt and create technology. In his view, once the stage of import substitution, which demands primarily a capacity to adapt, has been achieved, the capacity to create becomes ever more important as the search for new products and processes must now follow, not only to satisfy existing demands but generate new ones. At this point, "it is necessary to have a creative system of research and development: a system designed only for adaptation would not do" (Sabato,p.71).

Implicit in the concepts of self-reliance is of course the aim of breaking with technological dependence in varying degrees. In this respect, as some more recent writings have pointed out, technological self-reliance does not necessarily mean the absence of dependence [Ernst(1980), Makange(1980)]. It does mean, however, "the ability to choose and control the areas of partial technological dependence, which in any country will remain unavoidable for many years to come" (Ernst,1980b,p.56). A similar view is stated in UNIDO (1981), where

"technological self-reliance is defined as the autonomous capacity to make and to implement decisions and thus to exercise choice and control over areas of partial technological dependence or over a nation's relations with other nations. It follows that technological self-reliance can be effectively pursued only when a nation understands the nature and extent of its technological dependence and possesses the will and self-confidence to seek to overcome it and to maintain its cultural identity. Technological self-reliance must thus be conceived in terms of the capacity to identify national technological needs and to select and apply both foreign and domestic technology under conditions that enhance the growth of national technological capability" (UNIDO,p.11).

The strategy which emerges from this view of self-reliance is thus twofold. On the one hand, it involves the selection and appropriation of foreign

technological inputs, demanding the existence of well developed capacities to select and acquire, and to adapt and absorb technologies for their effective operation in their new environment (ibid.). This would be roughly what Dore (1984) denominates as an independent technology learning capacity (ITLC). On the other hand, it involves the stimulation of indigenous supplies of technology, demanding the mobilization of the national technology system in pursuit of technological innovation and development (UNIDO,1981). This would in Dore's terms be an independent technology creating capability (ITCC) (Dore,1984).

Various other authors have concerned themselves with the problem of self-reliance and indigenous technological capabilities and have distinguished the various specific capabilities involved. By and large, however, little can be added to the concepts reviewed above, since they tend to embrace most of the distinctions which can be made within the broad spectrum of technological capabilities. This is the case, for instance, for the capacity to select appropriate technologies (Cooper and Maxwell,1980); the capacity to master and duplicate imported technologies (Desai,1984); the capacity to introduce a degree of novelty in the production of products and processes (Fransman,1984); and also for Morehouse's broader capacities "to create, acquire, adapt and use technological solutions appropriate to their economic and social conditions" (Morehouse,1980, pp.532). In this respect, if anything can be added, it is from the point of view of a detailed content of the different capabilities rather than from their overall definition. Dahlman and Cortez (1984) have attempted such a more detailed approach and have distinguished five broad types of technological capabilities.

"The first type of capability has to do with the acquisition of existing product and process knowledge. It includes the capability to search for, assess and select technology appropriate to specific local needs and conditions. It also includes the capability to negotiate favourable terms for the acquisition of that technology...The second has to do with the translation of product and process knowledge into products and productive facilities. It includes the capability to conceive, plan, design and implement products, plants, processes and equipments to produce specific products...The third has to do with the efficient operation of those plants, processes and equipments. It includes the capability to produce the specified outputs with the given plants and processes, equipment and raw materials, including the repair and maintenance of the productive facilities involved...The fourth has to do with the capability to adjust and/or improve plants, products, processes, inputs and equipments, in order to remain competitive in light of different and often changing conditions in demand, technology, government regulations, and input factor prices and availability...Finally, the last has to do with the capability to create new technological knowledge (products, processes, and equipment), which satisfy specific needs and local conditions better or more efficiently" (Dahlman and Cortez,p.602).

Clearly, a lot has been said and identified in relation to the concept of indigenous technological capability. However, what we have seen so far is basically a static picture of the content of ITC with little indication of its relation to the wider societal framework within which it develops. In this respect, the existence of a social connection has been widely acknowledged by most writers although, as we shall see later on, the meaning attached to it has been the subject of a great deal of theoretical variations. For some authors such as Dahlman and Cortez (1984), for instance, different social factors seem only to affect the development of a technological capability but they are not part of one and the same process. A similar position is found in Sabato (1975) when he deals with economic, political and sociocultural factors as either forces compelling or obstacles retarding the process of innovation. Here, the latter process although immersed in a social milieu still possesses a separate identity of its own which seems to be valid for every form of society. This means that in order to appropriate the process of innovation of most advanced nations, "closing the gap" as others have put it, the task for UDCs becomes mainly one of removing the societal obstacles which neutralize the effect of the forces compelling the technological process. Sagasti (1975,1978,1980) also sees the role of internal socio-economic and political transformations as crucial for the goal of technological self-reliance. In his view, however, the social and technological dimensions interact with each other insofar as "technological self-reliance cannot be pursued out of the context of an autonomous development style and strategy. Therefore, the issues of technological self-reliance and alternative development styles interact with each other, to the extent that cannot be considered independently" (Sagasti,1975,p.942). For the same commentator, the orientation and pace of S & T growth at present are determined by the interests of power elites in the industrialized North. Such interests, however, have nothing to do with the aspirations and goals of UDCs, with the result that there is a need for the UDCs to break with their dependent mode of insertion into the world economy and seek new ways of linking up with it. Hence, his conclusion that "socioeconomic transformations must take place before endogenous S & T capabilities could be developed in order to escape from the condition of underdevelopment" (Sagasti,1980,p.602). Herrera (1972,1978) shares this conclusion in his analysis of, and search for, alternative forms of technological development for UDCs. His own argument also emphasises that "technologies are created in response to social demands based on certain social, economic and cultural determinants" (Herrera,1978,p.1470). Looking at some of the experiences of both DCs and UDCs, he contends that there are implicit and explicit policies



in the scientific and technological development of a given country. The explicit policy can be found in laws, regulations, etc. but the implicit policy is far more difficult to identify because, although it determines the real role of science in society, it has no formal structure; in essence, it expresses the scientific and technological requirements of what Herrera (1972) calls the 'national project' of each country, i.e., "the set of objectives (or model of the country) to which the social classes which have direct or indirect economic and political control aspire" (Herrera,p.28). With Herrera, therefore, it is the concrete interests of those exercising power which ultimately determine the shape of the S & T process and not any supposedly broad 'national interests' unless the latter two actually coincide.

Morehouse (1980) has argued along similar lines of power groups controlling the S & T process in DCs and UDCs but has pointed towards the determinant role played in such a process by an international alliance of power, privilege and technology in industrialized and Third World countries. This 'unholy alliance', as he refers to it, is basically between the rich countries, which collectively generate their own technology, and that 10-20 percent of the population of poor countries which have adopted rich country consumption patterns. The latter are largely the urbanized upper income groups in the TW which include most of those with political and economic power -and the privileges which go with that power- and who, for the same reason, interact with those in rich countries who also occupy positions of power and privilege there, that is, political leaders and senior official of banks, multinational corporations, and international agencies. Out of this 'unholy alliance', there emerge the social determinants of the technological process, or in Morehouse's own words, "we are thus confronted with an alliance of those within rich and poor countries who determine the direction and character of technological change in order to maintain their own status and power and to serve in the first instance their own needs and only secondarily the needs of others" (Morehouse,1980,p.538).

The theme of the interrelation between the technical and social dimensions of an indigenous technological capability is also found in various other writers. For instance, Kaplinsky (1985) states, "we reject the perspective that technology determines social relations, for technology is, itself *a product of social relations*." (Kaplinsky,p.423). From within the Marxist tradition, Leys (1984) argues that "technology is never neutral but is intimately related to the social relations of

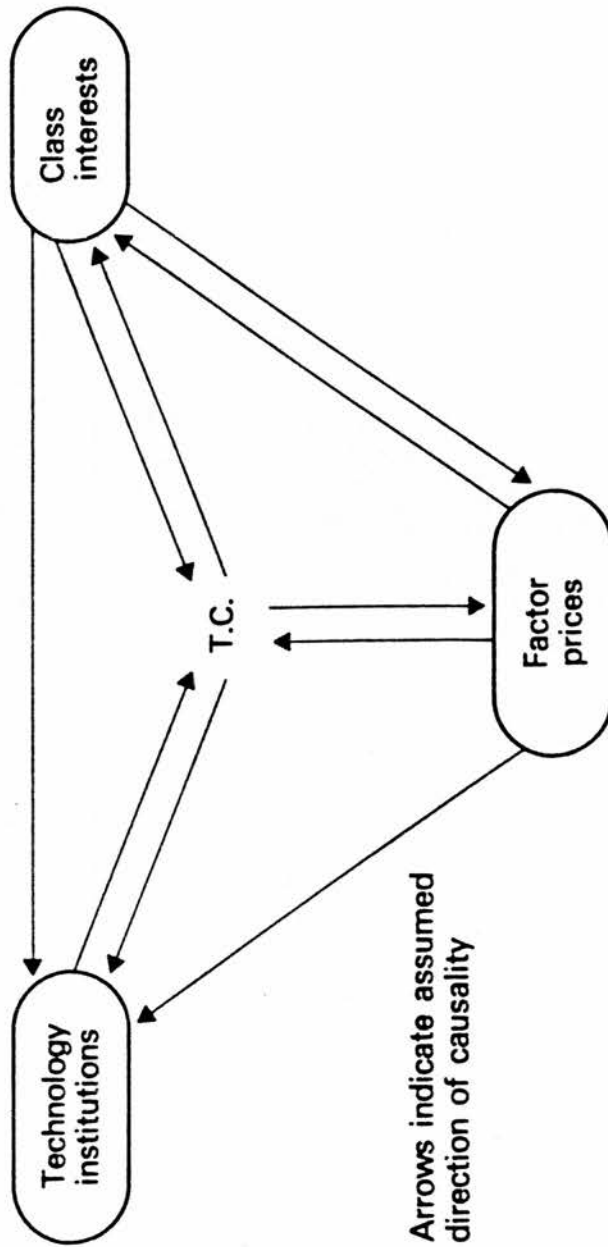


production; indeed it is an aspect of those relations" (Leys,p.175). This means that where "the dominant relations of production are in conflict with a given technology, the technology is replaced" (ibid.,p.176)). Ernst (1980b) expands upon this view when he argues that technology, as a product of science, fulfills a twofold function: it is a force of production, and an instrument of social control. He specifically defines technology as "the specific way in which labour and means of production are combined, to use knowledge for the appropriation of and change in one's material and social environment" (Ernst,1980b,p.49). More importantly, while Ernst (1980b), points out that a technology is determined by the material conditions of the object which has to be processed, the final product, and the process of production which makes possible that transformation, he also clearly emphasizes that the development of such a technology does not take place in a social vacuum. In his words, technology

"...is the result of a specific historical mode of accumulation. In other words, each historical mode accumulation requires a specific mode to produce and supply technology, its *dominant technology system*. A technology system will be dominant, if it fits some basic material characteristics of the mode of accumulation and the class structure and patterns of state intervention underlying it. On the other hand, those technology systems which happen to be ineffectual or even counter-productive to the development of a historical mode of accumulation, will be displaced and suppressed" (Ernst,1980b,p.51).

With different shades or emphasis, therefore, the social understanding of the problem of an indigenous technological capability is a well established viewpoint. For this reason, Stewart (1984), in her review of different theoretical approaches to the ITC problem, has concluded that "a major element in any work on indigenous technical change should be to trace how the interests and rewards of the major decision-makers relate to a static or dynamic environment and to local or foreign sources of technology" (Stewart,p.88). Hence, after criticizing the limitations of some prevailing approaches, particularly within the field of economics, Stewart (1984) proposes her own "comprehensive/eclectic approach", which is graphically depicted in figure 5.1. As it is possible to see, in this model, technology institutions, class interests, factor prices and technical change all interact with each other in a process which emphasises multiplicity of causal factors. As Stewart (1984) herself explains in relation to a UDC's context,

"In this comprehensive approach, class interests, for example, in the form of foreign interests, an industrial bourgeoisie with foreign connections and an urban 'elite' working class, would contribute to the determination of factor prices (low capital prices, relatively high urban wages) and would directly, and indirectly via these factor prices, help



**Figure 5.1.-** A Comprehensive/ Eclectic Approach

determine the nature of technology change. But the factor endowment would also play some independent role in that the price of labour would still be relatively (compared with developed countries) low. Technology institutions are themselves influenced by the conglomeration of class interests and by the prevailing factor prices. Yet they may also have some independent role, depending on their own logic, itself a function of their design, the interests they serve and the training and objectives of the scientific community. The outcome of this complex interaction is a certain type of technical change, which is of significance in determining the configuration of variables in the next period - what class interests emerge, for example, how factor availability is influenced, and so on" (Stewart,p.92).

Stewart's "comprehensive/eclectic approach", therefore, clearly puts the social and technical dimensions in a closely knit structural process of multiple and interactive cause-and-effect relationships between the major factors distinguished. From our point of view, however, this approach is still limited with little indication, for example, of the role of contradictory struggles and alterations under changing historical circumstances. It conveys the idea of a process evolving on its own with an intrinsically a-historical dynamic. Indeed, in a feature very much in common with all the other views we have seen previously, Stewart's approach does not really help us to understand the whys and hows of the social determination of the process of an indigenous technological capability. The fundamental realization of such social determination is thus left at levels of generality which overlook too many critical problems. For instance, what is the basic nature of the process which accounts for the interpenetration of technical and social factors within an ITC ? Or, on which basis and why the specific social interests which are said to influence the development of technology in a given society actually converge or interact ? On the latter question, for instance, the views we have just examined appear to imply a total lack of contradictions between the dominant groups of society with the result that technology seems to evolve through a coherent path reflecting the control and influence of a non-conflictive power alliance. Among Marxist scholars in particular, there is a tendency to subsume the role and interests of all social forces to the particular process of reproduction of the capitalist social relations of production. This has meant that the main thrust of the analyses normally focuses upon capital as the dominant social force, by and large dealing with government and the military, for instance, as subservient to capital and the needs of the process of capital accumulation. Thus, although degrees of autonomy are explicitly acknowledged, the role of contradiction within the power structure upon technological development is generally overlooked. Inevitably, this leads to levels of generalization which make it difficult to explain, for example, the basic

differences seen in the development process of an ITC in different capitalist countries. From what we have seen in the course of this thesis, we believe it is possible to improve upon and, consequently, offer a more elaborate approach or framework which contributes not only to the explanation of the problems we have raised in our critique but, more broadly, to the understanding of the complex problematique involved in the nature of an ITC. In the following, our aim is to advance in the direction of such a framework by examining the theoretical tradition of the sociotechnical approach to the understanding of technology.

## 5.2. The Theoretical Tradition of the Sociotechnical Approach to Technology

It is the theme of the present section that there is a fundamental unity which somehow relates to a common realm all those technical and social processes, artifacts, knowledge and skills which are constantly referred to as technology in diverse studies. In the past, as we shall see below, this fundamental unity has been present in different forms in the work of various writers, although, in practice, it has seldom been treated systematically with the aim of producing a formal theoretical framework for its understanding. On the other hand, it is much more common to see studies concerned with technology, which cancel from the very start the possibility of such a systematic treatment by reducing technology to only one or some of its partial aspects. To mention just a few instances of the latter case, technology is dealt with as mostly knowledge by authors such as Mansfield (1969), Mesthene (1970) and UNESCO (1979). While knowledge and devices is the essence of technology for authors such as Derry and Williams (1975) and Leikind and Miles (1975). Childe (1965) sees technology as the study and result of those activities directed to the satisfaction of human ends. In turn, Stewart (1978) is not as keen on devices but sees skills (3), knowledge and procedures for making, using and doing useful things as the essence of technology. Clearly, in all these views the nature of technology is limited by definition, a feature which is mostly absent in the approach of those authors who have understood the broad technical and social nature of the constituent elements, and historical process, of the development of technology.

In effect, going as far back as Marx (4) and his dialectical materialist analysis of the development of the productive forces/social relations of production within capitalism, various scholars, particularly those finding in the interpenetration of technology and society an interpretation to the actual shape of society's development, have understood technology not only as a dynamic social process embracing and interrelating devices (i.e., tools, machines, products, etc.), people, organization, procedures, etc., but also as a process which is inseparable from society at large, influencing the latter's development as much as

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(3) Feibleman (1966) had also argued that skills are components of technology.

(4) See Marx (1977a,1977b), and various works dealing with Marx's conceptualization of science and technology, particularly, Mishra (1979), MacKenzie (1984), Rosenberg (1974,1975), Cooper (1971). See also Muller (1980) for a systematic sociotechnical conceptualization along Marxist lines of thought.

being influenced by it. Among these scholars, theoretical constructs, perspectives and emphases dominating the analyses of the technology/society interpenetration have certainly been varied and even contradictory, but, ultimately, they all share what we refer to as a sociotechnical approach to technology in that the social and the technical pervade each other in the course of society's development.

In Marcuse's analysis of advanced industrial societies (5), for instance, modern technology, as the totality of instruments, devices and contrivances which characterize the machine age, is at the same time a mode of organizing and perpetuating (or changing) social relationships, a manifestation of prevalent thought and behaviour patterns, and instrument for control and domination. In the latter sense, technology, through its material achievements and rationality, as productive force and ideology, has come to provide the legitimation of the expanding political power which absorbs all spheres of culture. Today, domination perpetuates and extends itself not only through technology but *as* technology, for in the medium of technology, culture, politics and the economy merge into an omnipresent system which swallow up or repulses all alternatives. For Marcuse, therefore, the technological and social world are inseparable in advanced industrial societies as both intermingle with each other in a single system of domination, namely, the technological society.

Other authors have tread a similar path to Marcuse. In particular, Ellul's work (6) has also identified technology as having taking over all of man's activities, not just his production activities. Indeed, man himself has become the object of technique with the development of such human techniques as medicine, genetics and propaganda. For Ellul, however, more than a system of total domination, the technological society has become a world of its own where the quest for the one best means, in a mathematical sense, in every field has given technology the primacy of social developments over any other consideration or social force. This has come about because, ultimately, all major social groups in society (e.g., workers, capital, the state, the public, etc.) have become possessed by a technical state of mind which posits an identification between technical progress and their own special interests. On this basis, technology has become the prime mover of societal development eliciting and conditioning social, political and economic change. As with Marcuse, therefore, although with a

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(5) See Marcuse (1941,1964) and also Habermas' critical analysis of Marcuse conceptualization of technology published in 1971.



different theoretical construct, technological and social development are inseparable aspects of the same technological society.

Lewis Mumford's work (7) puts forward an equally all-embracing interpretation of the way technology and society have come to pervade each other in present-day advanced society. His megamachine involving people, devices, organization, etc., represents the dominant reality in today's society which tends to subsume all forms of human expression and social relations to those forms of mechanical relations intrinsic to all machines. For Mumford there are specific social machines (e.g., the labour machine, the military machine, etc.) which fulfill specific tasks but the megamachine is their projection to the entire societal realm; a realm where increasingly only those expressions of humanity which are consistent with the workings of the machine become the valid ones and are able to develop unhindered. For Mumford, the coming into being of the modern megamachine has been the result of a historical process where the crystallization of a dominant complex of power, under enormous pressures such as war, has gone hand in hand, in a process of reciprocal compulsions, with the development of the megamachine itself. The Pentagon of Power which merges dominant social interests in a dynamics of power and prestige, property, productivity and profits is thus the social counterpart of the megamachine, reproducing and furthering itself through the latter's own reproduction and further development. In this process, society becomes increasingly totalitarian, for not only is the megamachine intrinsically authoritarian but, also, its development is intrinsically monotekhnical in that it tends to embrace all areas of human activity while excluding polytechnics, i.e., all forms of techniques other than those consistent with the megamachine. Polytechnics, for Mumford, are intrinsically democratic in that they are under the direct control of the participants, providing them with security and a means of self-expression. Thus, as they are gradually wiped out by the development of the megamachine, it is the very base of society's democracy which is actually disappearing. The shape of present-day society, therefore, is inseparable from the shape of present-day technological development. They give each other their respective characters.

From the field of economics, it has been J.K. Galbraith's work (8) on the nature of the new industrial state which has produced one of the most wide-ranging interpretations of the ways in which technical and social factors

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(6) See Ellul (1963,1965,1967,1972,1981).

(7) See Mumford (1934,1957,1969,1964,1966,1967,1970).

interplay with each other in the shaping of modern industrial society. In Galbraith's analysis advanced technology possesses intrinsic characteristics in terms of size, complexity, costs, time and organization which within a market environment of risk and uncertainty lead to sociotechnical forms of economic organization whose result is the negation of such a market and its replacement by a planning system where all factors pertaining to the reproduction of the economic organization (i.e., the large corporation) are sought to be incorporated. The technostructure thus emerge, a kind of sociotechnical structure which is the technical brain of the corporation as well as its controlling power. The technostructure has as its overriding goal the growth of the organization and hence its own reproduction. In this process, the technostructure seeks not only to control the market but, indeed, to influence all those social forces, such as the government, which are important for the materialization of its goals. In practice, the result is a process of confluence of interests whereby the values and purposes of the technostructure pervade the other social forces and vice-versa. A power alliance is thus created which not only is ultimately rooted in advanced technology but, conversely, reverts its influence upon it by shaping the direction of its development in accordance with the interests of the controlling forces. Social and technical factors, therefore, reciprocally influence each other in Galbraith's sociotechnical account of the new industrial state.

Thus far, with the above scholars, the main preoccupation has clearly been that of unveiling the nature of human society, particularly, advanced industrial society, where technology is perceived as having become a pervasive reality whose process of development involving people, machines, organization, values, etc., expresses and shapes more than any other the development of what has gradually evolved into the technological society itself. In this sense, with writers such as Marcuse, Ellul, Mumford and Galbraith, the sociotechnical conceptualization of technology is not for the sake of understanding technology alone but it leads to the understanding of society from the start, for in it modern society and technology defines each other's fundamental character. In the technology literature, the influence of such a wide-ranging approaches has been noticeable so that it is not difficult to find some of the important perceptions of the above scholars' analyses clearly present in the work of other sociotechnical writers who have concerned themselves more directly with the nature of technology.

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(8) See Galbraith (1952,1958,1963,1967,1971,1974).

D. Goulet (9), for instance, acknowledges the premise that in modern societies, technology has come to play a dominant and pervasive role so that the organization of contemporary modern society itself is along dominantly technological lines. Ultimately, this means that, in these places, the tendency is for technology to reduce the totality of human meaning to those elements which are amenable to problem-solving. In his work, Goulet has sought to highlight, primarily, the character of modern technology as a dynamic system of its own; a system which, although constantly evolving and interacting with broader forces of social change, has its own value universe which unrelentingly pervades all societal activities wherever technology becomes the dominant reality. This value system is what Goulet identifies as a particular Western approach to rationality and efficiency which associates the former with decomposition of reality and quantitative measurement and the latter mainly with productivity. This Western approach also exhibits a predilection for the problem-solving stance in the face of nature and human events, and a Promethean view of the universe which emphasises the control and domination of nature. In modern society, this value system is paramount, helping to shape both technology and society through a reciprocal interplay of such dynamic forces as the infatuation of contemporary human beings with their own creativity (technology's imperative), the search for the competitive edge, and the interests of identifiable social groups (e.g., TNCs) using technology as instruments of social control. Out of this mix, technical and social factors become a single sociotechnical system where only a change in society's dominant values can alter the present state of affairs.

Another scholar, whose sociotechnical approach to modern technology has much in common with some of the concepts we have seen earlier, is J. McDermott (10). In his own interpretation, however, McDermott sees modern technology primarily as systems of rationalized control over large groups of men, events and machines by small groups of technically skilled men operating through organizational hierarchy. These systems tend to impose their basic characteristics on all those areas of activity or supporting systems related to their own development. Thus, like in Ellul's quest for the best method, in all these areas of activities sharp pressures exist for improving and rationalizing the performance of machines, men, techniques, etc. In so doing, technology acquires its own momentum, tending to resist and exclude intervention from outside the system. Thus, in McDermott's view, technology is not influenced by the "politics"

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(9) See Goulet (1975,1977,1983).

(10) See McDermott (1969,1972).

of a given situation, rather technology creates its own politics in the same way as it has created its own ideology, value system and its own elite. It has become, in short, an institutional system of its own; a system whose social and technical factors interact in a single process of rationalized control by a technical elite.

In a similar way to McDermott, Dickson's work (11) has also used the concept of institution in his particular sociotechnical view of technology. His idea is that technology is in itself a social institution just like the legal and the educational systems. As such, he argues, that not only technology has become an integral part of our social environment but, simultaneously, it does possess a fundamentally political nature. Unlike McDermott, however, Dickson does not argue that technology creates its own politics. Rather, his point is that technology and social patterns reinforce each other in a dialectical process at both material and ideological levels. By this he means that technology does not just provide the physical means by which a society supports and promotes its power structure, it also reflects, as a social institution, this structure in its design. As a result, for Dickson, a society's technology can never be isolated from its power structure and technology can never be considered politically neutral.

The latter theme has also been the kernel of D. Noble's work (12), whose sociotechnical approach has clearly emphasized the social determination of technology's development by the interplay of social forces characteristic of capitalist society. In Noble's view, technology is an essentially human phenomenon, a social process which does not simply stimulate social development from outside but, rather, constitutes fundamental social development in itself. In this character, technology is but one important aspect of the development of society as a whole and, in its own development, inescapably reflects the contours of that particular social order which has produced it and sustained it. For Noble, the latter means that technology does not unfold automatically but, in fact, contains a subjective element which drives it, in such a way that its particular form of development is determined by the most powerful and forceful people in society, in struggle with others. Hence, in his perception, it is ultimately people and the basic relations of domination which bind and divide them, the shared dreams and delusions which inspire and blind them, that shape

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(11) See (Dickson 1974a,1974b).

(12) See Noble (1977,1979,1984,1986).

the actual development process of technology as much as of society. For Noble, this is the substrate from which all technology actually emerges, the power and promise which give technology its shape and meaning. Thus, in following the history of automation in America for instance, Noble's analysis shows how dominant institutions, ideas and social groups operating in a context of class conflict and informed by what he calls the irrational compulsions of an all-embracing ideology of progress, have actually determined the design and use of a particular technology. Noble's sociotechnical conceptualization of technology, therefore, again underlines the inseparability of technical and social factors in the understanding of technology and, indeed, societal development.

Somewhat in contrast to Noble's emphasis on the social shaping of technology, the sociotechnical approach of another scholar, L. Winner (13), has primarily followed the theme that technology is itself a political phenomenon. He has argued this point, mainly, in relation to the momentum of large-scale, complex, centralized, high-energy sociotechnical systems which dominate the modern age. In these systems, he sees technical and social factors deeply interpenetrating each other in such a way that, in their operation, they ultimately constitute ways of life. In this sense, technologies are never neutral they are deeply political insofar as they legislate and govern the fundamental patterns which much of modern life assumes. Technology is itself legislation, for it legislates the conditions of human existence. Winner is also clearly aware of the social determination of technology, i.e., that technology is itself shaped by the interplay of social forces. In this respect, the shape of a specific technology can be the result of a particular struggle within a particular community and, eventually, a way of settling that particular conflict, as it would be the case, for instance, with the introduction of machinery in a particular labour process to break a workers' strike. The distinctive trait of Winner's technological politics, however, is that it draws attention to the characteristics of technical objects and the political meaning of these characteristics. In this respect, his perspective looks at the shaping of society's politics by what he calls inherently political technologies, i.e., man-made systems that appear to require, or to be strongly compatible with, particular kinds of political relationships (14). For

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(13) See Winner (1977,1979,1985).

(14) For a similar argument, see Edquist and Edquist (1979), Edquist (1985). For these authors... "The development of techniques is conditioned by the laws of nature, and techniques are formed by the limits and constraints set by such laws: physical, chemical, biological, etc. No human wish can create techniques that go against natural laws...[As a result A.M.]...many techniques have intrinsic properties: with important social, economic and



Winner, these technologies (e.g., the atomic bomb with its inherent need for security and centralization) are political phenomena in their own right, and by looking at them as thing in themselves, an explanation may be found to what he sees as the all too common signs of adaptation of human needs to technical means.

To an important extent, Winner's suggestion has been precisely what the work of historian T. Hughes (15) has tried to do by looking at the historical development of some concrete large-scale technological systems, particularly, that of the electric power network. Hughes, however, possesses his own sociotechnical conceptualization, which emphasizes the category of systems as crucial for the understanding of the development of technological processes (16). In Hughes' general meaning, systems are coherent structures comprised of interacting, interconnected components. But, more specifically, he differentiates technical systems, such as an electric transmission systems, from large technological systems where the interacting components are not only technical but also institutional. In the latter system, interconnected components are as diverse as physical artefacts, mines, manufacturing firms, utility companies, academic research and development laboratories, and investment banks. For Hughes, they constitute a system because they fall under a central control and interact functionally to fulfill a system goal, or to contribute to a system output. In addition, when the technological systems' sphere of control grows to encompass, for instance, regulatory and law-making bodies and even educational institutions are coordinated to satisfy the needs of the system, then Hughes chooses to talk of sociotechnical systems rather than of simply technological systems. A crucial characteristic of these sociotechnical systems is their high momentum or inertia of development which, according to Hughes, is rooted not only in the substantial amount of capital invested in machines, devices, structures and other physical artefacts but, also in the commitment of many people whose professional skills are particularly applicable to the system. Furthermore, supportive legislation is involved as well as the commitment of many institutions such as business concerns, government agencies, professional societies, educational institutions, and

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political consequences...Some techniques require social structures with a high degree of centralization of power and economic resources. In this sense, they are less 'democratic' than others" (Edquist and Edquist,1979,pp.316). In a similar vein, Ernst (1980b) states that..."Basically, a technology is determined by the material conditions of the object that has to be processed, the final product, and the process of production which makes possible this metabolism" (Ernst,p.50).

(15) See Hughes (1969,1979,1981,1983,1986).

(16) For an early discussion of technology as systems, see Drucker (1970).



other organizations that shape and are shaped by the technical core of the system. Taken together, in their dynamic interaction, all these factors generate the momentum of the system, a powerful conservative force tending to exclude technological change in directions which may fulfill radically different social or economic goals. Hughes does not see these systems as autonomous, however, rather he points to the fact that values may need to be changed, institutions reformed, or legislation recast, if an attempt to control and change their present form of development is ever likely to be effective. As we have seen with other sociotechnical writers, therefore, in Hughes' conceptualization of technology clearly technical and social factors collapse together in an integrated framework of understanding. His is a "seamless web" approach to use the illustrative power of his own metaphor.

Finally, to bring the present excursion into sociotechnical approaches to an end, we must mention some recent contributions emerging from the field of sociology. First is the work of Pinch and Bijker (17) which has sought to expand into the technology field concepts originally developed in the area of sociology of science. The main contention is that both technology and science are both socially constructed cultures sharing various basic developmental mechanisms. On this basis, Pinch and Bijker make an effort to explain technology wholly in terms of societal processes but focusing their analysis, primarily, on the interaction between those who design the technology and the social groups most directly defining the particular problems being addressed by the technology. A second current is the actor-network approach (18) which has sought to erase all societal boundaries (e.g., technical, political, economic, etc.) in the conceptualization of the development of technology. For actor-network writers, from physical laws to legislative bodies, including machines and tools, researchers and companies, consumers and producers of a technology, they all constitute actors of a coherent and heterogeneous sociotechnical network. In this network, actors lose their individual entity and are transformed and shaped in such a way that their interaction produces the harmonious integration and working of the system. Both in the process of generation of a sociotechnical network or in its continued development, the heterogeneous engineers or actor-network builders (e.g., innovators, entrepreneurs, etc.) are the driving actors who mobilize all others, i.e., the human and non-human elements necessary for the

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(17) Pinch and Bijker (1984,1986), Pinch (1986). See also Russell (1986) for a critical review.

(18) Callon (1980), Latour (1983,1986a,1986b), Law (1986), Callon and Law (1982), Callon

system to be materialized. But the process of mobilization never stabilises since particularly human heterogeneous actors tend continuously to alter the roles designed by the system builder. Thus a process of mobilization and/or creation of new actors, technical or social, is constantly under way. In this mobilization, the systems builders choose from many alternatives, all leading to the furthering of the system. For instance, they may decide between different qualitative and quantitative mixes of human and non-human actors. Also they may see it appropriate to attempt to raise feelings such as passion, love, fear, etc., from human actors such as consumers or workers, etc. It is for these reason that some actor-network writers actually talk of the technological process as a cloth weaving together such different elements as stones with laws, telephones with love, fears with atoms, etc. In addition, for this school of thought, in the process of actor-network building, what is actually taking place is the constant remaking of power relations. In this sense, society and power relations do not exist as causes of the sociotechnical process, rather, power and society are the result of the sociotechnical process and the changing relations between the myriad of its heterogeneous actors. As one actor-network writer has put it "science and techniques are politics by other means" (Latour,1986b,p.25). In all, in the actor-world of these scholars, all societal dimensions (e.g., economics, politics, techniques, psychology, etc.) loose their separate identity and collapse together in a single process where actors interpenetrate each other moving freely through a societal fabric where there are no real boundaries.

As it is possible to realize, therefore, the sociotechnical approach to the understanding of technology has a long and well-established tradition as well as a great deal of theoretical variety among its many exponents. Obviously, in the review above our aim has been basically to expose some of the main tenets of the views of each of the selected writers and/or schools of thought rather than to criticize them one by one. As we shall see below, the latter was not a task necessary for our purposes of advancing a sociotechnical conceptualization of an ITC, mainly because such a conceptualization will revolve primarily around the main concepts we have used in trying to grapple with the sociotechnical nature of the microtechnological process. In this respect, the review of sociotechnical approaches was necessary for two reasons: first, to show that a sociotechnical approach to technology is nothing new and that several of the points we are about to raise in our discussion of the nature of ITCs have been made before

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although mostly in a different fashion, and, secondly, to establish the state-of-the-art base whereupon the contribution of our systematic treatment of the interpenetration of sociotechnical elements within an ITC can be more distinctly highlighted. At a more general level, however, before beginning with such a systematic treatment, it is necessary to point at two major aspects which, from the start, will differentiate our approach from those we have discussed above.

a) Almost without exception, the main focus of the analyses above is limited to the experience of developed countries in isolation. That is to say, a systematic treatment of interrelated international issues is mostly lacking in the conceptualization of technology of most of the above writers. In particular, for our purposes, the systemic interpenetration of UDCs' technological development with that of DCs has seldom been given attention.

b) Closely related to point a), and basically due to the prevailing attitude to associate the concept of indigenous technological capabilities exclusively to technological development in the Third World, almost without exception the analyses above only indirectly touch upon the conceptualization of ITC which constitutes the main focus of our attention. True enough, we shall find that there is a great deal of overlapping in the sociotechnical conceptualization of, for instance, technology, the technological process or an ITC. In this sense, it is also true that most of what we shall say in relation to an ITC will be valid for the conceptualization of technology too. Yet, at the same time, the focus on the concept of ITC necessarily introduces particular emphasis on certain issues of technology and the technological process while leading to forsake the emphasis on others which may be of greater relevance for some other scholars. For instance, insofar as the study of an ITC implies the desire to understand the workings and factors involved in the appropriation and development of specific technologies such as microtechnology, it means that concerns about the rationality and morality of modern technology and the need for either its total rejection or acceptance in the abstract can hardly be a main line of preoccupation in ITC studies. In this respect, moral issues may certainly find an expression in the analysis of the content and dynamism of specific ITC sociotechnical processes themselves, but hardly in the rejection and/or acceptance of modern technology at large. On the other hand, the focus on ITC leads to put greater emphasis, for instance, on identifying the qualitative and quantitative

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and Latour (1981).

sociotechnical factors implied in the possession of the resource-requirements necessary for the materialization of a given technological process. By contrast, the latter issue is seldom given any prominence by scholars dealing with technology basically in the advanced industrial countries, where the possession of such resource-requirements is commonly taken as a matter of fact.

With these two general points, therefore, we now turn our attention to the sociotechnical conceptualization of indigenous technological capabilities which is the central objective of the present chapter.

### 5.3. Towards a Sociotechnical Theory of Indigenous Technological Capabilities

For purposes of clearer presentation, the discussion in the present section will revolve around figures 5.2 and 5.3, which provide a useful way to systematically represent the national and international character of the elements and forces involved in the unfolding of an ITC sociotechnical system. We have to emphasize, however, that these figures are strictly intended as a kind of visual support to the discussion and, in no way, they suggest either the actual shape of the sociotechnical process or an exhaustive list of the elements involved in such a process. In this respect, the three points made below should be always kept in mind in order to derive the greatest benefit from the illustrative power of the visual representation while, at the same time, avoiding the possibility of being misled by it into conceptual interpretations which bear no relation to the realities of the processes involved.

a) The rigid cube-like shape dominating the diagrams as well as their splitting into three interconnected blocks is just a convenient way of allocating space for many variables while, simultaneously, emphasizing the character of some crucial interrelations and the overall unity of the whole process. In no way, they suggest, for instance, that the ITC technological process is an orderly, well proportioned set of neatly structured interrelations amongst the elements shown.

b) The encapsulation implied in the closed cube-like shape should not be interpreted as if the elements and relations illustrated in the diagrams constituted in themselves the totality of a largely self-contained sociotechnical process. Far from it, for, in practice, the unfolding of a sociotechnical system does not occur in a vacuum, but is vitally related to socio-structural factors other than those immediately making up the system itself. These are, for instance, infrastructural resources of many kinds from transport and communications, power and water supplies, to educational and training infrastructure concerned with schooling and formation of human resources. It is clear that the development of a sociotechnical system is bound to be conditioned by the state of development of such an infrastructural base, in the same way as the latter may be itself influenced by the development of a given sociotechnical system. There is undoubtedly interrelation but here we cannot concern ourselves with the systematic treatment of all these factors; instead, our focus will be primarily upon those factors and relations most directly involved in the



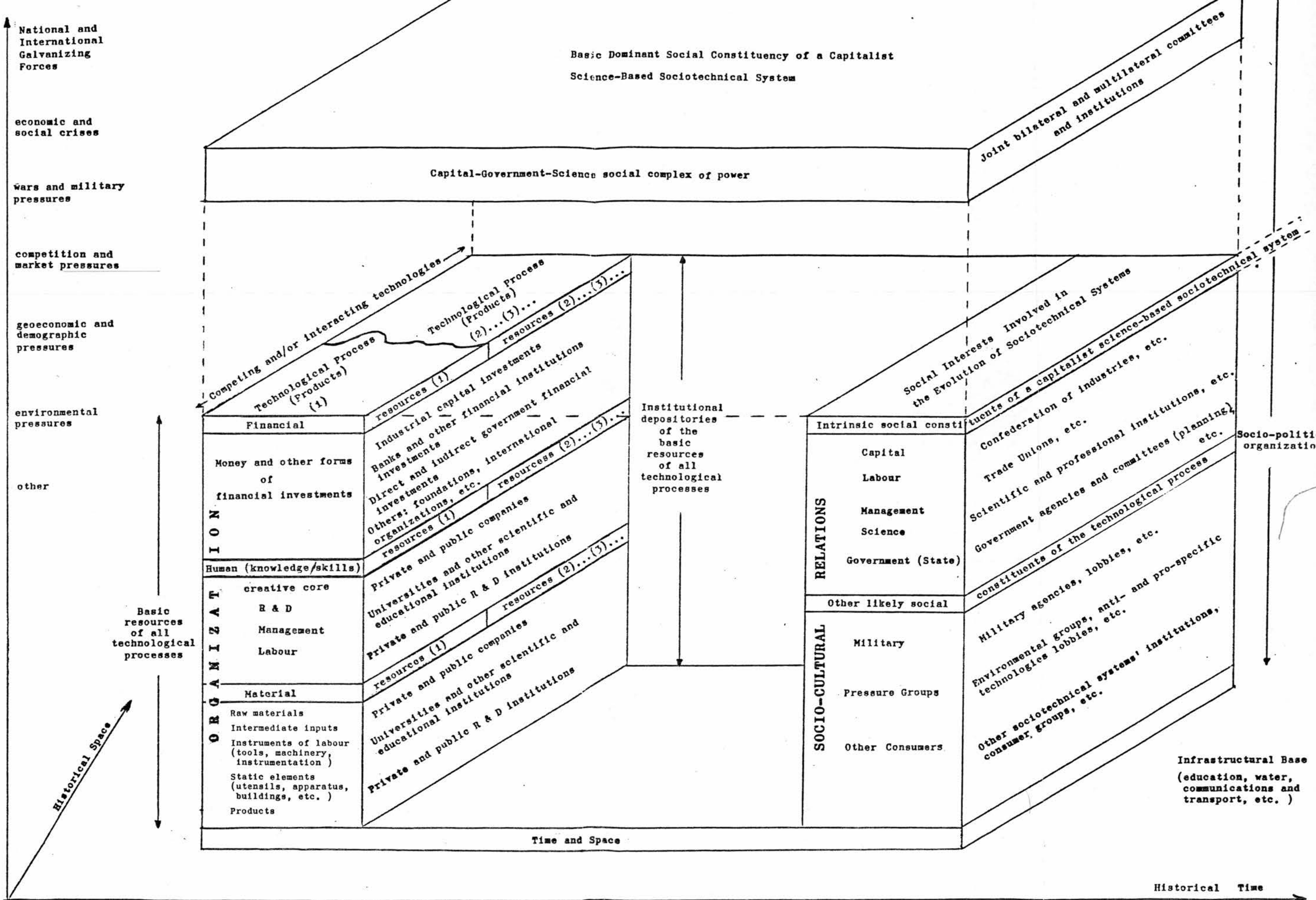


Figure 5.2.- Constituents and Galvanizing Forces Involved in the Historical Unfolding of a Sociotechnical System (Capitalist Science-Based).



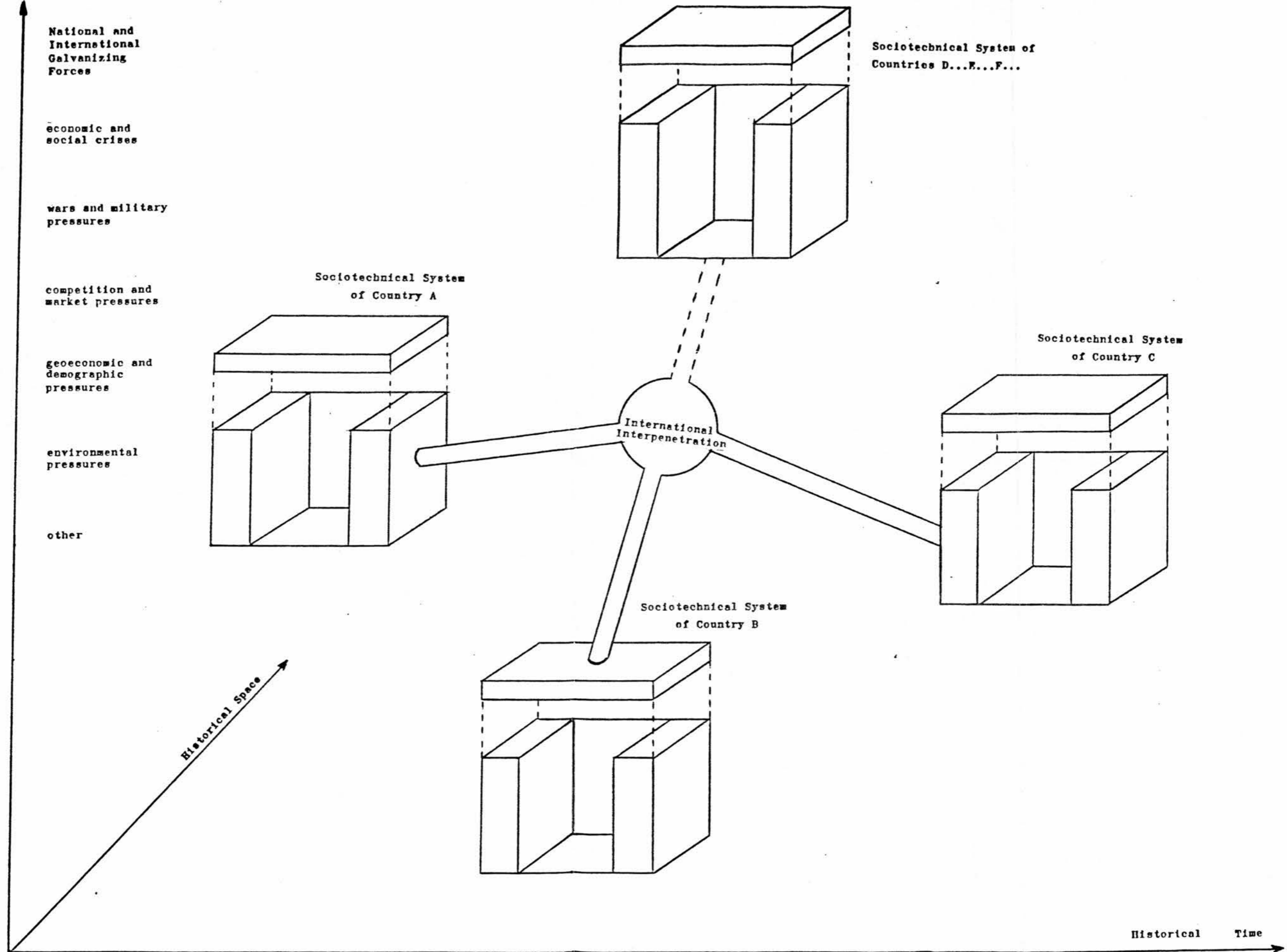


Figure 5.3.- International Interpenetration of Different Countries' Sociotechnical Systems.

sociotechnical process of an ITC (19).

c) The inevitably static appearance of the cube-like shape should not be taken as a suggestion of static relations in the sociotechnical system itself. Indeed, through the use of the three axis surrounding the cube-like shape, we have already tried to suggest that there is nothing static about the elements and relations comprising any sociotechnical system but that, in practice, such a system unfolds historically in a process involving constant motion and alterations. Here, as we shall see, national and international galvanizing forces as well as social constituents and their interrelations within the sociotechnical systems themselves play a fundamentally dynamic role.

The three points above, therefore, constitute a sort of basic guidelines of how not to see, or interpret, the shape and content of figures 5.2 and 5.3. In this respect, were we to alter the negative emphasis and briefly suggest a sort general guideline of how to see the diagrams, the best way would be to say that, by and large, what we are asking is simply for the reader to dissolve in his/her imagination, not only compress all the elements shown into a total and systemic interpenetration but, simultaneously, dynamize this interpenetration into historical motion, thus providing it with a past as well as a future however uncertain the latter may be. With this general approach in mind, we can now begin to explain the fundamental tenets of the sociotechnical conceptualization of ITCs we wish to put forward.

### **5.3.1. Some Broad Properties of the Development of Large-Scale and Complex ITC Sociotechnical Processes: Aggregate Development Trends, the Momentness of the Sociotechnical Process and the Role of Historical Galvanizing Forces**

For the sake of greater generality, but primarily because throughout this thesis we have dealt with the case of fundamentally capitalist IMCs, i.e., large-scale and complex capabilities evolving as part of, shaping and being shaped by, the context of capitalism, figure 5.2 will specifically refer to capitalist science-based sociotechnical systems where government themselves tend to play a crucial and inseparable part in the possession and development of such a system. True,

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(19) For an illuminating discussion on the role of infrastructural factors in the development of technological processes, see Muller (1980).

simpler technological processes may not be science-based and/or they may involve government in only a remote fashion. But in such cases, the content of the diagram in figure 5.2 needs only be simplified to account for the simpler set of constituent elements and relations characterizing such simpler processes. The latter would similarly apply, for instance, if we were to reduce the sociotechnical content of a technological capability merely to the ability to use a given technology in contrast to the goal of autonomy and production capability commonly implied in the concept of ITC. In the present discussion, however, as we have already said, the content of figure 5.2 is based primarily on the case of a capitalist IMC and this means that our point of reference will not be a technological process with limited relevance within the sociotechnical realm of society. Rather, it will be a large-scale, complex technological process involving the interpenetration of a wide range of technical and social factors into an autonomous capability which, by definition, implies the ability to choose, use, apply and produce the technical products and processes most relevant to the development strategies of given countries or regions. It is to the conceptual interpretation of the latter kind of sociotechnical system that we expect to contribute by using a systematic combination of such categories as basic resources of technological processes; institutional depositories of basic resources; intrinsic and dominant social constituents; overriding and particular interests of social constituents; national and international galvanizing forces, etc. It is these categories and various others that will enable us to deal with a complex ITC as a sociotechnical system in constant motion; a system not only possessing identifiable aggregate development trends but also constituted by clearly identifiable moments which are part of one and the same process of constant metamorphosis of elements and relations whereby the entire system actually materializes, alters, and reproduces itself in time and space. In addition, in its movement along the axis of historical time, such a system is constantly flowing from itself either in its reproduction and furtherance or in its waning and decadence as we shall see later on in our discussion of competing momentum-gathering/momentum-losing technological systems. That is to say, at any given time in history and whatever the power of the interests and galvanizing forces pushing in one or other direction, the future development of the system is completely conditioned by the nature and immediately prior state of development of, and specific interrelations between, the technical and social constituents of the system. In this respect, given the large number of elements and complexity of interrelations in large-scale and complex sociotechnical systems, major transformations of such systems are only likely to materialize

after many years of changes and accommodations whose character and pace will depend upon a myriad of specific factors but, more broadly, upon the combination of such aggregate factors as the quantitative and qualitative state of development of the sociotechnical system at any given time, its conflict and interaction with other competing and/or complementary sociotechnical systems within the socio-cultural and juridical context of the time, and the nature and strength of the galvanizing forces pressurizing for the furtherance and/or disintegration of one or the other of the conflicting and/or interacting sociotechnical systems.

With regard to the identifiable aggregate development trends of sociotechnical systems, they can be said to reside in the very nature and quantitative and qualitative development of both technical and social factors and determinants interacting in the development of such a system. The role of technical determinants in shaping the aggregate development of a sociotechnical system has already been dealt with by analysts such as Winner and Edquist and Edquist (see section 5.2 above), who have pointed out that there are man-made systems whose intrinsic technical characteristics appear to require, or be strongly compatible with, particular kinds of socio-cultural relations. As a result, in the present conceptualization our concern will be basically with the nature and role of social determinants in shaping the aggregate development of a sociotechnical system, although always keeping in mind that social determination is never arbitrary or voluntaristic but is realized in interpenetration with (i.e., within the limits and possibilities afforded by) the unfolding technical determinants themselves. In this respect, in the course of this thesis, we have seen, for instance, that in the case of a capitalist IMC not only was there an aggregate technical trend towards systemic convergence and synergistic development of signal technologies and corresponding industries but, simultaneously and in profound interrelation, there was an aggregate socially determined trend towards concentration and centralization in the process of electronics capital accumulation at a global scale. At the more specific level of countries, we also saw how in the case of the US, for instance, the aggregate socially determined development trends of that country's IMC showed a predominant bias towards competitive commercial and politico-military concerns which was consistent with the overriding interests of the social forces making up the dominant social constituency of the US's IMC. In other words, the aggregate development trends evident in the aggregate national patterns of utilization of the basic resources of the IMC sociotechnical process (e.g.,

investments, general character of projects, etc.) has reflected, by and large, the dominant patterns of social control of those resources and hence, the relative weight or correlation of forces between the social interests interacting in the heat of national and international historical galvanizing forces. In the case of the Japanese IMC, we saw the existence of a similar aggregate development trend but, in contrast to the US case, the dominant patterns of social control of the basic resources of the IMC technological process showed themselves in a much less militaristic utilization of these resources, with commercial concerns clearly dominating the aggregate development trends. Finally, in the case of Mexico, the aggregate development trends of the IMC sociotechnical process manifested themselves not in an aggregate pattern of utilization of basic resources of an autonomous sociotechnical system at work but, more specifically, in an aggregate pattern of system building which implies the very creation of various technical and social constituents currently missing or undeveloped, or simply under the control of social interests whose historical role has not been consistent with the goal of an autonomous Mexican IMC. The contrast of the Mexican case to that of advanced industrial countries is quite revealing since in a sort of negative way, via the absence or weakness of certain constituents of the sociotechnical system, it has highlighted the importance of their existence and systemic integration for the autonomous workings of the entire ITC sociotechnical process. From a different angle, if, as we have mentioned above and shall explain below, such sociotechnical process is constituted by clearly identifiable moments which are part of one and the same process of constant metamorphosis of elements and relations whereby the entire system actually materializes, alter, and reproduces itself in time and space, then it is clear that the absence or serious weakness of some important elements and relations, or the existence of some contradictory relations, can only mean that some moments must be either missing or crippled and hence, that the development of the entire sociotechnical system must suffer from a pattern of general distortion. Let us look at the "momentness" or moment-composite nature of an ITC sociotechnical process to understand more clearly the meaning of the latter contention.

The first thing that is crucial to grasp in relation to "momentness" is that an ITC as a sociotechnical process only exist *in action*, that is, it exists through the permanent and practical realization of all its constituents elements in the development process of a given society. This means that the technological process can neither be seen as static nor be reduced to any of its constituent parts, for in themselves each of these parts is largely sterile as far as the materialization



of an ITC is concerned. Financial resources without R & D or labour, for instance, are technologically meaningless in the same way that the latter factors may not fulfill themselves without financial resources. R & D without production process is also equally sterile in terms of an ITC as it is tools and machinery without raw materials and products. Hence, in an ITC sociotechnical process, partial aspects cannot fulfill themselves in isolation from the whole, they can only do it in interrelation with the others in such a way that their essential character, the meaning of their very existence, can be said to be *for* and *from* the others parts of the sociotechnical system. It is this essential characteristic of an ITC in action which underlies its moment-composite nature mentioned above.

In practice, such "momentness" assumes not just one expression. One particular form of "momentness", for instance, is that implied in the process of metamorphosis of financial resources which leads all the way to final products and back to financial resources, in a process which Marx lucidly unveiled in his analysis of the circulation of capital in capitalist society. Here, however, we want to highlight, in particular, the existence of another expression of ITC's "momentness" which is generally overlooked by sociotechnical commentators who tend to reduce technological processes primarily to the sociotechnical moment of knowledge and/or artefacts creation (20) and from here jumping, as in the case of Latour (1983), to the ensuing social transformations implied in the massive diffusion of the product or artefact. Completely missing in this conceptualization of technology is any reference to the necessary sociotechnical moment whereby the created product or artefact is made massively available for its ulterior diffusion moment. In other words, there can be no massive diffusion without massive production, and it is the latter production moment - which is so dear, for instance, to economists with their focus on costs of production, economies of scale and so on - that is mostly missed out by the sociotechnical conceptualization of the abovementioned scholars. It seems to us that this kind of implicit reductionism carries in itself various conceptual problems from the point of view of understanding the technological process as a whole. For the importance of the sociotechnical productive moment is not just for logical reasons of a missing link fulfilling the creating moment as a moment for production and diffusion. It is also because by flowing into the productive moment, the sociotechnical process actually undergoes a qualitative alteration in itself, not only in its structure and utilization of basic resources of the

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technological process but, also, in its specific form of interrelating to the other constituents, relations and galvanizing forces involved in the development of a sociotechnical system (21). For instance, different tools, machinery, and knowledge and skills will be needed along with different forms of organization, management and labour. Industrial relations become important along with competitive and market relations and legislative dispositions concerning the development of the technological process, etc., etc. Most importantly, the creating activity does not stop with the development of the artefact. All the way in the materialization of the productive moment, it continues under different forms, not only in the demand for, and generation of, technical processes, skills, tools, machinery, etc. but, also, in the minor innovations improving the production process and products themselves. This creative activity which make the implementation (diffusion) and further development of the sociotechnical system possible, is clearly reflected, for instance, in the learning curve characterizing the development of the production process of any product (22). In the production process is where workers, the great missing actor in the actor-network writings, play their creative role in the technological process (23), although as Layton (1977) points out, their contribution often goes unreported or is credited to management apart from the historical fact that the deep separation between manual and mental labour long fostered by advanced capitalist societies, has meant that effective systematic mechanisms for releasing workers' creative

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(20) For instance, see the work of Pinch, Latour and Law.

(21) In the context of the diffusion of a new technology, Rosenberg (1977a) has dealt with some of the mechanisms in the flowing of a new technology from its creating moment to its production moment.

(22) In this respect, Rosenberg (1977a) states that..."While the existence of learning curves within the framework of an *established* technology is well recognized, the role of learning experiences in accounting for gradual improvements of *new* technologies and their slow diffusion has not received much attention (Rosenberg,p.198).

(23) Describing the nature of incremental innovations, Freeman (1986) states..."These innovations may often occur, not so much as the result of any deliberately research and development activity, but as the outcome of inventions and improvements suggested by engineers and others directly engaged in the production process, or as a result of initiatives and proposals by users...They are particularly important in the follow-through period after a radical breakthrough innovation... and frequently associated with the scaling up of plant and equipment and quality improvements to products and services for a variety of specific applications. Although their combined effect is extremely important in the growth of productivity, no single incremental innovation has dramatic effects, and they may sometimes pass unnoticed or unrecorded" (Freeman,p.28). From a different angle, Shaiken (1985), discussing the possible consequences of completely automating the manufacturing process, points to the fact that removing the hiccups of a production process "without sacrificing creativity may be difficult if not impossible" (Shaiken,p.23). In this connection, he quotes a former vice-president of engineering as saying..."If you carry a process like this too far, you tend to suppress new ideas...We don't want to standardize one landing gear to the extent that we don't give anybody the opportunity of building a better one" (ibid.).

energies have been seldom in existence. In this respect, such managerial concepts as suggestion schemes or the Japanese concept of quality circles (24), recognize at least in principle the importance of the creative role of labour. It is in the production moment, therefore, where workers become not just an intrinsic part of the technological process as a whole but, indeed, an intrinsic part of the very creative core of such a process. In other words, it is not possible to reduce the overall creative activity in a sociotechnical system in action to that of engineers, scientists and laboratories working in a specifically creating moment, for such an activity also extends itself into the production moment, altering itself in its form, but essentially fulfilling the existence of one and the same sociotechnical system in action. In practice, creation, production, and diffusion are all inextricably interrelated moments in the life of a sociotechnical system and by this we mean not a one-flow process but a dialectical process of reciprocal influences, where constant interpenetration and feedbacks take place between all moments in such a way that the production moment, for instance, not only represents the materialization (diffusion) of the results of an specifically creating moment but, to the extent that it contains creativeness of its own, is in itself a metamorphosized prolongation of that specifically creative moment. In short, the production moment of an unfolding sociotechnical system clearly influences the specifically creating and diffusion moments of such a system as, in turn, the latter two not only influence each other but, simultaneously, the former production moment of the system. For example, when a product fails to diffuse in the market because it is too expensive or unreliable, this may feedback to the

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(24) "The quality control circle is a Japanese innovation, circa 1962, that formally mobilizes small voluntary teams of workers in order to improve quality and productivity...The agenda and procedures of a quality control circle are usually quite structured, but the details vary somewhat from firm to firm, depending upon the objectives that are being emphasized...Methods and quality objectives are generally important in Japanese quality control circles but are sometimes not emphasized in U.S. circles. In both Japan and the States, morale-enhancing ideas -softball leagues, vending machines, repainting the lunchroom and so on- are legitimate topics for QC circle discussion, and motivational benefits are expected from the employee participation that takes place in circles" (Schonberger,1982, pp.181 and 185). A more colourful description is given by Chrysler's president Lee Iacocca,..."Of course, quality doesn't stop with the engineer. It has to be part of the consciousness of the workers in the plants. Through the establishment of "quality circles", our plant workers have become far more involved than they used to be in the building process. We sit them down in a room and we say: "How about this operation ? Can you do it ? The engineer says you can, and the manufacturing guy says you can. But you're the ones who have to build the thing. What do you say ?...So off they go to try it for a couple of days. If it doesn't work, they come back and tell us: "That's a bad idea. Here's a better way to do it". The word get around pretty quickly that management is listening, that we really care about quality, that we're open to new ideas, we're not just a bunch of dummies. That may be the most important consideration of all when it comes to quality - that the worker believes his ideas will be heard" (Iacocca,1984,pp.184-185).

production moment as a need for improvements in the production process: eventually, it may prove that the very design was intrinsically flawed, thus reverting the influence of the market diffusion moment to the originally creating moment. Likewise, if a product has undesirable side effects which become apparent only at the diffusion moment, then the feedback goes right back to the creating moment and, indeed, in extreme circumstances, the entire sociotechnical process crystallized in the diffusion of such a product may collapse altogether. On the other hand, a product or artefact may never reach the diffusion moment simply because the technical constituents or basic resources required for its materialization in the production moment are not available. It is clear that many other instances could be given showing the reciprocally interacting and inextricably interrelated nature of all moments in the development of a sociotechnical system. For our purposes, however, this is not necessary since all we have said suffices to support the contention that sociotechnical systems in action possess a broad moment-composite character, and that in such action the moments are not just inseparable but reciprocally interact with each other giving the unity to the whole process. Admittedly, we have looked primarily at one particular expression of "momentness" in the workings of a sociotechnical system, namely, that involving creating, production, and diffusion moments. In this respect, as we have indicated earlier, a somewhat different expression is given by the metamorphosis of financial resources into human and material resources and the latter into the final products crystallizing the sociotechnical process of transformation and utilization of resources. Here, we shall only mention the existence of such a different expression since it leads us straight into the analysis of the basic resources or technical constituents of all technological processes and hence, into the detailed work of theoretically reconstructing the workings of a capitalist ITC sociotechnical system.

Before doing so, however, we need to say a few words about the category of national and international galvanizing forces which we have often used in the course of this thesis, and which is truly central to the understanding of the historical unfolding of sociotechnical systems. In figure 5.2, we have sought to depict some important national and international galvanizing forces in the vertical axis on the left-hand side of the diagram. There, we have listed, for instance, economic and social crises, wars and military pressures, competition and market pressures, etc., that is, all historical phenomena and events which, as the name galvanizing forces implies, truly exercise strong pressures on societies and, particularly, societies' social constituents, for actions in directions that are

consistent with, and indeed demanded by, the overriding interests of such constituents. Below, we shall discuss the concept of overriding interests. Here, suffice it to say that they relate to the very existence and *raison d'etre* of each one of the social forces making up a given society. This means that, in the final analysis, the galvanizing forces themselves relate to the very existence and *raison d'etre* of social constituents, which would account for the imperative character of their pressure upon the historical behaviour of all social forces, individually as well as in interrelation with each other. In practice, this imperative character of galvanizing forces is always present, playing a dynamizing and shaping role, in the process of historical development of a given sociotechnical system. Its particular manifestation, however, is a matter pertaining to the specific forms of development of given societies and, particularly, to the specific nature of both the galvanizing forces themselves and the social constituents interrelating in the development of a sociotechnical system. Thus, if we consider the list of galvanizing forces provided in figure 5.2, there are various relevant points which can be made. Firstly, not all, or even the same, galvanizing forces appearing in the diagram need be exercising a major role during a given historical period. There may be one, another, or combinations of them and, also, with different and varying degrees of strength. In addition, some of them may possess a basically national character, whereas others may be more international in nature. In practice, the range of possibilities is very extensive. Secondly, there are some galvanizing forces such as international wars which may have catastrophic consequences for a society as a whole, so that they will most likely be perceived as threatening the overriding interests of all social forces with the result that a national galvanization may more easily arise. As we have seen in the present thesis, in these circumstances, the overriding interests of some social forces (e.g., the military) will inevitably become much more prominent than those of other forces in shaping the development of a given sociotechnical system. Thirdly, there are galvanizing forces such as market competition which, although may have wide implications for the development of a given society, are first and foremost related to the overriding interests of capital accumulation and hence, to the behaviour of those social forces directly involved in such a process. In practice, because they pertain to the role of existing social interests, the operation of this kind of galvanizing forces tends to assume a permanent role in the shaping and dynamism of a sociotechnical system. In this sense, they differ from the more eventful nature of galvanizing forces such as those emerging from a major war or any other relevant event of a catastrophic nature. It is interesting to note here that military galvanizing forces such as

military competition may also become ingrained in the historical dynamics of a sociotechnical process as long as war pressure are continuously reproduced. Finally, while there are galvanizing forces which are inexorably beyond the control of a given society (e.g., a geographical catastrophe, or a development imposed from outside such as a military aggression, or a development beyond national control such as an international economic crisis, etc.), this does not mean that all galvanizing forces fall in this category as if they were something exogenous to societies themselves, nor it means that all societies, or social forces, are in the same position regarding their capability to influence the nature and strength of the galvanizing forces involved in the unfolding of a sociotechnical process. Thus, as we have seen in the present work, the galvanizing force of international competition can be subject to control and attenuation by means of a variety of protectionist mechanisms. In other words, at least within the confines of a given country or region, international market competition is not an inexorable galvanizing force and, indeed, since it relates to the overriding interests of specific national constituents, it is very much to the latter constituents to influence the role of this particular galvanizing force. Of course, this is not in isolation but always in accordance with the development strategies defined by the national constituents themselves within the context of their specific interrelations and correlation of forces with other social forces in the international arena. From a different angle, such possibility of exercising some degree of control upon galvanizing forces can also be seen in the influence which some social constituents do exercise in reproducing and/or increasing the strength of these forces in accordance with the dictates of their own overriding interests. Here, military galvanizing forces furnish the clearest example, being, on the one hand, inextricably tied to the effective role played by military interests in shaping the development of a technological process and, on the other, susceptible to manipulation by means of diverse tactics, strategies and policies which may either diffuse or increase international politico-military tension. In practice, military interests possess a strong tendency to seek the reproduction of some kind of military galvanizing forces as a means of reproducing and furthering their own overriding interests vis-a-vis those of other social constituents. As we have said, however, not all societies, or social forces, are in the same position to actually influence the nature and strength of galvanizing forces. Thus, a country which does not possess nuclear weapons is simply unable to influence the ups and downs of nuclear-related military galvanizing forces. More generally, a country which has scant military power is very unlikely to influence, by itself, the strength of international military galvanizing forces. Whereas the strength of



these forces may easily change as a consequence of action by military superpowers. All in all, it is clear that there is a great deal of variety in the nature and role of galvanizing forces in the development of sociotechnical processes. In this respect, the crucial point to keep in mind is that, for the analysis of any given place and historical period, there can hardly be thorough understanding of the historical development of such sociotechnical processes without the proper treatment of the nature and role of the galvanizing forces involved.



### 5.3.2. Basic Resources of an ITC Sociotechnical Process

As the left hand side of the cube-like shape in figure 5.2 seeks to portray, the materialization of all technological processes demands the systemic integration and utilization, of financial, human, material, time and space resources. Organization and final products are also included among the resources, for the former is what ties the discrete elements systemically together and the latter represents a crucially crystallizing moment of the systemic process whereby financial resources metamorphose into other resources and all of them into the final products whose realization as use values and commodities leads to the reproduction of the entire sociotechnical process along the axis of historical time. In this conceptualization, the category of basic resources or technical constituents is a dynamic one just like all other elements and the sociotechnical system as a whole. To make this point clear, one has to consider that the reproduction of a sociotechnical system does not mean in any sense a process of exact replication of the same quantity and quality of basic resources and their relations time and again. On the contrary, given the combination of a constantly changing mix of historical galvanizing forces with the dynamism implicit in the conflict, convergence and pursuit of overriding interests by the social constituents controlling in one way or another the resources of the technological process, the fact is that such basic resources and their basic relations are in a state of flow, experiencing unending qualitative and quantitative transformations which, ultimately, become themselves part of a single sociotechnical dynamics of galvanizing forces, overriding interests and technical and social change. Basic resources, in consequence, are not something completely and readily available in a society's "technological shelf". Rather, there is a process of constant creation going on which is most manifest in the emergence of new forms of knowledge, skills, processes, machinery, instrumentation, products, etc. Indeed, all sort of innovations, major and minor, are the permanent expression of the dynamic character of the basic resources of technological processes.

The dynamic character of organization, financial, human and material resources and their inextricable relation to each other in the realization of a sociotechnical system in action is not difficult to perceive. Thus, it is clear that no resource is in itself sufficient for the realization of the sociotechnical process and, indeed, we have already pointed out the relation of metamorphosis and "momentness" existing between financial and other resources, between the latter and final products, and between the realization of final products in the diffusion

moment of the sociotechnical process and financial resources and so on and so forth. Another expression of the same dynamic interrelationship is apparent in the way changes in some of the basic resources affect the quality and quantity of others and hence, the entire mix of relations bringing them systemically together. The introduction of new and more powerful machinery in a production process, for instance, will affect the quality and quantity of labour, the skills, procedures and organization as, indeed, the concrete way assumed by the transformation of financial resources into all others (25). Something similar will happen when an important R & D breakthrough diffuses throughout the technological process demanding changes at every point. But changes in basic resources need not be important innovations in order to affect the quality and quantity of the whole mix, for minor, gradual innovations bringing changes in productivity, for instance, will equally alter the interrelation between such basic resources as raw materials and labour to mention just a couple.

In the diagram of figure 5.2, we have also included time and space as basic resources of the technological process. To a certain extent this may appear as an obvious choice since the materialization of a sociotechnical system in action can only take place in time and space. What may be not as obvious, however, is the dynamic character of time and space as basic resources in interrelation with organized financial, human and material resources. Time, for instance, is intrinsic to the "momentness" of a sociotechnical system in action and in this respect it can be imagined as stretching and contracting depending upon the variations of tempo in the materialization of the different moments of the sociotechnical system. Within the US and Japanese IMCs, for instance, we have seen that the tempo of creation, production and diffusion of semiconductor technology is quite high and this means, in a very real sense, that the time resource available for the reproduction of the sociotechnical system is much more limited than for other industries (26). In this case, high volumes of

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(25) An interesting example is provided by Bessant and Haywood (1985) who have studied the results of the introduction of Flexible Manufacturing Systems (FMSs) in various companies. "In most cases, FMS led to a major revision of product planning, with grouping of parts into families, rationalisation and pruning of product ranges and much more integrated design for manufacturing. This often led to surprising savings - as in one case where the number of operations (handling and machining) for a particular part was cut from 47 to 15 simply by revising design...It also became clear that when the product range is rationalised, the operations and layout may need rethinking, and this has led to group technology, smoother flow-lines and other alternative layouts, all aimed at making the most of the new plant and existing facilities...Another area where the firms acknowledge the need for new approaches is manning levels. In a nutshell, flexible manufacturing needs flexible manning, both in terms of the skills required and the working practices involved" (Bessant

financial resources devoted to R & D under the galvanizing pressures of competition have done much to contract the time resource, at the same time that the contraction of the latter has, in turn, reinforced the high volumes of financial expenditures, in a process which has constantly involved the transformation of the entire resource-base of the semiconductor technological process and eventually that of an IMC at large. Of course, Marx, in his discussion on necessary labour time, already showed the dynamic and historical nature of time as a resource of the technological process. He related increases in productivity and the consequent reduction in the value of labour per unit of production to a decrease in the necessary labour time to produce such a unit. For him, the minimum necessary labour time set the historical standards for all those involved in the process of production of a particular commodity, so that, in practice, it played a direct role, just like the other resources, in shaping the specific form of development of a sociotechnical system. Thus, initial changes in socially necessary labour time as a result of technical change in the mix of material and human resources, for instance, became themselves systemically integrated into the sociotechnical process stimulating the spread of technical change to the system as a whole.

Another expression of the dynamic interrelation of time to the other basic resources of a technological process lies in the social constituents' struggle for its control and utilization which is particularly manifest in the productive moment of such a process. Again, it was Marx who showed that the control and utilization of time for and in the labour process constituted a fundamental expression of the capitalist class struggle. Thus, historically, the development of a sociotechnical system under capitalism has reflected the effects of this class struggle in the clear alterations of the systemic integration of time with the other basic resources. The shortening of the working day, for instance, in all its forms (e.g., less working hours per week, various breaks, holidays and even

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and Haywood, pp.68-69).

(26) The following assessment of the increasing tempo of technical change in the computer industry provides a powerful example of the consequent reduction of the time resource for those involved in the industry. "Companies that can't master the intricacies of niche marketing will have to scramble to stay abreast of accelerating product cycles and the fierce competition stimulated by network standards. Already, dozens of hot startups that make midrange systems based on the Unix operating system have emerged. These companies...move at a killing pace. As Sun and others start building mainframe power into their desktop boxes, the entire industry will have to speed up. "The minicomputer companies are used to building \$500,000 machines with five-year cycles", says McNealy of Sun. "Our prices are under \$50,000, and our product cycles are only 18 months" " (*Business Week*, 21 April 1986a, p.95).

stoppages), constitute a means by which labour has varied the time resource of the sociotechnical system and, ultimately, affected the entire development of its systemic action. Simultaneously, in reciprocal interaction, capital's struggle for control and utilization of labour time can be seen in the efforts to extend the working day, both by reducing workers' breaktimes and other stoppages and by increasing the number of hours through overtime and multiple shifts. Most importantly, for the historical development of sociotechnical systems, it can be seen in the increase in the intensity and productivity of labour time, ultimately leading to automation and hence, to the potentially absolute control of the time resource in accordance with the dictates of capital. At this point, free from the restrictive ties of the human resource of labour, the time resource of the productive process may be stretched to its ultimate limit (no labour breaktimes, strikes, etc.) in a development which most certainly will completely transform the shape and workings of sociotechnical systems as we know them today. Interestingly enough, as we have seen in the course of this thesis, it is in the unfolding of the IMC sociotechnical process where the foundations and most advanced developments of this process of automation are actually taking place.

As regards the role of space as a basic resource of the technological process, it is clear that the development of a sociotechnical system such as an IMC has effectively claimed the terrestrial as much as the extra-terrestrial space as an intrinsic element systemically integrated and interacting with other basic resources of the technological system. To make an obvious point, there could have been no satellite communications without the orbital space necessary for its materialization. In this sense, the orbital space with all its particular physical characteristics has certainly conditioned the specific technical characteristics of satellites, determining with its existence and physical laws, in the same way that all sociotechnical systems are determined by the existence and physical laws of the specific space they claim as a basic resource. On the other hand, space as a basic resource of a sociotechnical process is only meaningful in relation to this process so that without its practical and systemic integration, for instance in an IMC, a given space is not an actual resource in the same way as any one person is not a human resource of a sociotechnical system in action. In this context, therefore, space can undoubtedly be seen as a dynamic resource; as a resource in constant creation and alteration through its systemic interaction with other basic resources of the sociotechnical system as a whole. An important expression of this dynamism lies, just as we have seen with the time resource, in the social struggle for control of space which sometimes becomes openly

manifest in the geographical restrictions or even total denial of space for the development of a given sociotechnical system. In the case of satellites, for instance, Third World countries, who can hardly use orbital space as a resource since they lack most of the other resources of a satellite capability, are concerned that the most advanced nations will control and use space primarily for their own interests (27). Thus, what has been expanding as a resource for advanced nations has been hardly a resource for the underdeveloped ones. In other instances, it may well be that a nation may potentially count on the financial, human and material resources necessary for the development of a sociotechnical process, but such a process may be denied space (and time) for its materialization by social opposition which may be based on prevailing socio-cultural and juridical relations under the historical circumstances of a given period. In this case, which may be exemplified by the absence of a nuclear-weaponry sociotechnical system in Japan, only an important change in the latter circumstances (e.g., military galvanizing pressures) may lead to the creation of the necessary conditions and hence, space for the development of the sociotechnical system. Conversely, it is in the struggle for control of space where groups such as conservationists, anti-nuclear lobbies, etc., possess an important chance for limiting or shaping the development of a given sociotechnical system, although this will clearly depend upon the relative strength of all the social interests involved in the development of such a system.

Finally, to bring the discussion on the basic resources of sociotechnical systems to an end, it is necessary to underline some aspects related to the creative core of the technological process. In this respect, we have already draw attention to the weakness of some writings which, by overlooking the importance of the productive moment in their conceptualization of the sociotechnical process, have implicitly reduced the creative core behind technical change, primarily, to scientists and engineers working in specifically creating R & D activities. In contrast, in the present conceptualization, labour and management are also seen as part of the creative core of a sociotechnical system in action, although their activities may not be specifically designed for searching and producing technical innovations as in the case of R & D personnel. In other words, while we acknowledge the dominant creative role played by R & D

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(27) So far, only India and China, two of the largest nations of the Third World, have developed a satellite capability of their own, although they lag considerably behind the capability of the most advanced nations. See Vidal-Hall (1982) and Whitehouse (1986).



organizations, particularly in science-based sociotechnical systems such as an IMC, we also raise the point that this should not obscure the fact that labour and management can and do play a creative role in terms of the sociotechnical system as a whole. In effect, products and process innovations emerging from the labour process, new forms of organization and even new techniques in social relations (e.g., incentive schemes, etc.) are all forms in which the creative role of labour and management influence the practical realization of a sociotechnical system. The fact that often the creative potential of labour and management remains untapped, or is stifled by organizational practices which are in themselves forms of socio-cultural relations, does not cancel the existence of the creative potential of labour and management, it rather points to the role of socio-cultural relations in shaping the development of a sociotechnical system via its influence upon the workings of the elements of the very creative core of such a system (28). Socio-cultural relations, however, are not the only factors interacting with the action of the creative core of a technological system; indeed, just like the technological process as a whole, the specific realization of the creative core in practice can only take place in systemic integration with the other resources of the sociotechnical system. Thus, financial, material, time and space resources, their quantity and quality and the specific way in which they are systemically utilized to enable the creative activity of human resources, are all factors which condition not only the very possibility of the creative activity but, also, its form, content and dynamism. For instance, the fact that the creative potential of labour has seldom been fully realized within the capitalist sociotechnical process clearly constitutes both immediate cause and effect of the specific form, content and dynamism of such a process. On the one hand, it reflects a specific form of systemic utilization of creative resources which tend to neglect the creative potential of labour while giving complete preeminence to the R & D laboratory within the creative core of the technological process. On the other hand, it clearly affects the form and content of such a process by the very mechanism of emphasizing the contribution of one source of technical

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(28) In this connection, it is interesting to note that currently a wave of creativity training for management is sweeping the world of US corporate companies. As a report has put it..."With the intensity of itinerant evangelists, "creativity consultants" are roaming the corporate landscape preaching an appealing gospel to management: You can *learn* to be creative. And business is listening. This year more than 20,000 executives will...attend workshops that they hope will help them to invent new products, conceive new strategies, and become better managers" (*Business Week*, 30 September 1985, pp.46-52). By now, there are several leading creativity consultants offering a variety of training programmes. It is acknowledged, however, that the first in the field was Edward de Bono who developed in the 1960s the concept of lateral thinking as way to improve creativity. De Bono has written



change (i.e., R & D constituent) over the contribution of another (i.e., labour constituent) which, as we shall see below, may bring different interests to bear into the shape of technical change. The latter is important since, in the final analysis, as we have consistently argued throughout this thesis, it is the conflict and convergence of interests between the social constituents of the technological process which actually determines the shape of such a process under given historical circumstances and state of development of the basic resources themselves.

Finally, we must point to the crucial and dynamic role of non-human resources in the creative activity of a technological process, particularly in the shape of instrumentation and all forms of real-time and abstract data processing machinery. As we have seen in the case of microtechnological development, the increasingly powerful sensing, measuring and processing capabilities of instrumentation and computers used for creative purposes has fundamentally amplified the ability, particularly of R & D constituents, to deal with large and complex technical problems. Moreover, to the extent that this development has in itself enabled the generation of even more powerful instrumentation, it is clear that a sort of "virtuous circle" effect is in operation which, as we have observed in the case of advanced countries' IMCs, is constantly creating new knowledge resources which, when systemically integrated, eventually leads to the alteration of the sociotechnical process itself. For the future, AI scientists hope to create machines themselves capable of creating new knowledge. If that promise ever materializes machines will then join human beings as legitimate parts of the creative core of the technological process. For the time being, as it is indicated in figure 5.2, we prefer to reserve the place of creative core for human beings alone, although in the fulfilment of this capability it is clear that human beings and instrumentation go hand in hand as inseparable parts of a dynamic system which involve the participation of all other basic resources too.

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many books. See, for instance, de Bono (1971,1978).

### 5.3.3. Institutional Depositories of the Basic Resources of an ITC Sociotechnical Process

The systemic integration of basic resources of sociotechnical systems can only take place in and through institutions or complexes of institutions which, in fundamentals, represent a direct embodiment of the interpenetration of social and technical factors characterizing the development of the sociotechnical process. In effect, it is in institutions such as companies, banks, R & D laboratories, universities, etc., where the specific character of basic resources merges with specific socio-cultural and juridical relations in a process ultimately determined by both the material determinants of the technical relations involved and the overriding interests implicit in the very *raison d'être* of the institutions themselves. In this sense, institutions are not only the dynamic depositories of the basic resources of a technological process but, simultaneously, forms of technical and socio-cultural and juridical relations mediating the systemic integration of these resources in agreement with the overriding social interests of those who exercise their control. To develop this argument further, we need to explain at this point the pair of concepts of overriding/particular interests which, by and large, enable us to conciliate the apparent contradiction between the determining role of imputed interests in the technological process and the obvious flexibility and manifold manifestations assumed by the concretization of these interests in practice [see Callon and Law (1982)]. This problem is an important one since it also holds the key to understand the sociotechnical process as one of constant and simultaneous alteration and reproduction of the socio-cultural relations of a given society. The latter is the process of change without change that Noble so aptly characterized in his *Forces of Production* (1984).

#### 5.3.3.1. Overriding and Particular Interests

Overriding interests, as we saw in Chapter III, relate to the *raison d'être* and, indeed, to the very existence of social constituents (29), whose members are

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(29) "...we shall define the overriding interests for all social forces as the need to ensure access to, or the control or share of those resources which constitute the lifeblood of the specific activities which define their *raison d'être* and which make them distinctive forces in a given society. It is the control, share or access to these resources which enable the reproduction and furthering of these activities and with it that of the social forces themselves. In the last analysis, such command or access to resources may be simply reduced to the possession of effective social power either directly by controlling economic and/or political power, or indirectly by having relation or access to and hence, influence upon those

bound by ultimately common generic pursuits and activities which they seek to imprint in, and express through, the development of the sociotechnical system. On the other hand, particular interests relate to the concrete and manifold ways in which the overriding interests are actually fulfilled in the specific historical circumstances characterizing the development of a sociotechnical system at any given time and place. Particular interests and overriding interests, therefore, are part of the same process but while overriding interests imply the existence and reproduction of ultimately unavoidable pursuits by the members of a social constituent, particular interests imply the existence of unlimited and constantly altering forms of practically fulfilling these unavoidable pursuits by the members of such social constituent. To put it in a different way, overriding interests, because they pertain to the very *raison d'etre* of social constituents, ultimately dominate the overall sociotechnical activity of these constituents and hence, the overall or aggregate development of the sociotechnical system itself. Whereas particular interests, because they pertain to the practical day to day activity of institutions and people, are not only informed by the overriding interests themselves but also by many factors such as concrete economic and political circumstances, organizational traditions, legislation, quality and quantity of available technical resources, and even the personalities of the individuals working and making the day to day decisions in particular institutions. In this respect, to use the terminology of sociologists such as Callon and Latour, particular interests would undoubtedly be the subject of transformation and can hardly be imputed as unchangeable realities. Furthermore, in historical perspective, one can only say that particular interests are truly in a process of constant transformation reflecting the fluidity of the interaction and interpenetration between diverse social and technical constituents. Such fluidity manifests itself in varying and multiple ways and interrelations between these social constituents in a process informed and dominated by changing national and international galvanizing forces and changing correlation of forces between social constituents and hence, the institutional structures housing them. The point of the overriding interests, however, is that, notwithstanding the fluidity and process of constant transformation of particular interests, such transformations ultimately take place within a context of no change, or more precisely, within a context of reproduction of social constituents and the pursuits implied in their *raison d'etre*.

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in direct command of power and resources" (see Chapter III above).

Overriding interests, therefore, set the general goals and also the ultimate limits for the possible transformation of particular interests. Thus, the latter cannot transform themselves into forms which would imply a permanent negation of the overriding interests and hence, a negation of the very *raison d'etre* of a social constituent. True enough, occasionally and in the short-term particular interests may and do assume forms which are contradictory to the overriding interests implied in the *raison d'etre* of social constituents. For instance, capitalists, whose overriding interests is to make profits for capital accumulation, do consciously indulge themselves in money-losing activities such as dumping. On closer examination, however, these apparently contradictory pursuits always reveal themselves in consonance with the long-term overriding interests of social constituents. Dumping for capitalists, for instance, is not a pursuit in itself, it is in fact a pursuit for the long-term objective of capital accumulation since, by breaking competition, it is expected that greater shares of markets will result which, in turn, will have a positive effect in the process of capital accumulation. A similar case would be that of integrated (electronics) companies which may run losses in a particular division (e.g., semiconductors) while keeping overall profitability because the technology is strategic for the long-term accumulation process of the company. In this sense, overriding interests represent the bottom line always guiding the pursuits and activities of social constituents and they themselves cannot be transformed but only given concrete expressions which fulfill them. This is the reason why in this thesis, when referring to the process of interaction of two or more social constituents, we have preferred the term convergence of interests to emphasize the basic agreement of overriding interests which actually takes place, whatever the specific form assumed by the particular interests expressing such a basic agreement. Of major relevance, this conceptualization enable us to explain the problem of conflict of interests and particularly, the existence of antagonistic interests which cannot be transformed into conciliation without the very denial of the *raison d'etre* of at least one of the social constituents. For instance, the anti-nuclear lobby has as its overriding interests the abolition of all nuclear weapons. These interests are untransformable to the extent that were this lobby to accept the need for the existence of nuclear weapons, whatever the reasons, its anti-nuclear *raison d'etre* would immediately collapse. As a result, the particular interests, pursuits, and actions of the anti-nuclear lobby are bound to never converge with those interests which are pro-nuclear weapons for whatever reasons. Ultimately, there is here an antagonistic relation which denies from the start the possibility of any convergence fulfilling the overriding interests of all

parties. Only conflict reigns supreme in such circumstances. But, as we saw in the course of the present work, conflict and tensions are not just antagonistic, they can also arise between one time convergent interests as a result of changing national and international galvanizing forces and changing relative weight of social constituents. In the case of the US's IMC, for instance, we saw how the heavy weight of military interests and pursuits in the face international market competition has led to concerns that US's electronic corporate capital may eventually loose its leadership to other advanced capitalist nations. So far, US's corporate capital and military interests have had every reason to converge since they have both clearly benefited from a dynamics of profits and military power, but were the latter to become truly a hindrance to the process of capital accumulation, thus threatening capital's overriding interests in the long-run, then such a contradiction in terms of overriding interests would almost certainly leads to a process of divergence, as opposed to convergence, of particular interests, pursuits and actions between capital and military constituents. This, of course, if we disregard the possibility of other alternative developments such as a trade or, indeed, a military war which would completely change the prevailing wind of national and international galvanizing forces. In all, therefore, to round up this discussion on interests, we have talked of *raison d'etre* of social constituents, overriding and particular interests, convergence and divergence of interests, changing national and international galvanizing forces, and changing force correlation between social constituents. Taken together, and as we have already seen in the case of an IMC, it is our view that these elements, along with the understanding of the material determinants arising from the very nature and state of development of the technical relations involved, constitute a basic set of conceptual tools which effectively contribute to a systematic and unified analytical treatment of sociotechnical systems in action. Most particularly, these concepts hold the key to understand the development of sociotechnical systems not only as a process of constant alteration of sociotechnical systems themselves but, also, as a process of simultaneous reproduction of social forces and relations in and through the sociotechnical systems themselves. By the same token, they also hold the key to understand the dominant features and trends characterizing the aggregate development of a sociotechnical system.

### 5.3.3.2. Some Common Forms of Institutional Depositories of Basic Resources



Going back to the role of institutions in the ITC sociotechnical process, therefore, we are now in a position to explain our previous statement that institutions are the dynamic depositories of the basic resources of the technological process and, simultaneously, forms of technical and socio-cultural and juridical relations mediating the systemic integration of these resources in agreement with the overriding interests of those who exercise their effective control. In figure 5.2, we have listed what are perhaps the most common institutions involved in the materialization of a sociotechnical system in action. In effect, companies, banks, government institutions, foundations, international organizations are all clearly identifiable depositories of basic resources of technological processes. Taken separately, however, these institutions, although interrelating through and in the sociotechnical process, can be said to differ in their *raison d'être* and, consequently, not only in the specific character of the basic resources they are depositories of but, equally, in the very relationship of their overriding interests to, and hence their role in, the sociotechnical process as a whole. Of course, we must make clear that, in practice, the situation is seldom one of clearcut separate institutions, since, for all analytical purposes, the variety of existing institutional forms is simply unlimited. This means that in relation to the classes of institutions named above, in a developed sociotechnical system in action one can find not only a myriad of qualitatively and quantitatively different intra-institutional forms but, also, a great deal of inter-class institutional overlapping and arrangements. For instance, there are many forms of companies, some large and diversified, some small and narrowly specialized, some producing a broad range of products and possessing a broad range of technical resources, some revolving around the production of a particular piece of equipment, or even just knowledge as in the case of consultancies, etc. The same happens with banks and other institutions. Banks, for instance, may be involved in a given sociotechnical process in all sorts of degrees and, of course, as only one in a set of other financial activities. Also, banks and industrial companies may be just parts of a larger economic group, or they may be industrial development banks particularly and more fully committed to the development of a sociotechnical system in a given country. In the latter case, banks themselves are more likely to be government institutions directly inputting financial resources into the technological process. This takes us to government institutions which not only can have various sizes and purposes or be just direct depositories of basic resources, but may also be direct depositories of all other resources of the technological process through, for example, public companies and government R & D institutions directly involved



in the development of such a process. In the latter case, there is a clear institutional overlapping between government and companies, for instance. Likewise, where the military exercise a direct command of basic resources and their institutional depositories, a similar situation to that of government institutions applies. After all, government and the military are inextricably related within the state with the resources of the military very much as a special case of government use of technological resources in accordance with the weight of the military and their concerns within a given historical period. The military, however, although part of the state, possess a distinctive set of interests of their own and, in this sense, it is useful to treat them as a separate social force in the development of the sociotechnical process. In addition, and reminding the reader that, in the final analysis, all the institutions and constituents depicted in figure 5.2 interact with each other in the ITC sociotechnical process, I am also inclined to include those government institutions such as policy-making bodies which act as indirect depositories of basic resources through their possession of regulatory powers and hence, the ability to influence the availability of resources through, for instance, taxation, price-regulation, royalty and tariff policies, etc. Also, in the line of depositories of basic resources, we can consider those institutions which act as banks of information and diffusion of basic resources of a sociotechnical system. These may be specialized libraries or data-banks and may be public or private enterprises as in the case of consultancy firms. Finally, to say a word about universities, foundations and international organizations, they also may exist in a variety of sizes and shapes and may be depositories of a variety of basic resources of technological processes. Foundations, for example, may provide financial resources for the activities of individual researchers or other institutions such as universities but they may also run their own R & D laboratories. Universities carry out R & D activities and constantly reproduce necessary human resources for the technological process, but they may also run their own companies commercializing knowledge and expertise through patenting and consultancy, for instance, or even through commercial production of artefacts. As to international organizations, they are more commonly associated with United Nations-type of institutions which, particularly in the case of Third World countries, may make available financial and some human and material resources for the development of an ITC sociotechnical process. In principle, however, international organizations are not just the UN-type of organizations, they are indeed all sort of bilateral and multilateral international institutions involving all sort of institutional arrangements between companies, government institutions, universities,

foundations, etc., which are relevant to the sociotechnical process. We shall discuss the international dimension of an ITC later on, for the time being, we need only to underline the point that, in practice, nationally and internationally, the number of institutional forms and arrangements that can fulfill the role of institutional depositories of basic resources of an ITC is virtually unlimited.

At this point, from the perspective of our theoretical conceptualization of a sociotechnical system in action, there are two paths which the present discussion can follow. The first would be to go right down to the level of real-life institutions, as it were, and explore some of the theoretical implications and limitations for our model which are present there. The second would be to go right up into more abstract levels and discuss a model of institutions as forms of technical, socio-cultural and juridical relations mediating the systemic integration of basic resources in agreement with the overriding interests of the social constituents who exercise their control. Here, we shall briefly explore the theoretical implications of the first path to proceed later to the second path where we shall bring together the analytical tools we have been developing so far.

#### **5.3.3.3. Development of Real-Life Institutions. Transformation of Particular Socio-Cultural Relations for Reproduction of Fundamental Socio-Cultural Relations**

In this section, the main point that has to be made immediately is that at the level of real-life institutions one can hardly expect to produce some kind of general model explaining why real-life institutions assume the specific form and behaviour they assume in practice, both internally and in their relation with others. For, at this level, the number of explanatory variables will touch not only upon such factors as national and international galvanizing forces, interplay of overriding and particular interests, and nature and state of quantitative and qualitative development of basic resources. It will also touch upon general cultural factors such as the technological rationality identified by Goulet and Winner and specific cultural factors such as institutions' own idiosyncratic practices and, indeed, right down to the character and values of individuals who, by making specific day-to-day decisions, lead institutions into shapes and path of developments which are unique to each one of them. Thus, on the one hand, it can be said that at this level the variety and richness of institutions are such that they do not lend themselves to general, simplifying models as the

one we are trying to elaborate here. On the other hand, however, and because of the same variety and richness, it can be said that it is at this level where the character of particular institutions as dynamic forms of specific technical, socio-cultural and juridical relations of the sociotechnical process reveals itself in its most conspicuous and detailed expressions. In other words, it is here, in the concrete sociotechnical world, where the historical unfolding of sociotechnical institutions can be more clearly seen as actually transforming as much as reflecting the written and unwritten legislation, i.e., legal provisions, customs and values prevalent in a given society. In effect, if we consider, first of all, that by transforming themselves in the course of the sociotechnical process, particular institutions are actually altering past as well as leading into new forms of relations between people -individually or in social groups-, artefacts, processes, ideas, attitudes, etc., (30) then their role as transformers/creators of socio-cultural and juridical relations and hence, written and unwritten legislation (31), becomes clearer. In this respect, perhaps the most powerful illustrations are likely to be found in periods of large-scale institutional transformations such as those involved in technological revolutions, (e.g., the current microelectronics revolution, or the transformations accompanying the substitution of the machinofacturing system for the manufacturing system of production described by Marx in *Capital*). But gradual, cumulative institutional transformations are also likely to bring about changes in the written and unwritten legislation of a given society, although in a less dramatic fashion. The constant expansion and transformation of the Bell System in the US in the first half of this century, for instance, not only led to, and was reinforced by, its legal recognition as a

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(30) An interesting example in this respect is provided by the current attempt within some US institutions to introduce computer networks at various levels. Two of these institutions are American Can Co. in Greenwich, Conn., and Bank of America. As a report describes, "...installing such a network in a company as decentralized as American Can, where subsidiaries prize their independence was complicated. "We had to agree on technical issues, but that wasn't the hardest part", says M. Smalley who heads technical services at the corporate level. "Dealing with corporate culture issues was harder"...Bank of America is facing similar challenges. Such a network, says R. Dennis Wayson, head of professional support services for the San Francisco-based bank,..."won't be good for anything until we solve the management and cultural questions it raises"... (Business Week, 21 April, 1986a.p.94).

(31) Written and unwritten legislation are both expressions of socio-cultural relations of a given society, and both are equally important in the development of an ITC sociotechnical process. Thus, although until now we have talked of socio-cultural and juridical relations to emphasize the presence of the latter, from now on, we shall use socio-cultural relations as including juridical relations too. In the final analysis, technical relations can also be seen as forms of socio-cultural relations. However, in order to emphasize their particular importance regarding sociotechnical systems and because of their intrinsic properties relating to the laws of nature, we shall continue to talk of sociotechnical systems as ensembles of technical and

natural monopoly but, also, completely altered the shape of the sociotechnical constituency of the US communications system and, indeed, the very customary patterns of communication of American people (including social constituents, of course) by introducing the telephone in their daily life. This particular argument may be more generally illustrated by referring to the diagram in figure 5.2. Here, we would have to say that what is implied in the role of sociotechnical institutions as creators/transformers of socio-cultural relations is, in fact, the existence of a flow of changes which from left to right of the diagram, that is, from basic resources and particular institutional depositories themselves to socio-cultural relations and the social complex of power, ultimately encompasses not just the sociotechnical system but indeed society at large. By and large, this is the process which actor-network writers have focused on most, and which lead them to deny the existence of an actual society shaping the technological process. As we saw before, for these writers society is in itself in a constant process of creation, flowing out from the continuously changing interrelations and interactions between sociotechnical actors themselves. While agreeing with the actor-network writers in the existence of such society transforming/creating flow of sociotechnical changes, in the present conceptualization, however, we have argued that the historical unfolding of sociotechnical institutions and hence, basic resources, also and simultaneously reflect society's socio-cultural relations and thus its written and unwritten legislation. In other words, we argue for the simultaneous existence of an opposite and interacting flow of influence which from right to left in the diagram in figure 5.2 truly informs and broadly shapes the development of real-life institutional depositories of basic resources. More specifically, as we have made it clear in our discussion on overriding/particular interests, our argument is that not only there are ultimate limits (technical and social) regarding the kind of society-creating transformations which satisfy the reproduction of those interests controlling the basic resources of technological processes but, also, that in all their possible variety and richness, real-life institutions are ultimately informed by, and indeed represent themselves dynamic crystallizations of society's fundamental forms of socio-cultural relations. In this way, in the development process of real-life sociotechnical institutions we have both, transformation of socio-cultural relations and reproduction of such relations. Or more precisely, just as with particular/overriding interests, we have transformation of particular relations *for* reproduction of fundamental relations. In effect, if we consider that at any given time a society's written and

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socio-cultural relations.

unwritten legislation not only contains the guiding principles and rules broadly governing the societal behaviour of the members and institutions of that society, but that this legislation is in itself a kind of evolving historical register of that society's past and present process of social conflicts and changes involving dynamic social interests in a context of changing national and international galvanizing forces, then we shall see that, in a society where definite social interests exercise the dominant control of the basic resources of sociotechnical processes, there is a continuous process of transformation for reproduction taking place. This is so, because in such a society, its evolving legislation will show that there indeed exist fundamental socio-cultural relations which throughout history and many particular changes tend to remain unaltered because they pertain to the very existence and continuous reproduction of such dominant interests. In a capitalist society like the one which concerns us here, for example, the relation of private property of basic resources of technological processes is fundamental to the very existence of capital as a dominant social constituent of the sociotechnical process. Thus, although particular socio-cultural relations may change into many forms in the historical development of a capitalist society, it is clear that, while capital continues to exercise its dominant role, such particular relations will hardly evolve into negating the relation of private property of sociotechnical resources and, on the contrary, they will be ultimately shaped by it, expressing it and reproducing it, in accordance with the changing historical context of a given society. In the same vein, there are other fundamental socio-cultural relations which, like the property relations, have tended to remain unaltered while deeply shaping and expressing themselves through the particular forms of development of sociotechnical institutions in advanced industrial societies. For instance, the hierarchization of organization which goes hand in hand with the control of basic resources by dominant social interests and, also, the kind of general relations and rationality which various scholars such as Ellul and Goulet have imputed as intrinsic to the very nature of the present technological society.

These fundamental forms of socio-cultural relations, therefore, ultimately shape the society transforming/creating flow of changes which is constantly emerging from the development process of real-life sociotechnical institutions. As such, rather than the arbitrary society-creating flow of changes offered by actor-network writers, what we have in our conceptualization is a dialectical process where such a flow of change is ultimately shaped into a process of reproduction of fundamental socio-cultural relations in a context of changing historical



circumstances and force correlation between the social interests controlling the basic resources of the sociotechnical process. Again, referring to the diagram of figure 5.2, we can illustrate this process by saying that it goes from left to right and right to left in a kind of spiral development which has no definite starting point, or which, as we said at the beginning, should be seen as truly compressing all the elements of the diagram into a single sociotechnical process. In this way, the social and the technical interpenetrate each other and the sociotechnical system not only flows *from* itself but *for* itself.

Finally, before finishing the present discussion, it must be said that throughout the argumentation bringing out the dialectics of change and reproduction of the sociotechnical system, we have implicitly assumed the existence of an effective control of the basic resources of the technological process by dominant social constituents seeking to reproduce and further themselves in and through such a process. It is clear, however, that there may be periods of severe crisis where such control may be seriously undermined and, indeed, the social constituency itself radically altered -for instance, in a revolutionary situation altering the fundamental socio-cultural relations of society as a whole- with the result that it will be hardly possible to talk of a process of reproduction of the sociotechnical system. Perhaps, not to the same extent, other cataclysmic situations such as wars may also lead to major alterations of the social constituency and hence, of the development of the sociotechnical system as a whole. The latter we saw quite clearly in the course of the present thesis when both the First World War and the Second World War brought about momentous changes in the historical development of the US's R & D system. World War II, in particular, effectively galvanized a complex of power which clearly and greatly altered the previous development process of the US's R & D system. And, once it was operational, we saw how the postwar development of the R & D system tended itself to reflect and reproduce the constituents and interacting interests of the very same complex of power which during the war came to dominate the control of the R & D system's basic resources. The latter, in a process which not only reflected changing historical galvanizing forces and relative weights between social constituents but, equally, involved the continuous efforts to reproduce the very galvanizing pressures keeping the social constituents both necessary and together. Thus, we can say that whereas World War II was a highly disruptive historical moment which broke with the pre-war evolution of the US's R & D sociotechnical system, the postwar period has been substantially one of reproductive evolution of the



dominant and interacting social interests of the complex of power crystallized during the war. In the present conceptualization, our main concern has been with the dialectic dynamic of the process of transformation for reproduction of the sociotechnical system since, clearly, cataclysmic situations can hardly be anticipated in their character, extent, and consequences. Thus, in the following our discussion will continue to refer mostly to the more analytically manageable reproductive evolution of sociotechnical systems.

#### 5.3.3.4. Institutions, Systemic Integration of Basic Resources and Overriding Interests. Ensembles of Technical and Socio-Cultural Relations

Above, we have said that sociotechnical institutions are dynamic forms of technical and socio-cultural relations of an ITC sociotechnical process; and that, in a society where definite social interests exercise the dominant control of the basic resources of this sociotechnical process, their historical unfolding actually materializes a process of constant transformation of particular relations for reproduction of fundamental relations associated to the very existence and furtherance of such controlling social interests. In the present section, our concern is to offer a general explanation regarding the workings of the latter process by formulating a model of institutions as forms of socio-cultural relations mediating the systemic integration of sociotechnical constituents primarily in agreement with the overriding interests of those social constituents who exercise the control of the basic resources. For these purposes, we shall first make abstraction of all the rich variety and complexity present in the concrete world of real-life institutions and particular interests. In other words, as we have done through this thesis, we shall work with highly aggregate levels of classes of institutions as dynamic expressions of highly aggregate levels of classes of overriding interests. On this basis, the following fundamental points are useful to summarize the gist of our approach.

a) In a given society, at any given time, there are definite social interests who express themselves and interact with each other in the sociotechnical process on the basis of their overriding interests and in fulfilment of their *raison d'être*. In the course of this thesis, we saw, for instance, how in the case of the US capitalist IMC, the convergence of the overriding interests of capital, science, military and government has clearly dominated the development process of such a sociotechnical system.

b) In the sociotechnical process, social interests express themselves and interact with each other within institutions and in between institutions. By and large, what takes place is a process of convergence between distinct social forces into institutional forms, which tends to develop, as we argued in Chapter III, when the product of the activities of one force, or the basic resources possessed by that force, are perceived as important to the reproduction and furtherance of another force commanding resources which, in turn, are essential to reproduce and further the activities of the former force. In this case the interests of the latter force, say, capital accumulation in the case of capital, will tend to shape the content and the product of the activities of the latter force, say, the scientific and technical knowledge produced by science. Altogether, what would have happened is a social convergence into institutional forms between these forces which would come to fulfill the overriding interests of each one of them, within the limits afforded by the nature and state of development of the technical knowledge and relations involved.

c) In a class society such as the capitalist society, definite social interests exercise a dominant control of the basic resources of technological systems. As a result, in this kind of society, the same interests effectively dominate the social process of convergence of overriding interests into institutional forms as much as the very unfolding of such institutions in practice. Analytically, this means that, in this kind of society, separate institutions as well as a complex of institutions can be dealt with as ultimately sharing the same general character. Namely, that they are all forms of systemic integration of overriding social interests and basic resources dominated by the overriding interests and hence, *raison d'être* of those social interests in dominance of the basic resources of an ITC sociotechnical process. Such dominance and the form of systemic integration itself depend, among other factors, upon the nature of the technical relations involved and upon the correlation of forces between different constituents within the context of changing national and international galvanizing forces.

d) In the sociotechnical process, there are institutional forms such as public companies or development banks, which tend to embody a duality of overriding interests such as the accumulating interests of capital and the political interests of government. In this case, one or the other overriding interest may well predominate in the pursuits of the institution, in a process which is very much related to the character of the prevailing galvanizing forces and the particular interests of those forces in control of government. For example, it may well be

that, in the name of government's politico-economic strategy, public companies can run long periods of losses financed by the government; or, alternatively, that in the face of an economic crisis threatening the political stability of government, public companies must become a profitable part of the capital accumulation process. In the latter case, the overriding interests of capital tend to coincide in both private and public companies and specific policies of privatization sometimes just materialize this situation.

Let us now see how the approach just summarized works to explain the fundamental character and role of some of the broad classes of institutions within the sociotechnical process of a science-based capitalist ITC as the one illustrated in figure 5.2. We shall first deal with separate classes of institutions and then with the complex of institutions basically involved in such an ITC. In both cases, however, it is necessary to characterize the overriding interests and *raison d'etre* of the aggregate social interests we are about to distinguish as major constituents of a science-based capitalist sociotechnical process. Thus, in Chapter III, in following the convergence and ups and downs of the capital-science-military-government social complex of power which has dominated the post World War II development of the US' R & D system and IMC, we already characterized the overriding interests and *raison d'etre* of each one of these aggregate forces by saying that, for all cases, they may be reduced to the pursuit of quantitative and/or qualitative accumulation and implementation of some form of power factor. In the case of capital, this manifests itself in the accumulation of capital through profit-making activity; for the military, in the accumulation of destructive power through improved weaponry; for science, in the accumulation of scientific and technical knowledge through the advancement of the frontiers of this knowledge; and for government, in the accumulation of political power both nationally and internationally, among other ways, through the economic, military, and scientific-technical power derived from the other forces. Of course, within each of these aggregate social forces there are not just a myriad of institutional manifestations but, also, some important social subdivisions which manifest in their own particular way, sometimes in conflict with others, the overriding interests we have just mentioned. Within capital, for instance, there is financial, industrial and merchant capital; within the military there is the different branches of the Armed forces; within science there is university, industry and government R & D; and within government, there is not only a complexity of ministerial subdivisions but also overall changes in political-economy strategies which may have momentous implications for the

development of sociotechnical systems. Clearly, these social subdivisions go right down to the level of real-life institutions, but, it is our contention that always the overriding interests we have identified above remain valid as the ultimate common factor enabling us to talk of the aggregate social forces of capital, the military, science and government.

As figure 5.2 illustrates, however, the abovementioned aggregate social forces are not the only social constituents of an ITC sociotechnical process nor, indeed, are they all necessary as we saw with the case of the military in the development of the Japanese IMC. In this respect, the fact that, in the course of the present work, we focused primarily on the convergence of interests between those forces making up the dominant social constituency of an IMC, certainly justified our assumption that the interests of all other social forces were subsumed in the specific interplay of such social constituency. In the present discussion, however, where we are attempting to conceptualize the workings of sociotechnical institutions as both depositories of basic resources of technological processes and as forms of systemic integration of sociotechnical constituents primarily in agreement with the overriding interests of those social constituents in control of the basic resources, the role of other social forces and, particularly, the role of labour cannot be disregarded. In effect, as we have already seen in our discussion on basic resources and, indeed, on the creative core of the technological process, labour is an intrinsic dynamic constituent of a capitalist science-based sociotechnical system in action as much as science and, indeed, financial (capital) and material resources themselves are.

In figure 5.2, the intrinsic role of labour is illustrated on the left-hand side of the diagram where labour appears along with R & D and management within the category of human resources. Within this category, although fulfilling different specific roles in the capitalist science-based sociotechnical process, it can be argued that, ultimately, has a great deal in common to management and R & D personnel within the unfolding of such a process. To put it in a different way, as human resources, both R & D personnel and management can be seen as specialized forms of labour, both as necessary as skilled and unskilled labour for the materialization of the ITC sociotechnical process - at least until full automation does not become a reality - and all equally moved by the overriding interest to ensure access to, or the control or share of those resources which constitute the lifeblood of the specific activities which define their *raison d'être* and which makes them distinctive forces in the capitalist science-based

sociotechnical process. In the latter respect, we have already said that science's *raison d'etre* lies in the accumulation and implementation of scientific and technical knowledge through the advancement of the frontiers of this knowledge. In the case of labour, the *raison d'etre* is different in that generally within capitalist sociotechnical systems and whatever the satisfaction and creativity attached to particular forms of work, such *raison d'etre* lies primarily in the embodiment and realization of skills and labour power through and in the production process and into the final products of such a process. Thus, unlike science, the *raison d'etre* of labour does not pertain, by definition, to the advancement of the frontiers of knowledge dynamizing the unfolding capitalist science-based ITC, it rather pertains to the actual working, to the systemic operationalization of all basic resources at every stage of development of such an ITC. In this framework, the overriding interest of labour is, by definition, the same as that of all social forces, namely, to ensure access to, or the control or share of, those resources which are vital for its own reproduction within the context of historically and culturally determined social needs, galvanizing forces and force correlation vis-a-vis the other sociotechnical constituents. In practice, in a society where labour possesses no basic resource other than its own skills and labour power, such resources for its social reproduction relate primarily to a workplace, working conditions, and an income which enables the reproduction of its skills and labour power under socially determined conditions. It is on this basis that the overriding interests of labour converge with those of the other social constituents within the capitalist science-based sociotechnical system. However, it is not a smooth convergence, for in the unfolding of such a sociotechnical system the fulfilment of the overriding interests of labour tends to have a simultaneously contradictory effect upon the process of capital accumulation. This is so not only in that what goes to labour does not go to capital but also in that the process of science-based capital accumulation is constantly demanding increases in the productivity of labour and hence, the embodiment of new skills as well as the displacement of existing ones in a dynamic which threatens the very *raison d'etre* of many forms of labour as constituents of the sociotechnical system. The resolution of such contradictions certainly pertains to the realm of history and, in this sense, will depend largely upon the socio-cultural relations of a given society, the nature of the national and international galvanizing forces and, indeed, the force correlation of the constituents involved in a context of changing relations between the basic resources of the sociotechnical process. Sometimes such contradictions will reach highly conflictive levels, manifesting themselves in ways which may disrupt the



workings and development of the sociotechnical system itself. As we shall see later on, it will correspond to the social organizations of labour, i.e., trade unions, confederations, etc., to further the interests of labour both in particular institutions and the sociotechnical system as a whole, by attempting to influence the entire realm of technical and socio-cultural relations associated with the development of such a system.

In the case of management, we can define its *raison d'etre* as one of planning, organizing, supervising and controlling the institutional workings of the capitalist science-based sociotechnical system. As we said before, like science, management can be taken as a highly specialized form of labour which ultimately has similar overriding interests in ensuring access to the resources enabling its own social reproduction and hence, the reproduction of its *raison d'etre* within the sociotechnical system. In this respect, like other forms of labour, management can only fulfill itself within the sociotechnical system in action, but given the planning-organizing-supervising-controlling nature of its *raison d'etre* its overriding interests additionally entail the accumulation of organizational power, not necessarily authoritarian power, to enable it to fulfill itself as a management constituent of the sociotechnical process. In this way, management is not just a constituent distinct from the labour constituent above but, to the extent that its *raison d'etre* is normally exercised on behalf of the overriding interests of those social constituents dominating the basic resources of the sociotechnical process, management interests can be hardly distinguished from those of the dominant constituents and, indeed, they generally only gives practical expression to the overriding interests of such dominant constituents of the sociotechnical system. In this respect, only when the very existence of management is threatened, for instance, in a period of drastic organizational adjustments affecting managerial levels too, one is able to see the separation and even contradiction of interests between, say, management and capital. But this is mostly in a partial way since such readjustments are normally the work of higher levels of management still acting on behalf of the overriding interests of dominant constituents. All in all, we have briefly characterized the *raison d'etre* and overriding interests of management and labour as sociotechnical constituents of a capitalist science-based ITC. These theoretical elements, together with those already in store from our characterization of the overriding interests of the capital-science-military-government social complex of power, are all we need at the moment to broadly reconstruct the fundamental character and role of some aggregate classes of institutions within the sociotechnical process of a capitalist



science-based ITC. Let us illustrate the case of some of the separate classes of institutions named in the diagram of figure 5.2.

First, let us take banks and other financial capital institutions which are involved in the sociotechnical process as depositories of financial resources alone. From our conceptual point of view, they are ultimately forms of technical and socio-cultural relations not only bringing together the interest of financial capital, management and labour (plus individual customers at large) (32) but, above all, bringing them together into a dynamic institutional system dominated by the *raison d'etre* and overriding interests of financial capital. In other words, financial capital, because it possesses the control of basic financial resources, is the dominant social constituent and hence, it is its overriding interests in capital accumulation which ultimately shape and dynamize the *raison d'etre* of the institution as a whole. For the sociotechnical process, this means that the very involvement of a financial capital constituent will be enough to inject this dynamizing and shaping force of capital accumulation in the development of a sociotechnical system as a whole. The shape and dynamics of the latter, therefore, begin with the institutions and, indeed, the overriding interests of the social constituents themselves.

Undoubtedly, and although in practice a capitalist science-based sociotechnical system is made up of the whole complex of institutions, it is companies and industrial capital institutions geared to production for profit which form the core of such a sociotechnical system. Indeed, it is here where all the different basic resources of technological processes are normally found in systemic integration, materializing the interpenetration of technical and social constituents through all the moments (i.e., creating, production and diffusion moments) of such sociotechnical process. Ultimately, however, this does not alter

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(32) Science seems also to be finding a place within financial capital institutions, at least since the 1970s as it has been recently reported. A new breed of scientists has moved into Wall Street where they have become known as the "rocket scientists" or "quants". "These former academics, trained in mathematics, and the whiz kids, most from the physical sciences, who have come after them, are revolutionizing the stock and bond markets...Today the top firms employ more than 1,000 rocket scientists and usually pay them well over six figures...The first rocket scientists on Wall Street were cut from a different mold. In the early 1970s they and their computer programs were used for back office functions such as data processing to handle increased trading volume. Although they vastly increased the efficiency of the brokerage industry, they were pigeonholed by top management...By the end of that decade, as interest rates began fluctuating wildly and the deregulation of the financial markets was picking up steam, Wall Street houses turned to the quants in increasing numbers...Now the quants are in the mainstream of virtually all activity in the markets" (*Business Week*, 21 April 1986, pp.84-85).

the fact that, just like financial capital institutions, industrial companies (science-based) are equally forms of technical and socio-cultural relations bringing together different sociotechnical constituents into a dynamic institutional system dominated by the *raison d'etre* and overriding interests of those constituents in control of basic resources. In effect, in capitalist science-based industrial institutions, the *raison d'etre* and interests of industrial capital, science (R & D), management and labour organically integrate together into an operational sociotechnical system of financial, human, material, time and space resources. Most importantly, this system is dominated by the overriding interests of industrial capital which means that, inevitably, its shape and dynamism is fundamentally pervaded by the profit-making driven process of capital accumulation. For R & D, management and labour, this means that while their *raison d'etre* are certainly fulfilled in the actual workings of industrial capital institutions, this fulfilment is generally mediated by, i.e., takes place through and in pursuit of, the overriding accumulating interests of industrial capital. As we have said before, it is a case of the activities of one force, or set of forces (i.e., R & D, management and labour), being important for the reproduction and furthering of another force (i.e., industrial capital) possessing resources which, in turn, are essential to reproduce the activities of the former set of forces. A social convergence into institutional forms takes place here in which the overriding interests of the dominating force of industrial capital tend to shape the product of the activities of the other force or set of forces. It is only when the shape and consequences of the developments stimulated by capital accumulation or, indeed, when the particular interests and actions of any of the social constituents tend to contradict the overriding and particular interests of another, that social conflict and disintegration result which may eventually disrupt the systemic workings of an industrial institution as a whole. In this respect, we have already mentioned the potential for conflict implicit in the contradictory nature of the convergence between labour and capital overriding interests. At any rate, it is difficult to generalize in this area as it is clear that the materialization and specific nature of conflicts and their resolution is something that belong to the level of real-life institutions and hence, to the specificity of, among other things, the technical and socio-cultural relations pertaining to an institution, the prevalent national and international galvanizing forces and the force correlation between diverse sociotechnical constituents. Here, what is most relevant for our purposes of conceptualizing the role and character of industrial capital institutions within the sociotechnical system, is that, through the shaping and dynamizing of their development by the overriding interests of

capital accumulation, it is indeed the sociotechnical system itself which is being generally shaped and dynamized in accordance with the interests of the controlling force of capital.

A third major class of institutional depository of basic resources of the sociotechnical system is found in universities and other scientific and technical institutions where relevant R & D activities are pursued. Obviously, as forms of technical and socio-cultural relations embracing all forms of knowledge and educational development and, in principle, as major depositories of the critical consciousness of society, these institutions are larger than R & D and, indeed, than any particular ITC sociotechnical process. For our purposes, however, it is their role as depositories of R & D resources that we are concerned with insofar as it is in this role that they most directly shape, dynamize and express the unfolding of a given science-based sociotechnical system. In other words, as sociotechnical institutions distinct from the institutions of financial and industrial capital, we shall consider universities and other scientific and technical institutions as autonomous forms of technical and socio-cultural relations whose *raison d'etre* is primarily that of producing, accumulating and diffusing knowledge resources through the continuous advancement of the frontiers of scientific and technical knowledge for its ulterior publication and/or implementation. In this character, and additionally assuming that the control of the basic resources enabling the reproduction and furthering of such *raison d'etre* rests within the institutions themselves and not with any other social force such as capital, the military, etc., we can then say that, as forms of technical and socio-cultural relations, university institutions and the like not only bring together into an operational system of interests and basic resources the overriding interests of science, management and labour but, they do so ultimately in line with the *raison d'etre and interests of the science social constituent*. In fact, as we have defined them, the latter constituent's *raison d'etre* and overriding interests actually become those of the institutions themselves. In practice, these overriding interests of science converge with those of management and labour not just because, often in R & D institutions, science and management and even labour constitute different expressions of the same constituent but, also, because on the reproduction and furthering of the activities of the science constituent truly rests the reproduction of the other interests and, effectively, of the sociotechnical institution at large. Given the autonomy and control of the necessary basic resources, therefore, one is bound to find that it is in universities and the like institutions where the shaping and dynamizing of the

sociotechnical system take place more in accordance with the overriding and particular interests of the science constituent. In effect, given these conditions, it is here where the science constituent will be able to influence decisively the direction, content and pace of its own R & D activities both informed by the general state of the art in the respective fields and by the general development of society. By the same token, it is here where the written and unwritten legislation of its own culture (e.g., ethical principles such as freedom to pursue knowledge for common good and free flow of knowledge) is most likely to pervade the workings of the sociotechnical system in action. In practice, however, as we have seen in the course of this thesis, the basic resources for the reproduction of the science constituent and its institutions are not always easily available and, indeed, when the availability of these basic resources is in control of other major social forces whose own interests have come to be perceived as depending upon the product of the activities of the science constituent, then the most likely result is a convergence of interests which will transform the particular interests while advancing the overriding interests of each one of them.

To a large extent the broad classes of institutions we have discussed above, i.e., financial and industrial capital institutions and university and other scientific and technical institutions, represent the most basic forms of institutional depositories of basic resources of a capitalist science-based sociotechnical system in action. In effect, leaving aside institutions such as government policy-making bodies which are indirect depositories of basic resources, it is not difficult to relate the role and character of most of other direct institutional depositories to those of one or another of the institutions examined above. Let us take, for example, major government institutions such as public companies, development banks and government R & D institutions. Clearly, as institutional depositories, they are essentially the same as their private counterparts with financial resources deposited in banks, R & D resources deposited in laboratories and all resources in systemic integration deposited in industrial companies. Likewise, as their private counterparts, they are all forms of technical and socio-cultural relations bringing together different sociotechnical constituents and basic resources into dynamic institutional systems dominated by the *raison d'être* and overriding interests of those constituents in control of the basic resources. In the latter respect, it is only when we look at the systemic integration of social constituents and, most particularly, the character of the dominant social constituent whose overriding interests ultimately shape and dynamize the *raison*

*d'être* of the institutions themselves, that relevant differences can be found which justify their distinction as separate classes of institutions. In effect, unlike financial and industrial capital institutions and autonomous university and scientific institutions, government companies, banks and laboratories not only have government as a social constituent but have it as that social constituent ultimately in control of the basic resources of the technological process. This means that while the interests of financial capital, industrial capital and science were dominant in the systemic integration of overriding interests specific to their respective institutions, in government sociotechnical institutions such dominant influence corresponds to the overriding interests of government. Thus, development banks, for instance, can be seen as the organic integration of the interests of government, acting simultaneously as financial capital, and management and labour, into an operational system dominated by the interests of government/financial capital. This would give rise to the duality of overriding interests which we mentioned at the start of the present section. Similarly with state companies where the dominant interests will be those of government acting simultaneously as industrial capital. Finally, in government R & D institutions, the overriding interests of science, management and labour will converge with those of government who will exercise the dominant control, thus shaping the product of the activities of the other social constituents. Previously, we have broadly characterized the overriding interests of government as the pursuit of political power accumulation both nationally and internationally, among other ways, through the economic, military, and scientific-technical power deriving from capital, the military and science. This means that to an important extent, and as we have seen in the course of this thesis with the development of the capital-science-military-government social complex of power shaping and dynamizing the unfolding of the US's IMC, the reproduction and furthering of the interests of capital, the military and science implies the furthering of the interests of government themselves. The coincidence, however, can never be complete and since, in practice, the interests of government are broader than those of any of the forces abovementioned, it follows that it is in the government's own sociotechnical institutions (e.g., companies, banks and laboratories) where such interests acquire it most direct expression shaping and dynamizing the development of the sociotechnical system as a whole. In other words, it is here where government directly materializes itself as an intrinsic social constituent of a capitalist science-based sociotechnical system just like we have seen with capital, labour, management and science.



Finally, and since it is not our intention to discuss here the role and character of all the variety of aggregate classes of institutional depositories of basic resources of an ITC sociotechnical process, we shall merely point to the fact that institutions such as military R & D research centre or other military sociotechnical institution follow a similar logic to that of government R & D institutions but with the overriding interests and *raison d'etre* of the military as the dominant force ultimately shaping the activities of the other constituents. On the other hand, institutions such as foundations and other funding bodies which are depositories of financial resources, can be either autonomous in which case the interests of science are most likely to shape the direction of their funding activities; or they can be instruments of the corporate image of private capital or specialized government bodies devoted to funding R & D primarily in universities and other scientific and technical centres, in which case the interests of capital and government are likely to mingle with those of science in shaping the funding patterns of these institutions. Certainly, in the world of real-life institutions, the aggregate classes of institutions we have distinguished above need not exist separately and, in principle, all sorts of interrelations and overlaps of *raison d'etre* and overriding interests are possible. The latter, however, does not alter the fact that, in the final analysis, the conceptual elements we have just exposed constitute a coherent base for the interpretation of most of them.



#### 5.3.4. Networking of Institutions and Sociotechnical Interests in an ITC Sociotechnical Process. Momentum of the Sociotechnical System

In a sociotechnical system in action, the interests and institutions we have characterized above are found in a mesh of interrelations which is the sociotechnical system itself. Here, all the basic resources, interests and institutions come together and interpenetrate each other in a complex ensemble of technical and socio-cultural relations which, under conditions of relative stability and, indeed, reproduction of major galvanizing forces, will tend to acquire a great deal of historical momentum, i.e., the sort of inertia of development identified by T. Hughes and described earlier in our review of sociotechnical approaches. The achievement of such a momentum is clearly a slow process equivalent to the build up of the sociotechnical<sup>system</sup> itself. Thus, all the relevant variety of basic resources, interests and institutions need be in existence for such a sociotechnical momentum and, indeed, as Hughes (1983) has argued, it is precisely the substantial commitment of basic resources, interests and broad range of institutions involved in a sociotechnical system that explain the existence of the momentum itself. In this respect, once a particular sociotechnical system (e.g., the capitalist science-based system illustrated in figure 5.2) has achieved a high momentum as a broad ensemble of technical and socio-cultural relations, expressing and shaping the interrelations between sociotechnical constituents under given historical circumstances, the likelihood is that such a system will keep its aggregate direction of development for long periods until changes in the galvanizing forces or, indeed, the emergence of new competing technological processes effectively introduces powerful disruptive elements and tendencies which will alter or stop the momentum of the system. In the course of the present thesis, for example, we have seen how the post-World War II development of both the US's R & D system and the US's IMC has followed a definite aggregate direction of development consistent with the dominance of both systems by the capital-government-science-military complex of power galvanized during the war. Indeed, it can be said that after the war both sociotechnical systems developed and acquired a momentum which, under the galvanizing forces of national and international economic and politico-military competition has by and large remained in force, reproducing as much as being reproduced by their continuous dominance by the abovementioned social complex of power. It was only when the galvanizing force of war dwindled during the 1970s in the aftermath of the Vietnam War and the rise of strong social concerns threatened

the stability of the very social complex of power, that the postwar momentum of the US's R & D and US's IMC sociotechnical systems underwent some noticeable alteration. Historically, however, such a period was shortlived and the postwar social complex of power has been re-strengthened again with the result that the pre-Vietnam War momentum of both the US's R & D and US's IMC has been generally regained too. As we have seen, however, this time the mixture of national and international galvanizing forces and internal force correlation within the social complex itself is not as clearcut as in the pre-Vietnam War period so that contradictions may develop within the social constituency which may threaten the newly regained stability and hence, the very momentum built up for both sociotechnical systems. But let us go back to our conceptual reconstruction of the network of sociotechnical interests and institutions which is the ITC sociotechnical system itself.

Our main point is that the interpenetration of basic resources, interests and institutions which takes place in an ITC sociotechnical system in action follows basically the same principles of convergence (and contradictions) of overriding interests we have disclosed in relation to the aggregate classes of institutions discussed previously. Thus, in broad terms, an ITC sociotechnical process can be seen as a complex ensemble of technical and socio-cultural relations bringing together different institutional depositories of sociotechnical constituents into a dynamic and systemic process dominated by the interrelating *raison d'etre* and overriding interests of those social constituents in control of the basic resources or the different institutions which are their depositories. This time, however, the situation is much more complex than with the case of separate institutions where normally the *raison d'etre* and overriding interests of the dominant social constituent defines the *raison d'etre* of the institutions themselves. Instead, in an ITC sociotechnical system no such clearcut *raison d'etre* is possible since what we actually have is an institutional interaction mainly determined by the convergence of overriding interests of social constituents who remain dominant in their own institutions. As a result, and as this thesis has shown, in an ITC, more than a *raison d'etre*, we shall find aggregate patterns of historical development which will be broadly related to the relative weight of the different aggregate dominant social interests under changing historical circumstances. In the present thesis, for instance, and at the level of aggregate social forces, we have clearly seen how in the case of the US's IMC, the relative weight of government-military interests plainly dominated the first period of post-World War II development of microtechnology in the US. Later,

under changing historical circumstances and increasing relative weight of corporate capital, the latter force became the most important and the shape of development of the US's IMC reflected this fact clearly, while lately the military constituent has been making a come back which will enable it to influence the shape of microtechnology's development in accordance with its own overriding interests once again. Thus, all the time the dominant aggregate social constituents have been realigning themselves in terms of their relative weight and this has been reflected in the aggregate shape of development of the US's IMC sociotechnical system which has become the common ground for the reproduction of all of them. The important fact is that throughout the postwar period these dominant social forces have remained as a complex of power converging around, shaping and expressing themselves in and through, microtechnology which has come to be perceived as a decisive input to the process of accumulation of economic, socio-political and military power. In other words, to the extent that the overriding interests of all the dominant forces have become constituent parts of a microtechnological ITC, it has been the interplay of these overriding interests in conditions of changing relative weights and galvanizing forces which has determined the "*raison d'etre*", or aggregate shape of development of the US's IMC. In this respect, it can be said that while the overriding interests and *raison d'etre* of each of the constituent social forces and institutions express themselves in and through the sociotechnical system in action, the latter's *raison d'etre* can only be the result of the specific convergence, contradictions and force correlation characterizing the dynamic interplay of such sociotechnical forces and institutions at any given historical period and place.

Let us now look at the sociotechnical system from an institutional standpoint rather than from that of aggregate dominant social forces in order to see how the convergence and contradictions between sociotechnical constituents broadly take shape in the systemic network of institutional depositories which constitute the sociotechnical system itself. We have already said that the same basic principles we have used in the conceptual reconstruction of sociotechnical institutions are valid for the case of an ITC at large. Only that this time the situation is more complex because there will be, along with the intra-institutional interaction of social interests discussed above, an inter-institutional interaction which will bring into systemic convergence and contradiction the overriding interests not only of different social constituents who remain dominant in their own institutions (e.g., capital, military) but, also, of

generically similar social constituents whose existence is fragmented in a myriad of similar but autonomous institutions such as different companies, universities, etc. In addition, particularly in the case of different companies, there would be inter-institutional interrelations between labour constituents seeking to enhance their relative weight by overcoming, through unions and other broader labour organizations, the fragmentation attached to their individual as well as their institutional-specific stand vis-a-vis the dominant institutional constituent. Of course, to the extent that such option is also opened to other sociotechnical constituents, this will give rise, as we shall see later on, to the existence within the sociotechnical process of what we have called as the constituents' socio-political organizations (see right-hand side column of diagram in figure 5.2) because they do not play a direct role of institutional depositories of the sociotechnical system in action but can have an important influence in shaping the development of such a process. For the time being, let us stick to the analysis of the sociotechnical interlinking of the institutional depositories of an ITC sociotechnical process.

To a large extent, the interaction of overriding interests between different social constituents who remain dominant in their own sociotechnical institutions has been already dealt with in the course of the present discussion. It has also been a main theme of the whole thesis in the form of our analysis of the dominant social constituency of microtechnology in different countries. The basic principles of such interaction were briefly exposed in point b) at the beginning of section 5.3.3.4. Here, we shall only add what we said in Chapter III that, in fundamentals, the main feature of the social constituency which emerge from the networking of overriding interests of different dominant social constituents is that it makes available all the basic resources for the advancement of the ITC sociotechnical process while shaping its development, by and large, in accordance with the interests and relative weight of the constituents in control of these resources. In practice, this is the process which manifests itself in the sociotechnical networking of the variety of institutional depositories which we have discussed earlier. Here, institutional depositories converge on the basis of their *raison d'être* and hence, overriding interests of their controlling constituents, thus giving rise to the broad technical and socio-cultural ensemble which is the sociotechnical system and whose *raison d'être*, as we have said, can only be the result of the convergence and contradiction between the different dominant institutional constituents in a context of changing relative weight and historical galvanizing forces. In this respect, it is relevant to remember that not all

institutions have a clearcut *raison d'être* and that there are those, such as government companies, which will tend to embody a duality of overriding interests and hence, *raison d'être* susceptible to important alterations with important changes in the historical galvanizing forces. Whatever the situation, through the overriding interests of dominant social constituents who have come to perceive a given technological process as fundamental for their own social reproduction, the fact is that institutional depositories will converge into systemic and dynamic interactions, thus constituting the ITC sociotechnical system itself. In the course of the present thesis, we saw, for example, how in the case of the US's IMC, various kinds of formal links have been established between different institutions under the control of the social interests making up the dominant social constituency of microtechnology in the US. As a result of this interlinking, institutions such as companies, banks, universities, military and government institutions have been giving rise to large-scale networks of basic resources and interests which clearly represents the most effective interpenetration of social and technical factors shaping and expressing the development of the technology itself. Formal arrangements, however, are not the only kind of links that qualify as parts of an ITC sociotechnical process and, indeed, as we shall see below in the case of companies competition for instance, all other links are equally important. In our view, this is the case as long as institutional depositories and social interests make the shaping and development of a given ITC the focus for the convergence of their overriding and particular interests and, above all, the focus for their own reproduction as dominant social forces in society. On the other hand, as we have said, such convergence is not one of smooth accommodation of totally complementary interests. In practice, insofar as it involves interests who remain dominant in their own institutions, it is prone to generate tensions and conflicts when the interlinking of institutions which are in practice different ensembles of technical and socio-cultural relations leads to affect the interests of some of the social forces involved. The most typical case is that of the science constituent in institutions such as universities where its own overriding and particular interests can be said to be the dominant ones. In effect, unlike in companies or military R & D laboratories where the science constituent is mostly subordinated to the overriding interests of capital or the military without much ado, in the institutional arrangements bringing together universities and companies or military institutions, for instance, it is most likely that traditions, values and mechanisms which are part of the particular interests and culture of the scientific community will come under severe strain from contradictory demands



implicit in the overriding interests of social forces such as capital and the military. In the course of this thesis, for example, we have seen how freedom to pursue research for common good, freedom to disseminate knowledge and even the peerage and reward system of science have come under strain in the US as capital and military interests demand, in exchange for financial and material resources enabling the social reproduction and furtherance of the scientific community, priority access to newly-created knowledge or even outright suppression of its dissemination in the name of national security, for instance. In principle, for the scientific community there is always the alternative of disassociating itself from the direct shaping of the product of its own activities by social forces such as the military (33) who command resources necessary for the reproduction and furtherance of its knowledge-accumulating *raison d'etre*. In practice, however, that alternative only exists when the same crucial resources in the hands of capital or the military are available from alternative sources, otherwise it is the very existence and social reproduction of the scientific community which is at stake. Thus, in a capitalist society such as the US's where currently, as we have documented, capital, government and the military not only control the bulk of the basic resources needed by science but, also, have plainly come to perceive the products of science as crucial for the reproduction and furtherance of their own overriding interests in a context of national and international economic and politico-military competition, the likelihood of a massive disassociation of science interests from those of capital and the military is very small (34). Therefore, and although there may be some instances of such disassociation taking place with regard to particular arrangements, the latter seem to be more examples of the difficulties and tensions involved in the process of interlinking of different socio-cultural relations than the denial of such a process. Indeed, the current thrust of events in the US is clearly dominated by the convergence and networking of overriding interests and the consequent renewed strengthening of what we have called the capital-science-military-government social complex of power. In this context, conflicts of particular interests have clearly remained subordinated, with the particular forms of accommodation very much reflecting the relative weight of

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(33) Illustrative of this case is the current revolt amongst academic scientists against the so-called Star Wars research programme developed under the aegis of the US military [Shulman(1986), *Computing* (28 November 1985)].

(34) In this respect, it is interesting to note that the current revolt of academic scientists against SDI is not a revolt against the involvement of the military in the development of science at large. It is a revolt focused on the specific SDI project which is considered technically dubious and politically and morally objectionable (ibid.)



different social constituents under the pressures of prevailing national and international galvanizing forces.

From the standpoint of an ITC, therefore, we can already see how the inter-institutional interlinking which bring into systemic convergence and contradiction the interests of social constituents who remain dominant in their own institutions, makes its conceptual reconstruction much more complex than with the case of separate institutions. But, as we have said before, in an ITC, along with this kind of inter-institutional interaction, there is also that which bring into systemic convergence and contradiction the overriding interests of individual fragments of generic social constituents. In effect, we know that all social constituents materialize themselves in and through the action of a myriad of real-life institutions which are dynamic ensembles of technical and socio-cultural relations in themselves. The military, for example, have their different armed services, science its different universities, government its different ministries and agencies, industrial capital its many companies, etc. In an ITC such institutional fragments of generic social constituents are always found in interaction with each other in multiple ways which are very much the logical result of the fact that, in practice, overriding interests exist and manifest themselves only in the action of the institutions which house them. Thus, capital accumulation, for instance, is primarily capital accumulation within and for each one of the separate companies themselves. This is why in pursuit of a same generic overriding interests companies compete as well as enter into agreements with each other in a process which fundamentally influence the shape and dynamism of the sociotechnical system at large. Let us illustrate this point with the case we have seen most clearly during the present thesis, namely, the interaction between individual companies representing the inter-institutional convergence and contradiction between separate fragments of corporate capital. Here, we have seen how in the IMC sociotechnical process, companies have interlinked with each other in various ways which go from formal complementary arrangements to outright competition for the control of microtechnology's development. Many semiconductor companies, for instance, have established formal arrangements with electronic systems manufacturers in a way which fulfill the overriding interests of capital accumulation on all sides. Not that formal arrangements are the only form of sociotechnical complementarity, for simple market deals are equally valid expressions of this kind of systemic interlinking between separate fragments of the capital social constituent. To the other extreme of this systemic interaction, we have

competition between different companies producing for the same market which, by constantly threatening each other's processes of capital accumulation, effectively interlock them in a contradictory dynamics which permeates the development of the ITC sociotechnical system as a whole. In addition, competition does not exclude partial collaboration between competing companies in aspects where common efforts and mutual benefits are perceived as possible, convenient or even necessary in the face of market pressures which either threaten their existence side by side or simply stimulates them into collaboration in pursuit of mutual advances in capital accumulation. In the US's IMC, for instance, we have seen how in the struggle for control of the electronics infrastructure, competing semiconductor companies have entered into research agreements in the face of Japanese competition. And the same has happened between various computer companies stimulated by IBM's drive to maintain or increase the control of the market. In both these cases, collaboration in competition has taken place in the face of a third competing force and has taken various forms, from common support to relevant research in universities to the creation of formal institutions pooling financial as well as R & D resources for the performance of activities which are expected to benefit all the parties involved.

In practice, it is possible to say that, like the companies themselves, such collaboration agreements have now become part of the IMC ensemble of technical and sociocultural relations reflecting as well as creating the written and unwritten legislation of the US society. Specifically, they can certainly be described as crystallizations of the systemic interlinking of convergent and contradictory fragments of the US electronics capital social constituent, reflecting the relative weight and particular interests of the interacting fragments in a context of specific national and international galvanizing forces. More generally, for our conceptualization of an ITC sociotechnical process, we can draw the following conclusion: that the shape and dynamism of a capitalist science-based ITC not only rests on both the pursuit of overriding interests by its diverse social constituents and the systemic interaction of these overriding interests in a context of specific national and international galvanizing forces and degree of development of the basic resources of the technological process. It equally rests on the systemic and dynamic interlinking which results from the pursuit of overriding interests by the separate fragments of generically the same social constituents.

One crucial form of interlinking of the overriding interests of institutionally fragmented sociotechnical constituents is through socio-political organizations specifically designed to overcome the weakening effect of fragmentation in their relative weight vis-a-vis other sociotechnical constituents. This socio-political organizations, illustrated on the right-hand side column of the diagram in figure 5.2, constitute the clearest recognition that, notwithstanding the differences and particular interests normally associated with fragmentation, institutional social constituents sharing the same overriding interests tend to identify with each other as part of a generic social constituent of a sociotechnical process. Thus, capital, despite all inter-company competition, will have its industry associations and confederations, etc., to articulate and press forward for demands which generally advance the overriding interests of capital accumulation for companies at large. The same is true for the other social constituents. Thus, labour will have trade union organizations, science and management their scientific and professional institutions, the military their military agencies and lobbies, etc., while the government constituent will have its agencies and planning committees, etc., which, in practice, are the socio-political organizations *par excellence*. Because of the necessarily wider perspective of the latter institutions, however, they will not only articulate the interests of government which are more broadly based than those of any of the other social constituents but, also, they will incorporate the interests of these other social constituents, reflecting their relative weight and dynamic interaction and hence, that of their socio-political organizations, in the sociotechnical policies implemented. In the latter respect, government socio-political organizations, because of their power on policies and legislation, which can have a powerful shaping influence in the technical and socio-cultural interplay of an ITC sociotechnical process, can be said to be not only organizations of the government social constituent but, simultaneously, a dynamic arena where the interests of all social constituents meet in a struggle for shaping the policies and legislation of the sociotechnical process involving them all. Of course, this is why, and although we have not included them in the diagram of figure 5.2, different political parties in control of the machinery of government can make a relevant difference to the development of a sociotechnical system insofar as they may favour the overriding interests of some social constituents over those of others or simply articulate the complex interplay of interests in different ways. Conversely, and for the same reason, different social constituents such as labour and capital show a tendency to identify themselves with different political parties purporting to favour or represent the respective interests of each one of

them under given historical circumstances. Obviously, in practice the problem of political identification is one of a much greater complexity and there are many other variables involved. For purposes of our reconstruction of an ITC sociotechnical system, however, the latter is a problem we need not concern ourselves with. For what is most relevant for our argument is the very inclusion of the social constituents' socio-political organizations in the development of an ITC sociotechnical process. Through them not only is the fragmentation of social constituents overcome and hence, the relative weight of each constituent vis-a-vis others strengthened but, most particularly, these organizations actually contribute to shape the sociotechnical process in its very societal framework of written and unwritten legislation through their articulation of the social constituents' overriding interests in the socio-political arena. As ensembles of technical and sociocultural relations themselves, therefore, they at the same time operate to alter and/or reinforce the socio-cultural relations of the ITC at large in accordance with the overriding interests of the social constituents they represent. By so doing, they become, on the one hand, the result of the particular forms of, and interactions between, the diverse institutional depositories of basic resources and interests making up an ITC sociotechnical system and, on the other, a causal factor within such an ITC by seeking to influence the very development of these forms of interactions in the fashion we have mentioned above. In other words, while the fortune of these institutions depends very much upon the relative weight of their specific social constituents in given historical circumstances, conversely, such relative weight depends itself to an important degree upon the strength of the socio-political institutions. In this connection, an example particularly relevant to microtechnology is that of labour displacement by automation whose threat to the very existence of many kind of workers in the IMC sociotechnical process and, indeed, the sociotechnical realm of society at large, is also a threat to the very existence of these workers' unions organizations. Simultaneously, however, it is clear that the actual shape and dynamism of the automation process and hence, whether or not such threats materialize and when and how, and even the issue of the share of its benefits among the different social constituents, is something that will depend to an important extent upon the strength and struggle of the latter organizations in the context of specific national and international galvanizing forces. At any rate, if the strength of workers' unions organizations is continuously eroded by automation, it is clear that a vicious circle of diminishing strength tends to set in whereby the depletion of specific forms of the labour constituent in the sociotechnical process leads to the depletion of their socio-political organizations

so that the latter are increasingly unable to effectively influence the development of the sociotechnical process, with the result that more depletion of the labour constituent can more easily follow and so on and so forth.

Obviously, in principle, the vicious circle of diminishing strength is something that can happen to all social constituents and, indeed, as we shall see later on, is a process that is always involved, in one way or another, in the total or partial displacement of one sociotechnical ITC for another which is posed to achieve high momentum under the dynamism emerging from the interplay of basic resources, overriding/particular interests and historical galvanizing forces which drive all technological systems. Before coming to the analysis of this process, however, it is necessary to explain more systematically the conceptual place in the sociotechnical system of the different forms of social constituents, i.e., intrinsic, dominant, and other likely social constituents, we have identified in the diagram of figure 5.2.

### **5.3.5. Intrinsic, Dominant and Other Likely Social Constituents in the Development of an ITC Sociotechnical Process**

In the course of the present thesis, we have said that, in the final analysis, it is all the social forces and interests concerned with, and affected by, the development of a sociotechnical system which make up its social constituency. This means that, in practice, the specific shape and dynamism of a sociotechnical system is not the result of any one force but that of the convergence and contradictions characterizing the technical and socio-cultural interplay of all of them in given historical circumstances. As we have seen throughout, however, this is not to say that all social forces have an equal role in shaping the development of a sociotechnical system and, most particularly, this is not the case in a society where the control of the basic resources of technological processes rests primarily in the hands of a few powerful interests. Indeed, in the latter form of societies, the most likely situation is that, for any given ITC, there will always be an associated social constituency involving what we have called intrinsic, other likely and dominant social constituents.

In effect, in the analysis of the capitalist science-based ITC (IMC) which has dominated this thesis, we have found that there are social constituents who are rooted in the very nature of microtechnology and others who are rooted in the capitalist societal framework dominating its process of development. We have



called both constituents intrinsic social constituents, for without them the technology could not possibly exist or develop into a concrete sociotechnical system shaping as much as being shaped by the historical context of a capitalist society. In the case of the science constituent, for instance, its role as intrinsic social constituent of microtechnology lies in the unquestionable fact that had it not been for the scientific understanding of crucial properties of matter and energy, this technology would simply not have developed under any societal conditions. On the other hand, although the same degree of immanency cannot be attached to the capital social constituent given its socially determined character, its role as intrinsic social constituent lies in the fact that, by definition and whatever its form, a capitalist ITC can only exist when the overriding interests of the social force of capital fundamentally shape its development. This is the reason why in the diagram of figure 5.2 -which follows the capitalist science-based pattern of microtechnology's sociotechnical system which we have mostly dealt with in the course of the present work- both capital and science appear under the heading of intrinsic social constituents of a capitalist science-based sociotechnical system. Of course, if we look at the left-hand side column of the diagram in figure 5.2, we shall also remember that already in our characterization of basic resources of all technological processes and their institutional depositories, science and capital figure prominently as sociotechnical constituents pertaining to the very nature of, and giving their character to, the ensemble of resources, interests and institutions which constitute the ITC sociotechnical system itself. In particular, the necessary presence of R & D within human resources and, indeed, the creative core of a sociotechnical system, accounts for the very deep relation of science as an intrinsic social constituent to the development of such a system. Science, however, is not the only sociotechnical constituent to find its intrinsic character rooted at the very level of basic resources of the sociotechnical system. In fact, both labour and management share a similar standing as it is illustrated in the left-hand side and right-hand side columns in figure 5.2. Earlier in this chapter, we have discussed the role of labour and management as basic resources in themselves so that here we shall only register their consequent standing as intrinsic social constituents. To complete the list, in figure 5.2, we have also included government as an intrinsic social constituent although, unlike labour, management and science, its intrinsicity is not directly rooted at the level of basic resources but, rather like capital, at the level of institutional depository of basic resources in a capitalist society. In this respect, before in this thesis, we have concluded that in the case of a large-scale ITC sociotechnical process like the capitalist



science-based IMC, government is bound to become an intrinsic social constituent not only because the development of such a process is certain to concern the government's own overriding interests but, also, because the resource-requirements imposed by such a process in a context of national and international competitive galvanizing forces is equally certain to exceed the ability of the institutions of private capital and other non-government social constituents to satisfy them. Last but not least, it is also necessary to consider the crucial and direct role of government in technological policy-making and hence, in the creation and alteration of the very framework of written and unwritten legislation shaping and mediating the materialization of a sociotechnical system. Undoubtedly, these are all powerful reasons for government to join labour, science, management and capital within the ranks of the intrinsic social constituency of a large-scale capitalist science-based sociotechnical system.

Intrinsic social constituents cannot be left out of consideration, but, as we said at the beginning of this section, it is all the social forces and interests concerned with, and affected by, the development of a sociotechnical system which make up its social constituency. This means that, along with the intrinsic social constituents which give the technology its capitalist science-based character for instance, in our conceptualization we distinguish the existence of other constituents who, whatever their powerful influence in shaping the development of such capitalist science-based system, in the last analysis are simply not necessary or do not play a truly internal part in the fulfilment of its character. In practice, the main role of these non-intrinsic social constituents, or other likely social constituents as we have referred to them in figure 5.2, is that their interests will contribute to determine the particular form of manifestation of capitalist science-based sociotechnical systems (e.g., helping to explain relevant differences between the development of similar systems in different countries). The actual extent of such an influence will depend very much upon their degree of control, or influence upon those who control, the basic resources of the technology under the pressures of given historical galvanizing forces. For example, in the case of the capitalist science-based IMC we have dealt with in the course of this thesis, we have found that, notably in the case of the US, under the galvanizing force of war the presence of strong military interests within the social constituency of microtechnology has given strong militaristic overtones to the particular US's capitalist science-based IMC. In contrast, in the particular case of the Japanese IMC, the role of military interests, if anything, has been conspicuous by its small participation. The military, therefore, while

influencing the particular manifestation of a capitalist science-based IMC, do not actually constitute an essential requisite for the development of such an IMC. For this reason, in figure 5.2 we have included the military constituent and its social organizations under the category of other likely social constituents. It would be only if we consider the possibility of a militaristic ITC that we can begin to talk of the military as an intrinsic social constituent to the development of any sociotechnical process. But this is not the example we have been dealing with in this discussion.

Besides the military in figure 5.2, we have also listed as other likely social constituents all pressure groups and lobbies which, when they exist and have some strength, are likely to have some say in the development of an ITC, although their action will be mostly of an indirect nature. In effect, by various means, pressure groups generally seek to influence the decisions of those constituents in direct control of basic resources, most often the decisions of the government social constituent, so as to stop or divert an ITC sociotechnical process from developing into specific directions or, conversely, to support its development into others. In this respect, pressure groups may often be contradictory with anti- and pro-specific technological development stands, and the strength of their action will depend very much upon the impact of changing historical circumstances upon what is loosely referred to as society's public opinion. For the same reason, it is hardly possible to establish any definite pattern for the role of these groups in the development of an ITC sociotechnical process since sometimes they may go almost unnoticed and in other times they may have quite a relevant impact.

Finally, we have used the rather vague term other consumers to account for the role of all other groups, institutions and even collectively unrelated individuals, who by demanding, consuming as well as rejecting the products of a sociotechnical system in action, actually contribute to its shape and dynamism by exerting direct influence at the very diffusion moment of its global unfolding (35). This category of constituents would include, for instance, other ITCs'

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(35) An interesting example illustrating this point in relation to steel is quoted by Soete (1985), "...while the manufacturer of steel had to attain chemical control over the vagaries of his resource inputs in order to produce a satisfactory product, he also confronted an increasingly stringent set of requirements for steel imposed upon him by a widening set of customers. Each one was likely to be interested in a different property or, more likely, in different combinations of properties. Steel requirements in the electrical industries might revolve around conductivity, machine tool manufacturers required steel that retained its cutting edge at very high temperatures, manufacturers of steam engine boilers sought

sociotechnical constituents and institutions (e.g., companies) which will use and demand particular forms of products from the sociotechnical system under analysis. In the case of an IMC, for instance, given the pervasive nature of electronics products into the entire technical realm of society, the range of other ITCs' sociotechnical constituents and institutions exerting influence at its market-diffusion moment is truly vast. This, of course, accounts for microtechnology's clear potential to revolutionize the sociotechnical realm of society but, most importantly for our present argument, points to the fact that, in turn, the concrete form, dynamism, and sociotechnical interests involved in the existing sociotechnical realm of society will effectively influence the particular way in which such revolutionary potential is practically materialized. It is not our concern here to pursue the analysis of the nature and role of other consumers further, for this is a task very much related to the level of real-life institutions. Thus, to end the present discussion aimed primarily at registering the importance of their existence and role, suffice it to add that we have chosen the name 'other consumers', basically, because all the social constituents we have already dealt with, i.e., labour, capital, science, government, military and pressure groups, are themselves consumers of the products of a sociotechnical system in action. In fact, as we have seen in this thesis, it is often by offering a market (e.g., military, government) that the technological process is actually stimulated into particular directions by the overriding interests of a particular social constituent. All in all, therefore, with other-consumers we complete the list of other-likely-social-constituents which together with the intrinsic social constituents (see figure 5.2) make up the full range of social interests involved in the evolution of a capitalist science-based sociotechnical system. In consequence, we can now turn to the conceptual category we have used most in the course of the present work, namely, that of dominant social constituency of an ITC sociotechnical process which seeks to account for the hegemonic role played by particular combinations of intrinsic and other-likely social constituents in the development of such an ITC.

The basic character of the dominant social constituency was defined in Chapter III in relation to microtechnology. There, we saw this constituency as the embodiment of the convergence and interplay of social interests who, by possessing a dominant control of the basic resources of the technological process,

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corrosion resistance, army ordnance increasing strength and hardness, etc." [N. Rosenberg (1984). "The Commercial Exploitation of Science by American Industry", quoted in Soete (1985),p.412].

are able to effectively control the specific form of systemic integration of these resources and, ultimately, within the limits of the physical world, the shape and dynamism of the technology itself. In other words, it is the actions and interests of these forces under specific historical circumstances and development of basic resources which, primarily, explains the particular form of development of an ITC sociotechnical process in any given society. Although, as we have said, such a development is ultimately the result of the convergence and contradictions between all the forces and interests concerned with, and affected by, the development of the technology.

Above, we have already seen how a dominant social constituency actually materializes itself at the level of institutional depositories of basic resources through the process of inter-institutional interaction which brings into systemic convergence and contradictions the overriding interests of different social constituents who remain dominant in their own institutions. The main feature of such inter-institutional constituency was said to be that it makes available all the basic resources for the advancement of an ITC sociotechnical process while shaping its development, by and large, in accordance with the interests and relative weight of the constituents in control of these resources. Obviously, it is not necessary to repeat here the argument of the institutional level. Thus, all is needed to round up the concept of dominant social constituency is to say some words from the point of view of its embodiment of the convergence of overriding interests of aggregate dominant social forces. In this respect, the first thing that one has to point out is that such aggregate convergence is in itself to a large extent the reflection of the abovementioned process of inter-institutional intersections between different dominant institutional constituents. However, it is not only that, and in the same way that the specific socio-political organizations of aggregate social constituents constitute the expression and the medium to further the collective interests of the respective constituents, here, in the realm of the dominant social constituency, the convergence of interests of aggregate constituents also finds its expression in the existence and particular actions of various joint socio-political organizations such as joint bilateral and multilateral committees and institutions, etc. In the diagram of figure 5.2, we have tried to illustrate both these aspects of the dominant social constituency at an aggregate level through the latter's representation in the upper-layer of the cube-like shape. Thus, in the figure, the separation of the upper layer from the main body of the diagram and its subsequent joining by dotted lines implies, on the one hand, that the convergence of aggregate social constituents into an overall

social complex of power dominating the development of the sociotechnical process is in fact not different from, but, indeed, a reflection of the interplay of dominant interests between the sociotechnical institutions themselves. In other words, the capital-government-science social complex of power which in figure 5.2 appears as the basic dominant social constituency of a capitalist science-based sociotechnical system is not a superimposition of some external power upon the sociotechnical system but a reflection of the convergence and contradictions of the overriding interests of intrinsic social constituents whom we have already seen exercise the dominant control of the basic resources of the technological process. On the other hand, such a separation of the upper-layer in the diagram also implies that, at the aggregate level, in the convergence of dominant social constituents into an overall social complex of power, there are some important institutional features of their own. In particular, these would refer to the existence of various forms of bilateral and multilateral socio-political organizations whose *raison d'être* lies exclusively in the convergence of aggregate constituents and whose activities are bound to have an influence in the development of the sociotechnical system at large. From the standpoint of the latter system, therefore, it is possible to say that what we have is a kind of dialectical interaction whereby the convergence of aggregate social constituents and their institutions not only emerges from the interplay of dominant interests between the sociotechnical institutions themselves but, simultaneously, exercises an influence in the particular form of materialization of such an interplay of dominant interests. In addition, since it is not illustrated in figure 5.2, one has to say that it is not only the interplay of overriding interests of intrinsic dominant social constituents which is involved in the dominant social constituency and its bilateral and multilateral institutions. For, as we have seen in this thesis, in the prominent role played by the military and their institutions in the dominant social constituency of US's microtechnology, other-likely social constituents may equally be an important part of such a constituent. Likewise, socio-political organizations materializing the convergence and contradictions of different aggregate social constituents are not only restricted to the interactions between dominant social constituents. In fact, all sorts of bilateral and multilateral organizations can in principle exist, correspondingly expressing all sorts of possible combinations in terms of convergence of social interests. Here, however, our concern has been primarily with the socio-political organizations emerging from the convergence and socio-political institutions of those overriding interests whose control of the basic resources has given them the most important role in shaping the development of

an ITC sociotechnical process. In this respect, we can finish this discussion by saying that, in figure 5.2, this important role is somehow reflected in the position of the upper-layer with its complete coverage of the main body of the cube-like shape which does imply that the capital-government-science social complex of power effectively has the upper hand in the social shaping of the overall development of the capitalist science-based sociotechnical system of our example. Of course, as we have seen consistently throughout this thesis, within the dominant social constituency the convergence of interests is not free of contradictions and, in the last analysis, it will be the changing relative weight of the different social constituents under the pressure of specific galvanizing forces which will determine whose overriding interests are in fact the most influential.



### 5.3.6. Competing and/or Interacting Sociotechnical Systems: Momentum-Gathering and Momentum-Losing in the Unfolding of Sociotechnical Processes

In practice, as complex ensembles of technical and socio-cultural relations involving basic resources, interests and institutions, it is hardly possible to talk of sociotechnical systems as closed systems with definite boundaries within the sociotechnical realm of society. Indeed, we have already seen in our discussion on other-likely social constituents of a particular technological process how other sociotechnical systems' institutions, even without a direct role in the realization of the creating and production moments of a sociotechnical system in action, can and do play a part in the shape and dynamism of such a sociotechnical system by demanding and consuming its products and hence, contributing to materialize the diffusion moment of its overall development. In the latter case, a clear interpenetration of sociotechnical systems takes place insofar as the products of one system actually become part of the basic material resources (input) of another, or what amounts to the same thing, the consumption at the creating and production moments of the latter system actually become the product realization at the diffusion moment of the former. In this way, if, as happens with microtechnology for instance, the products of one ITC sociotechnical system have a pervasive and widespread impact throughout the entire sociotechnical realm of society, then the interaction of sociotechnical systems is widespread and the diffusion stage of the pervasive system becomes the result of the sum-total of interactions with other sociotechnical processes in addition to product consumption realized within the institutional ranks of the pervasive system itself. When two or more pervasive sociotechnical systems exist, the interaction goes full circle with the products of one becoming part of the material resources of the other and vice-versa. This would be the case, for instance, of the electronics and chemical ITCs and, more generally, of electronics and all those ITCs whose products are part of the material inputs of the creating and production moments of microtechnology. Clearly, therefore, technological processes and, particularly, large-scale and complex processes such as the capitalist science-based IMC do not and cannot exist on their own in a kind of self-sufficiently evolving world of technical and socio-cultural relations. In practice, at all moments of their materialization, they need to interact and interpenetrate with other sociotechnical processes, thus explaining why the existence and development of an IMC for instance, truly depends upon the characteristics and dynamism of the entire sociotechnical realm of society. And having already

analysed what is involved in the sociotechnical nature of a technological process, it is not difficult to see the variety and complexity of interrelations which will emerge from the interpenetration of different sociotechnical systems' basic resources, interests and institutions.

One particular expression of the complex reality of interrelations involving the entire sociotechnical realm of society is that relating to the development and diffusion of a technology through the economic realm of society. In this respect, Rosenberg (1976), Nelson and Winter (1977) and Dosi (1982) have introduced such concepts as 'compulsive sequence' based on imbalances, 'natural trajectories', 'selection environment', 'technological regimes' and 'technological paradigms'. Basically, this set of concepts permits them to portray the development of technology in the following manner. Within the technological realm, which involves knowledge, know-how, procedures, experience, and physical devices and equipment, it is possible to distinguish what Dosi (1982) calls technological paradigms. A technological paradigm, which is a more elaborate version of Nelson and Winter's technological regime is a 'model' and a 'pattern' of solution of *selected* technological problems, based on *selected* principles derived from natural sciences and on *selected* material technologies (Dosi,1982) (36). Consequently, such a paradigm determines the fields of enquiry, the procedures and the tasks to be accomplished by technologists by focusing their imagination within its confines and into the problems implicit in the fulfilment of its potential. In this sense, a technological paradigm once established is in itself a strong determinant of the direction of technical change. The establishment of such a paradigm, however, is a matter of selection by economic forces together with institutional and social factors which would involve the role of public agencies, the military, etc. These factors constitute what Dosi (1982) calls 'the selective device' and Nelson and Winter (1977) call 'the selection environment'. This selective device, therefore, would establish the development of one paradigm over that of other possible paradigms and later, primarily through the market, it would also select among internal developments by awarding or denying the possibility of commercial success. A technological paradigm, however, once established does show a momentum of its own which contributes to defining the 'normal' problem solving activity of technologists operating within the paradigm. This momentum of problem solving activity constitute the 'natural trajectories'

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(36) Dosi's concept of technological paradigm represents an attempt to transfer into the technological field T. Kuhn's concept of scientific paradigm used in his conceptualization of scientific revolutions. See Kuhn (1962).

of Nelson and Winter (1977) and Dosi's 'technological trajectories' and has also been identified by Rosenberg (1976) through such concepts as 'the compulsive sequence' of technical change emerging from imbalances and disequilibria in the evolution of a technical system. As we can see, therefore, within this perspective, the development and diffusion of technological processes would proceed, first, via their establishment and clustering into technological paradigms, a process which is in itself one of selection by the economic, institutional and social environment and, finally, once established, the process acquires a momentum of its own following natural trajectories implicit in the technical potential of the paradigm.

A similar conceptualization of the development and diffusion of technological processes, although with a much broader perspective, is that more recently put forward by Perez (1983a,1983b,1985) and Freeman (1985,1986) in the context of long-waves and the diffusion of microtechnology throughout the economic realm of society [see also Wolfe (1986)]. Here the concern is with technological processes whose diffusion lead to what is seen as technological revolutions, i.e., changes that affect the structure and the conditions of production and distribution for almost every branch of the economy (Freeman,1986) (37). According to Perez (1983b,1985), what is involved in these changes is the adoption and diffusion of a new techno-economic paradigm and the displacement of an old one which has exhausted its productivity potential. In this context, techno-economic paradigm is understood as a set of common sense principles indicating a best practice frontier for the activities of designers, engineers, entrepreneurs and managers. As such, the set of common sense principles defines a broad technological trajectory towards a general 'best practice' frontier and it is applied in the generation of innovations and in the organization of production within and across firms, branches and countries. In turn, the best practice frontier embodies the full productivity and profit potential implicit in the techno-economic paradigm and constitute the ultimate goal of the trajectory towards its fulfilment in the economic structure of society.

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(37) "For a change to justify the description of technological revolution it must not only lead to the emergence of new leading branches of the economy and a whole new range of new product groups, but also have deep-going effects on many other branches of the economy by transforming their methods of production and their input cost structure. Thus a technological revolution virtually requires a new input/output matrix for a satisfactory reclassification of economic activities" (Freeman,1985,p.217).

In practice, the emergence, establishment and fulfilment of a new techno-economic paradigm is a very long process most likely to run into decades. First of all, as with previous authors, there is a process of economic selection leading to the crystallization of one form of paradigm from a range of alternative technical possibilities and, subsequently, its diffusion process is a complex process of societal transformations involving an interplay between technological, economic, institutional and social factors. In the latter respect, the crucial fact to take into account is that the unfolding of a new techno-economic paradigm involves of necessity the emergence of a whole new socio-institutional framework (e.g., educational, financial, legislative framework, etc.) whose matching enables the widespread and full realization of the new paradigm's potential in the economic sphere. Thus, if we consider that normally such an unfolding of a new paradigm is simultaneously the process of displacement of an established but now exhausted paradigm with its own matching sociotechnical framework, it is not difficult to imagine the complexity of the interactions, struggles and transformations involved in the fulfilment of the new paradigm. In particular, Perez's argument is that at the technoeconomic level the profit motive will propel the adoption of the new paradigm because the latter represents a quantum jump in terms of potential productivity for all the economy at a historical conjuncture when the previous paradigm no longer has that potential. This process will start in a few leading sectors of the economy which will thus attract a great deal of capital investments and stand out from the rest of the economy for their high productivity and profits. Eventually, as the advantages of the new paradigm become clearly demonstrated and the crucial conditions of falling costs, rapidly increasing supply, and pervasive applications are satisfied, the widespread generalization of the paradigm leads to the technological revolution involved in its embracing by the whole economy. Such technological revolution, however, does not take place automatically within the economic realm of society and, indeed, it only materializes itself after, or along with, a major process of transformation and adaptation of society's socio-institutional framework to match the requirements of the new techno-economic paradigm. This means that a great deal of socio-institutional innovation is required involving not just the emergence of new institutional forms but simultaneously the overcoming of the inertia, resistance and vested interests of individuals, social groups and institutions associated with the old paradigm. In the context of long-waves, for Perez (1983a,1983b,1985), it is this period of socio-institutional adaptation to the emerging techno-economic paradigm which explain the long periods of depression in the long waves. Conversely, it is only

when a good match is achieved between the paradigm and the socio-institutional framework, and the entire economy enjoys a quantum jump in its productivity potential, that the economy enters into a long period of prosperity until the productivity potential of the new paradigm becomes itself exhausted and the whole process begins once again. Perez and Freeman both argue that, at the present time, we are witnessing a period of socio-institutional adaptation to a new techno-economic paradigm based on microtechnology (38). The current paradigm which began to emerge in the 1960's and began to penetrate most industries and services in the 1970's is still far from having realized its full potential in any sector and, indeed, many socio-institutional changes, from management practices to the educational system, and government involvement, etc., will be required before this actually happens. In this respect, the shape of the appropriate socio-institutional framework for microtechnology is not at all a predetermined reality but it will emerge from a process of trial and error where various alternative forms may actually fulfill the technology's potential. Here, the important fact for policy-making is to acknowledge the basic characteristics of the new techno-economic paradigm (39) in order to implement social innovations which effectively lead to the satisfaction of its potential in the knowledge the faster social adaptation takes place, the sooner the full economic benefits of its widespread implementation will be reaped by society. From the perspective of international competition, this situation becomes even more urgent since, in both Perez's and Freeman's views, competitiveness and hence, success and the place of different economies in the international arena will be eventually decided by the effectiveness and appropriateness of their social adaptation to the requirements of the microtechnological paradigm.

All in all, therefore, going back to the conceptualization of the development and diffusion of a technological process within the sociotechnical realm of society, Perez's and Freeman's approach offers the most systematic account of the development and diffusion process of a pervasive new technology. In fundamentals, however, it is clear that all the approaches above mentioned share a similar understanding of the nature of technological processes. Thus, they all start with a paradigmatic concept of technology which emphasizes its specific intrinsic characteristics and potential and which posits the fulfilment of that potential as the general base for 'natural trajectories' in the development and diffusion of technology. Likewise, in all the approaches the main concern is basically with the establishment and diffusion of the paradigm and hence, with the process leading to the fulfilment of its potential particularly within the

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(38) "This paradigm is based on a combination of microelectronics, computerization (microprocessors in the 1970s) and telecommunications and may be described as the 'Information Revolution'" (Freeman, 1985, p.218).



economic sphere of society. In the latter respect, insofar as there is no pre-fixed path of development, all the approaches emphasize a process of selection from feasible technical alternatives; a process where economic factors such as the profit motive, productivity and the market, play a determinant role. In addition, in all the approaches other societal factors (e.g., social, political, institutional) do play an important part in the process of selection, thus emphasizing the role of their interaction with economic factors in accounting for the specific form of materialization of the technology's potential. In this respect, the analytical role of these other societal factors is generally subordinated to the central role of the economic sphere in such a way that they either contribute to, or hinder, the process of realization of the paradigm's intrinsic technical and economic potential. In the case of technological revolutions, this leads to the conclusion that a process of socio-institutional adaptation to the requirements of the paradigm must take place. Notwithstanding differences of scope and problematique, therefore, it is clear that we can talk of the existence of a single school of thought, i.e., the paradigmatic school, offering a coherent set of concepts to interpreting the development and diffusion of a technological process in the sociotechnical realm of society.

From the point of view of our own conceptualization of an ITC sociotechnical process, it is possible to identify both clear similarities and differences with the paradigmatic school in terms of the overall approach to the problem of the development and diffusion of such technological process. The major similarity is that, ultimately, both approaches understand the unfolding of a technological process as involving the interplay of technical, economic, socio-political and institutional factors. Likewise, both approaches recognize the existence of intrinsic technical characteristics defining the broad nature and potential for development of every given technological process. These intrinsic technical characteristics are rooted in the very nature of the physical processes involved in the technology and, although we have not given them much importance as an organizing concept for the present general conceptualization of sociotechnical systems, in Chapter II we certainly did so as we unveiled the technical nature of the specific technology of the microrevolution. Here, we have preferred to deal with these intrinsic technical characteristics mostly in implicit terms, acknowledging in the very idea of the historical development of a specific ITC sociotechnical process, the existence of a broad technical path and potential for development within the ensemble of technical and socio-cultural relations which is the ITC itself. In this connection, therefore, we already begin to see

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(39) Perez (1985) attempts a characterization of what she calls the techno-economic paradigm based on microelectronics.



some relevant differences between the paradigmatic approach and the sociotechnical approach. For, as we know from above, in the paradigmatic approach the intrinsic characteristics and potential for development of a technological paradigm are at the very core of the conceptual reconstruction of technological processes. It seems to us, however, that such an approach while offering a coherent way of organizing historical factors, events and processes in the development of technological processes, particularly in long-term historical perspectives, has at the same time limitations insofar as tends to reduce and reconstruct the richness and complexity of the interrelations between such historical factors, events and processes, primarily, in terms of the fulfilment of the technology's intrinsic potential and, here again, primarily within the economic structure of society. True enough, a process of materialization of intrinsic potential does take place in the development of a sociotechnical system, and certainly the economic structure and the process of capital accumulation and productivity do play a fundamental role in it. The problem is, however, that by giving these factors the primary role in the analysis, one is somehow led to organize all other factors, even such major historical events as wars, for instance, or the clear importance of the arms race and military involvement in shaping the actual development of a sociotechnical system such as an IMC, as if their relevance revolved largely around the materialization of the techno-economic process (40). It seems to us that, by so doing, a great deal of necessary analytical flexibility is sacrificed eventually leading to substitute the

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(40) Dosi (1982), for instance, deals with institutional variables such as public agencies, the military, etc. as part of the selective device which determines the nature and development of a technological paradigm and its trajectory. In particular, he stresses "the role often played in the establishment of a particular technological trajectory by public ('political') forces. An obvious example is electronics, especially in the fields of semiconductors and computers during the first two decades of the postwar period. Military and space programmes operated then as a powerful focussing mechanism toward defined technological targets, while at the same time providing financial support to R & D and guaranteeing public procurement" (Dosi,p.155). On the other hand, Perez (1983) deals with the role of the military and the importance of World War II, primarily as crucial elements in the process of harmonization ('good match') of the socio-institutional framework with the mass-production technological style characterizing the postwar upswing of the fourth Kondratieff. In her view, this process involved the transition "into a mass production system catering to consumers and the massive defence markets"...and..."The big upswing of the world economy after the second world war was then a period in which there was a good 'match' between the requirements of a mass production technological style, based on the almost universal availability of cheap oil, and the social and institutional framework within which this technological style could flourish. But this good 'match' was only achieved after a period of deep depression and social turmoil in the 1930s and after a major world war. During the 1930s, it was by no means clear how to achieve a set of appropriate institutional and social responses... It was only after the second world war that gradually a mode of development crystallized in the leading industrial countries, which did create the necessary harmonization of institutional

understanding of the sociotechnical process as it unfolds in practice for a model which simplifies the reality of such a process, reorganizing it conceptually in such a manner that it is hardly possible to penetrate in a fruitful way the nature and workings of the complex web of interrelations between basic resources, interests, institutions and galvanizing forces which are involved in its actual development. Ultimately, this is the reason why we prefer to talk of a sociotechnical system as a complex ensemble of interpenetrating technical and socio-cultural relations instead of a techno-economic paradigm implying the adaptation of the socio-institutional framework to the requirements of its materialization. For, in the concept of sociotechnical system, every relevant sociotechnical constituent is as far as possible recognized on its own right, ideally reflecting its relative importance in a systemic network of convergent and contradictory interests where relative weights are by and large determined by the constituents' degree of control of basic resources of the technological process in a context of changing historical galvanizing forces. Consequently, in the sociotechnical approach, the emphasis is not put *a priori* on a somewhat inevitable process of materialization of a technological paradigm in the economic realm of society. Instead, the objective is that the interpretation of the technological process and hence, any policy-making which may be derived from it, should follow its unfolding out of the dynamic ensemble of factors and interrelations we have been trying to expose in the course of this discussion. This means, for instance, that, as we have seen in the present thesis, along with economic determinants, other, such as politico-military determinants, will also shape the development of a given sociotechnical process on their own right and not as subordinate to productivity and capital accumulation. As a result, the profit motive cannot be taken as the exclusive dynamizing force of a sociotechnical process for, from our perspective, this would imply total control of such a process by the overriding interests of capital and, as we have seen, this may not be so even within a capitalist form of sociotechnical system. From a different angle, this means that nor can the interests of capital be taken implicitly for granted as being the inevitable, let alone the most desirable, alternative to shape the development of a sociotechnical system. Indeed, other alternatives are possible and their emergence will basically depend on the ability of other social forces to participate within the ensemble of interests making up its social constituency and, of course, upon the state of development of the technology's basic resources in a context of given historical galvanizing forces. In

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framework with technological style" (Perez,p.370).

practice, this is of particular relevance for the case of the IMC sociotechnical process in underdeveloped countries, not only because in most of these places the overriding interests of capital have done little to shape the sociotechnical process in relation to the acute problems facing the mass of their population but, also, because with microtechnology we are in the face of a pervasive system whose developments and implications will protract themselves for decades, affecting the lives of generations of people. From the point of view of a sociotechnical approach, therefore, one is obliged to suggest caution against taking for granted the overriding interests of capital and, above all, to suggest the need for a broader and more democratic social constituency where the interests of other social forces are also effectively represented in the shaping of the technological process. Whether the latter can materialize, however, is something that will depend upon the societal conditions of every country or region within the international context, but, in all instances, it seems highly unlikely that changes involving loss of power by entrenched interests will take place without some kind of social strife.

Having seen what the important paradigmatic school of thought had to say in terms of the development and diffusion of a technological process within the sociotechnical realm of society, we can now continue with our own conceptualization trying to show how an explanation to the same problem can be constructed out of the concepts previously discussed in this chapter. Thus, at the beginning of this section, we have already argued that a large-scale complex ITC such an IMC, truly needs, at all moments of its materialization, to interact and interpenetrate with a wide range of other sociotechnical systems, thus shaping as much as being shaped by the characteristics and dynamism of the entire sociotechnical realm of society. We have also identified the basic mechanism explaining this fact as a process embodying a full circle of interaction between sociotechnical systems and where the products of the pervasive system actually become part of the material resources of all others and, conversely, many of the material resources of the pervasive system are, in turn, the products of other systems. In other words, what is involved here is the development of the pervasive system into a true nodal sociotechnical system interacting in a push-pull fashion with other systems within the sociotechnical realm of society. The pervasive system must push its products and processes into the process of materialization of other sociotechnical systems, while it must pull from the latter the products and processes necessary for its own materialization. Not only that, the pervasive system's push and pull action must, in turn, broadly coincide

with the corresponding push and/or pull action of interacting sociotechnical systems. That is to say, the products and processes either coming in or coming out of an IMC must of necessity come to be perceived as important for the reproduction and furthering of the overriding interests, primarily, of the dominant social constituents of the interacting sociotechnical systems. Only when this happens, one is entitled to say that the development and diffusion of the pervasive sociotechnical system throughout the sociotechnical realm of society effectively depends, on the one hand, on the magnitude, speed and product-specificity of the consumption of its products by other sociotechnical systems and, on the other hand, on the availability, in quality and quantity, of those other systems' products which are consumed as material resources by the pervasive system itself.

The above process sounds straightforward enough. In practice, however, it involves an enormous complexity not only because, in the interaction of sociotechnical systems, we are in fact dealing with different technical and socio-cultural ensembles of basic resources, interests and institutions but, above all, because the diffusion of a pervasive sociotechnical system by and large implies a double dynamics of mastering new forms as well as displacing existing forms of systemic integration of basic resources, both with their corresponding complexes of interactions and interrelations within the sociotechnical realm of society.

In the case of an IMC sociotechnical process, the latter is particularly true because of its systemic and synergistic interlinking of acquisition, measuring, storing, processing and transmission of real-time and abstract data which cut right across the turf of mechanical, pneumatic, hydraulic, electromechanical and other capabilities used to fulfill similar functions with real-time and abstract data. But not only that, for, as we have seen in Chapter II, the intrinsically superior range of technical possibilities implied in the very nature of the physical processes mastered by an IMC also means that a whole panoply of new products and processes has become feasible, hence expanding the realm of diffusion of an IMC not only into areas untouched by previous capabilities (e.g., AI) but, also, into all sorts of technological processes where until now the manual and mental activities of human beings have constituted one of the necessary basic resources. Put in a different way, the present process of development and diffusion of microtechnology throughout the sociotechnical realm of society involves, simultaneously, the displacement of already diffused sociotechnical systems whose products are already part of specific combinations

of material resources of other sociotechnical systems, and the emergence and creation of quantitatively and qualitatively new combinations of basic resources across the entire sociotechnical realm of society. Taken together, this constitutes the basis for a large-scale and contradictory process involving the emergence, rearrangement and dissolution of countless forms of systemic integration of sociotechnical constituents. In this process, all the kinds of interests and institutions we have dealt with earlier will actively participate and its shape and dynamism can only be the result of a complex struggle between entrenched and emergent interests both linked to a myriad of competing investments, skills, machinery, institutions, etc., and both acting within a specific context of given historical galvanizing forces. Ultimately, this is a process which can only be described as one of momentum-gathering of an IMC sociotechnical system given the broad span of sociotechnical forces and problems which have to be both mobilized and overcome to materialize its spread across the sociotechnical realm of society. Let us see how this process of an IMC momentum-gathering broadly operates.

To start with, one must acknowledge the fact that, in the development of an IMC, momentum-gathering has been first and to an important extent a process internally related to the systemic and synergistic convergence of the area of signal systems as a whole and hence, to the transformation of basic resources, interests and institutions involved in such a convergence. This has meant, on the one hand, a displacement of existing forms of technological processes related to the non-systemic development of the area of signal systems and, on the other, a great deal of momentum-gathering emerging from the very synergy of development implicit in the systemic convergence of previously separated sociotechnical systems. In the latter respect, it seems to be a particular characteristic of an IMC that an important part of its products has from the very beginning diffused internally, i.e., they have been internally and synergistically consumed by the convergent industrial constituents themselves and, indeed, by the institutions controlled by its dominant social constituency at large. In effect, in the course of this thesis, we have seen, for instance, how semiconductors have become important for computers and telecommunications, how telecommunications products have become important for computer networking, and how computers have become important for telecommunications, control, the production process of semiconductors and even for their own production process. Likewise, we have also seen how in the case of the US's IMC, for instance, such social constituents as government, military and science,



who have directly controlled the basic resources of the IMC sociotechnical process in the US, have simultaneously been among the first and most important consumers of such IMCs products. Hence, it is true to say that, for an IMC, to an important extent its momentum-gathering process has depended upon the constituents of an IMC themselves and, primarily, upon the institutions of the dominant social constituents who in pursuit of the reproduction and furtherance of their own overriding interests and *raison d'être* have first and decisively contributed to the materialization of the IMC's diffusion moment in a similar manner as they have contributed to its creating and producing moments. as we have indicated earlier, however, such an internal diffusion has gone hand in hand with the displacement of existing forms of technological processes related to the non-systemic development of the area of signal systems. Hence, it is also true to say that to an important extent it has been within the institutional realm of the IMC's dominant social constituents themselves where the process of transformation of sociotechnical ensembles of basic resources, interests and institutions associated with the diffusion of microtechnology has achieved its clearest and deepest manifestation. Of course, this is hardly surprising, not only because the very development of microtechnology has been largely in consonance with the overriding interests of the dominant social constituency but, also, because, technically, it is clearly in the sphere of its creation where the microtechnology's characteristics, advantages, limitations, and requirements for its implementation have been most clearly and easily understood. It seems to us that this combination of factors has certainly been at the very root of the high rates of growth, productivity and technical change that has transformed the electronics industry (e.g., semiconductors, computers, telecommunications, etc.) into the current growth industries within the economies of developed countries and hence, into what Freeman (1986) sees as the leading branches in absorbing and adapting themselves to the new 'information technology' paradigm. The important fact for our purposes, however, is that such an achievement has involved the gradual displacement of competing, previously established, technological processes and hence, from the vantage point of our conceptualization, a complex struggle between different ensembles of technical and socio-cultural relations which has gradually transformed the sociotechnical realm of the entire area of signal systems. Ultimately, it has been an interacting process of momentum-gathering and momentum-losing of competing technological processes manifested at both the socio-institutional and the aggregate levels of their historical unfolding.



In effect, as the alteration in the mix of basic resources has manifested itself in and through the simultaneous dissolution of existing sociotechnical relations and the emergence of new ones, deep intra- as well as inter-institutional transformations within the socio-institutional realm of the competing systems have taken place. In this respect, intra-institutionally, i.e., within the institutional depositories of an existing technological process, many forms of investments, skills, knowledge, machinery, etc., associated with, for instance, electro-mechanical capabilities, or vacuum tube capabilities have come to give way to the emergent IMC's semiconductor capabilities. Initially, this could not be an easy transition since it involved the interplay of interests of many people who as human resources, capitalists, etc., were constituents of the previous technology. In time, however, under the pressures of historical galvanizing forces and as the unfolding of the emergent IMC technology has gradually made available, in a constant stream of innovations, all the necessary basic resources for its competitive implementation and, above all, as it has become more advantageous (and indeed necessary) in terms of the overriding interests of dominant institutional constituents, the previous systemic integration of sociotechnical constituents has lost its momentum coming gradually to disintegrate in a process dominated by what we have earlier called as a sociotechnical constituent's vicious circle of diminishing strength (41). At this stage, therefore, through a process of intra-institutional transformation, the same institutional depositories of basic resources related to the non-systemic development of the area of signal systems evolved into the institutional depositories of an IMC technological process. In general terms, however, in a process of the kind we have just described, it seems clear that not all the institutional depositories of the momentum-losing technological process can make

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(41) It is interesting to note here that, as Rosenberg (1977a) points out, innovations related to the 'old' existing technological processes do not stop with the advent of the new one, "...the 'old' technology continues to improve after the introduction of the 'new', thus postponing even further the time when the old technology is clearly outmoded"...In fact, the advent of a new technology..."often appears to induce vigorous and imaginative responses on the part of industries for which they are providing close substitutes" (Rosenberg, pp.203 and 205). From our perspective, this would be a natural response of a systemic ensemble of sociotechnical relations which is threatened in its very existence. In this respect, the 'new' technological process would act as a strong galvanizing force in itself, giving a renewed lease of momentum to the existing system and, consequently, protracting the very process of its own momentum-gathering. An example of this case was the attempt by vacuum tube makers to follow the path of miniaturization opened by the transistor. As *Electronics* (1980) wrote,..."A strong attempt to stave off the threat of the transistor was made by RCA in introducing the Nuvistor, a miniature ceramic tube with low power drain and high-reliability. Despite many merits, it failed to halt the inexorable march of solid-state devices" (*Electronics*, p.319).

the transition in the same way. First of all, as we know, there are different classes of institutional depositories so that in some of them, e.g., universities, the transition is more likely to proceed smoothly while in others such as industrial companies it is likely to be much more time consuming and controversial given the involvement not only of the dual dynamics of learning/displacement of skills, knowledge, investments, etc., but, also, of the contradictory nature of the convergent relationship between capital and labour (for capital the technological process is just a means towards accumulation, for labour it is its existence as such). In practice, not all companies actually manage to overcome the difficulties involved so that some of them eventually collapse under the pressures of galvanizing forces and, particularly, the pressures emanating from the advance of the new sociotechnical system; others merge with or are absorbed by more dynamic or stronger companies, etc.; all in a process which manifest itself most clearly in a restructuring of markets associated with the competing technological processes. Ultimately, the specific concrete way in which this process materializes itself is dependent upon many factors, amongst them, the previous structure of the market, the legislative framework concerning the companies involved and, above all, the quantitative and qualitative character of the companies as institutional ensembles of technical and socio-cultural relations themselves.

Of course, as we have said before, the intra-institutional dimension is only part of the complex process of socio-institutional transformations involved in the momentum-losing/momentum-gathering dialectics of competing technological processes. For, along with it and, indeed, interpenetrating with it, is the inter-institutional dimension accounting for the transformation of previous forms of interlinking between separate institutions which bring into systemic convergence and contradiction the overriding interests not only of different social constituents who remain dominant in their own institutions but also of generically similar but institutionally fragmented social constituents. In this respect, going back to the competing technological processes in the area of signal systems as a whole, it is clear that several major inter-institutional transformations were involved in the process of IMC momentum-gathering. Among them, for instance, a host of new companies associated with the new IMC technology entered the industrial and market scene; an expansion of old and emergence of new university and private and public R & D institutions associated with the IMC technological process took place; financial institutions, foundations, etc., opened themselves to the new technological process providing necessary basic resources; most conspicuously, government institutions and, in the case of the US's IMC,

military institutions become much more involved in the development of the momentum-gathering technology than they had ever been in the development of the momentum-losing technological process. Indeed, to the extent that the intrinsic technical potential of an IMC enabled the materialization of such activities as space, completely new government organizations such as NASA actually emerged as strongly interacting components of the socio-institutional complex of the US's IMC. However, the most crucial socio-institutional transformation, and the one truly underlying all others, laid in the very systemic and synergistic convergence of the entire area of signal systems which the momentum-gathering process of the emergent IMC technology brought about. In effect, this process not only gave rise to completely new industries such as semiconductors and computers but, also, brought into systemic interaction the sociotechnical realm of the entire area of signal systems in a way that the momentum-losing technological process could have never achieved. With the dissolution of competing, previously established, technological processes, therefore, and their substitution by the IMC technological process, a completely new world on intra- and inter-institutional interrelations actually developed, making the transformation occurred at the socio-institutional level of the area of signal systems as a whole one of a truly radical character. Illustratively, in the diagram of figure 5.2, where the phenomenon of competing technological processes has been depicted on the left-hand side column, what occurred may be seen as a process where, from left to right and vice-versa, the whole ensemble of technical and socio-cultural relations involved in the entire area of signal systems was profoundly altered through a dialectics of dissolving and emergent systems whose concrete manifestation was, at every step, the result of such factors as the qualitative and quantitative development of the basic resources of the competing systems; the interactions, convergence and conflicts between the different social constituents' overriding interests and their social organizations; the qualitative and quantitative development and interlinking of institutional depositories; the development of the written and unwritten legislation of society; and the changing pressures of historical galvanizing forces both informing and interacting with the other factors above. In all, this was a truly complex historical process of deep transformations whereby the IMC sociotechnical process not only established itself within the area of signal systems as a whole but, simultaneously, began its diffusion journey into the sociotechnical realm of society. In effect, as we shall see below, the same kind of transformations as those above have been taking place throughout the sociotechnical realm of society as the IMC has gradually transformed itself into a nodal system interacting in a

push-pull fashion with all others in a process characterized by a similar dialectics of competing momentum-gathering/momentum-losing technological processes. Before coming to the sociotechnical realm of society, however, we need to deal with the changes accompanying the manifestation of such dialectics at the aggregate level of the social constituency of the area of signal systems.

At the aggregate level of social forces, the main point one has to make is that the transformations associated with the IMC momentum-gathering process were not as revolutionary as those we have identified at the socio-institutional level of the IMC diffusion process within the area of signal systems as a whole. Indeed, it is possible to say that, at this level, what did take place, in the US's case for instance, nicely fits our previous characterization of the development of sociotechnical systems not only as a process of constant alteration of the sociotechnical systems themselves but, also, as a process of simultaneous reproduction of dominant social forces and relations in and through the sociotechnical systems themselves. For, notwithstanding the particular characteristics of the capital-science-military-government dominant social constituency of the US's IMC, it is clear from our analysis in Chapter III that the deep transformations which occurred at the socio-institutional level of the area of signal systems did not involve any substantial alteration in, but rather a clear process of reproduction and furtherance of, the overriding interests dominating the historical development of such area of signal systems. True enough, some relevant changes took place in the magnitude, form, and degree of participation, as well as in the interrelations between, such aggregate social constituents as capital, government, the military and science. For the most part, however, this does not alter the fact that the overriding interests of capital clearly dominated the development of the non-systemic signal technologies as they have come to dominate that of the competing IMC technological process. Likewise, considering that electricity was one of the first science-based technologies, it is clear that the overriding interests of science were as much an intrinsic constituent of the electromagnetic development of the area of signal systems as they have been in the semiconductor-based development of an IMC. Furthermore, as we also saw in Chapter III (Appendix III), even the integration of the overriding interests of capital, science, the military and government into a well defined social complex of power actually finds its roots in the pre-IMC period of development of the area of signal systems. At the aggregate level of social forces, therefore, and with due consideration of differences between different historical periods, we can conclude that, in spite of the deep

transformation of the area of signal systems as a global ensemble of technical and socio-cultural relations, no qualitative alteration of the complex of overriding interests dominating such area of signal systems actually took place. On the contrary, if anything, the substitution of an IMC for the competing technological processes was not only presided over by, but indeed the result of the reproduction and furtherance of overriding interests of, the same aggregate social forces. We have seen the outcome in the course of this thesis: with the development of an IMC, under the pressures of historical galvanizing forces of economic and politico-military competition, not only the power accumulated by these aggregate social forces has increased for each one of them individually but, more so, it has increased collectively in their long-term structuring as a complex of social power controlling and shaping the development of US's microtechnology.

Finally, to bring the conceptualization of the momentum-gathering process of an IMC to an end, we turn our attention to the process involved in its diffusion into the broader sociotechnical realm of society, i.e., to the process whereby an IMC is gradually transforming itself into a nodal sociotechnical system interacting in a push-pull fashion with other systems of the sociotechnical realm of society. In this respect, the first point that has to be made is that this process is fundamentally the same, or more precisely, an extension of the process of IMC momentum-gathering just analysed above. Hence, it follows that most of the crucial features of the latter process will also characterize the unfolding of the IMC momentum-gathering throughout the sociotechnical realm of society. This would be the case, for instance, of the dialectics of change without change, that is, of the process of deep transformations at the socio-institutional level for reproduction at the aggregate level which has dominated the IMC momentum-gathering within the area of signal systems as a whole. In the present discussion, therefore, we shall not repeat the latter kind of analysis since it would add little new to our conceptualization; instead, we shall content ourselves with pointing out those general features which are specific to the process of IMC momentum-gathering throughout the sociotechnical realm of society. On this score, the fundamental point is that, as we noted earlier, a complex and pervasive ITC such as an IMC truly needs, at all moments of its materialization in practice, to interact and interpenetrate with a wide range of other sociotechnical systems, thus shaping as much as being shaped by the characteristics and dynamism of the entire sociotechnical realm of society. Ultimately, this means that in the process of



IMC diffusion throughout the latter realm, apart from the emergence of completely new IMC-based technological areas such as AI, a complex dynamics of simultaneous interpenetration with, and displacement of, other sociotechnical systems is always involved. More specifically, this means that for an IMC to diffuse at all, the two following conditions must always be satisfied. Firstly, the products and processes either coming in or coming out of an IMC must, of necessity, be perceived as important for the reproduction and furtherance of the overriding interests, primarily, of the dominant social constituency of the interacting sociotechnical systems; that is, the IMC system's push-pull action must broadly coincide with the corresponding push and/or pull action of interacting sociotechnical systems. Secondly, the IMC push-pull action must, in the specific historical circumstances of given historical galvanizing forces, be perceived as superior to that of any previously established competing technological processes so as to overcome the resistance implicit in the latter processes' momentum and successfully underpin the complex socio-institutional transformations involved in the dual dynamics of learning and displacement of skills, knowledge, investments, machinery, etc. In practice, only when these two conditions are satisfied does the diffusion of an IMC spread beyond the area of signal systems as a whole taking the dialectics of competing momentum-gathering/momentum-losing technological processes into the sociotechnical realm of society as a whole. And in the case of an IMC, given the potential all-pervasiveness of microtechnology, the latter means not just the displacement from the sociotechnical realm of society of the full circle of interactions materializing the diffusion of competing technological processes associated to the non-systemic development of the area of signal systems but, also, as we have said before, the potential displacement of a much wider range of sociotechnical relations where the manual and mental activities of human beings have constituted necessary basic resources. In short, it means the potential transformation of the entire ensemble of technical and socio-cultural relations making up the unfolding sociotechnical realm of society. In practice, as we have seen during this work, the above process of global transformation is already on its way in the most advanced DCs, manifesting itself in a dialectics of dissolving and emerging ensembles of technical and socio-cultural relations whose sum-total truly tends to embrace the entire sociotechnical realm of society. In this respect, in a way determined by specific and changing historical galvanizing forces, it is possible to say that, in the long-term, the aggregate crystallization of this complex process of transformations is clearly leading to the realization of an IMC as a nodal sociotechnical system and, consequently, to the



transformation of the aggregate ensemble of technical and socio-cultural relations which make up the sociotechnical realm of society itself. Thus, from basic resources to legislation and social constituents' socio-political organizations, the IMC sociotechnical realm of the future is certain to differ substantially from its pre-IMC historical manifestation. It is this process, particularly in its aggregate socio-institutional transformation, which has led some scholars of the paradigmatic school of thought to talk of an adaptation of the socio-institutional structure of society to the requirements of the unfolding microelectronics paradigm. Here, however, we prefer to see the transformation of the sociotechnical realm of society as flowing out from itself in a process whose shape and dynamism is, at every step, the result of the qualitative and quantitative interpenetration of competing/interacting basic resources, interests, institutional depositories, written and unwritten legislation, historical galvanizing forces, etc. In this way, the overall shape of the process reveals itself not just as an envelope of aggregate transformations but as an outgrowth of what is in fact a very heterogeneous reality of sociotechnical interactions stemming from the fact that the relative development of an IMC vis-a-vis interacting/competing sociotechnical systems tends to vary for different areas within the sociotechnical realm of society. Thus, in some instances there can be a greater degree of resistance to change, specifically in those areas where the displacement of systemic ensembles of skills, knowledge, investments, etc., is bound to affect deeply the interests of entrenched social constituents. In other instances, the resistance to change can be minimal or even non-existent as in the extreme case of a complete absence of a competing momentum-losing sociotechnical system. In the latter case, in principle, the situation should be more favourable for a process of IMC momentum-gathering, if only because its unfolding can proceed unhindered by the contradictions emerging from the struggle with a competing sociotechnical process. To a large extent, it is the latter realization which has led some commentators to note the beneficial side of the weakness of non-systemic signal technological capabilities in underdeveloped countries, thus emphasizing the possibility for them not only of more easily 'leap-frogging' such previous technologies but even of catching up, or closing the gap, with developed countries in the process of IMC momentum-gathering, given the more complex and contradictory nature of this process in the latter countries. For instance, Soete (1985) has argued that, in a context of intense competition in the electronics market and rather easy international accessibility to inventions and innovations due to difficulties of implementing legal protection, the potential for UDCs, specifically semi- and newly-industrializing countries, to leapfrog into

microelectronics has never been greater than today. He recognizes that there are great difficulties in this undertaking but emphasizes that the techno-economic advantages of electronics technology, particularly in labour and capital productivity growth, make it very favourable for UDCs to attempt to leap-frog into it. This is so, because electronics technology favours UDCs on two major accounts: first, on their general capital shortage problem and, secondly, on their bottlenecks in highly specialized technical skills which, at the same time, imply less resistance to the electronics technology's deskilling effects than it will be the case in developed countries. The science-based character of the technology would be an additional advantage given that scientific and technical education is not a crucial bottleneck in semi- or newly-industrializing countries (42) In all instances, appropriate government policies play a fundamental role. Undoubtedly, this view is correct so far as it goes and, in principle, leap-frogging and catching up are possibilities in the global unfolding of the microelectronics revolution. It seems to us, however, that insofar as the sociotechnical nature of an IMC technological process is not unveiled in this kind of analysis of the international diffusion of microtechnology, then certain crucial difficulties may be underestimated. This seems to be the case, for example, with the development of a powerful and coherent social constituency which, as we have seen, is needed in and for the development of any ITC sociotechnical process. In this respect, considering that microtechnology has originated in the developed countries under the shaping control of a particular social constituency, in the leap-frogging analysis there is a certain tendency to emphasize the advantage of the late-comer and the 'willingness' of transnational capital to transfer its technology under the pressure of competition without much attention to its contradictory role in the social constituency of the host country. In other words, the fact is overlooked that microtechnology -as it was the case with previous competing signal technologies- is truly an outgrowth of an *internationally* interacting/competing sociotechnical system, which means that although there may be less contradictions emerging from the momentum-gathering/momentum-losing dialectics of different competing technological processes, simultaneously, there may be quite a lot more emerging from the international interplay of basic resources, interests, institutions, galvanizing forces, etc., which make up the international dimension of the development of sociotechnical systems. It is to the basic tenets of this international dimension that we now turn our concern in the last section of the present conceptual

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(42) for a similar view applied to the field of telecommunications, see Hobday (1985,1986),

framework for the understanding of ITC sociotechnical processes.

### 5.3.7. International Dimension of the Development of ITC Sociotechnical Processes: Interaction and Competition Between National Sociotechnical Systems

Thus far, we have dealt with the historical unfolding of large-scale and complex ITCs as if such an unfolding took place within the confines of a particular country or region and oblivious of the contradictions emerging from its interlinking and projection in the international arena. In practice, however, as we have seen in the case of the capitalist science-based IMC, large-scale and complex technological processes are subject to a double form of expansion. On the one hand, they do tend to project themselves internationally through both the overriding interests and actions of their social constituents and the requirements of their basic resources (i.e., sociotechnical autarchy is hardly an option). On the other hand, they tend to replicate themselves in other countries or regions where, as indigenous ensembles of technical and socio-cultural relations, they assume forms and dynamism which are very much the result of the character and quantitative and qualitative development of basic resources and social constituents in those countries or regions. This double and interacting form of expansion gives rise to the process of internationally interacting/competing sociotechnical systems which not only involves most of the issues dealt with above but, indeed, adds some important new dimensions to the reconstruction of the historical unfolding of ITC sociotechnical processes.

At the core of the new dimensions lie the contradictions and tensions implicit in the simultaneous development and interpenetration of the two forms of sociotechnical systems' expansion abovementioned. In particular, the replication of sociotechnical systems in various countries or regions plays a crucial role for, being commonly informed by the pursuit of national technological self-reliance, it clearly interlinks as well as counterposes both the national and the international unfolding of different countries sociotechnical systems. Of course, as we have seen in the course of this work, this national and international differentiation is never a clearcut matter of countries interrelating on the basis of national interests in the abstract. Nor is it one of a replication of some universal sociotechnical system valid for all countries. Rather, the situation is one of much greater complexity involving not only the interlinking and counterposition of overriding and particular interests of nationally-based social constituents operating nationally and/or internationally but, more generally, the interlinking and counterposition of different national ensembles of technical and

socio-cultural relations. In this respect, there are various aspects which is important to highlight.

a) As we know, in the case of a specific sociotechnical process such as a capitalist science-based IMC, there are intrinsic sociotechnical constituents rooted in the very nature of certain fundamental technical and social relations associated with microtechnology and a primarily capitalistic control of its basic resources and hence, development. This means that whenever a specific sociotechnical system tends to replicate itself in two or more countries, then the inevitable consequence is for those countries to acquire and possess the intrinsic sociotechnical constituents of such sociotechnical system. This necessary level of intrinsic sociotechnical constituents, therefore, offer a first and basic channel for the international interaction of nationally-based sociotechnical systems. In the case of a large-scale and complex capitalist science-based ITC, for instance, we have distinguished capital, science, labour, management and government as intrinsic social constituents of the technological process. As such, it can be said that each and every one of these constituents represent, among other elements, a potential channel for an international interaction which, as we shall see later on, will manifest itself in and through many and variegated forms of international socio-institutional combinations.

b) Beyond the level of intrinsic constituents, and as ensembles of technical and socio-cultural relations, nationally-based sociotechnical systems tend to differ from each other substantially in both the quantitative and qualitative shape and dynamism of their development. The reason is simple, no two countries are alike technically, culturally and legislatively just to name a few relevant aspects. Thus, not only do nationally-based sociotechnical systems tend to differ in the aggregate magnitude and state of development, and even in the specific character, of the basic resources nationally available at any given time. They also tend to differ in the process of creation and systemic integration of these basic resources into sociotechnical institutions which are ensembles of technical and socio-cultural themselves. The latter is particularly the case as the evolving cultural and legislative differences between countries are necessarily incorporated and reflected in the respective developments of nationally-based sociotechnical systems. More specifically, as we have seen in this work, these systems may differ markedly in the complexion of their respective social constituents and, most importantly, their dominant social constituents. In this respect, disparities may involve not only differences in the composition of the complex of social interests making up

the respective social constituents but, simultaneously, differences in the particular correlation of forces characterizing the evolving interrelations between social constituents themselves. Ultimately, the combined effect of these disparities only emphasizes the uniqueness characterizing the complexes of overriding and particular interests shaping the development process of different countries' sociotechnical systems in the context of changing historical galvanizing forces. Furthermore, since there is a plain relationship between some galvanizing forces and the overriding interests of some social constituents, this uniqueness is only reinforced by the fact that differences in the social constituency tend to involve, simultaneously, differences in the very nature and role played by historical galvanizing forces in the development of given nationally-based sociotechnical systems. Of course, all this without mentioning that, in practice, galvanizing forces such as social crises, geoeconomic and demographic pressures, etc., tend to assume very particular expressions in the historical development of particular countries.

c) The international interlinking of sociotechnical systems materializes itself in and through a complex interplay of basic resources, overriding and particular interests, institutions, galvanizing forces, etc. In such an interplay, each one of the nationally-based social constituents involved will pursue the fulfillment of its overriding and particular interests, thus entering into complementary as much as contradictory interrelations with other social constituents. In this framework, one can say, for instance, that the overriding and particular interests of science are more likely to lead into complementary international interrelations between different nationally-based science constituents. Socio-institutionally, this amounts to saying that it will be between those institutional forms where science interests remain dominant that one is more likely to find bilateral as well as multilateral arrangements interlinking in a more complementary fashion different nationally-based sociotechnical systems. On the other hand, if we take the accumulating interests of capital, the clear likelihood is for contradictory as well as complementary international interrelations between different nationally-based capital constituents. Thus, in socio-institutional terms, while various kinds of formal arrangements may interlink some nationally-based capital institutions in complementary fashion, at the same time, the need for control and competition associated with capital accumulation may lead not only to inter-institutional relations of domination and control but, most importantly, to contradict the very development of the aggregate process of capital accumulation in some of the countries involved. Of course, the latter is something that will depend upon



the relative strength of the interrelating institutions and, ultimately, upon the nature and strength of the overall nationally-based sociotechnical system of which they are essential constituents. In the latter sense, it must be noted that social constituents relate internationally not only with those of their own kind (e.g., capital-capital) but with other generic social constituents too. For example, in the internationalization of the productive activity of corporate capital, the latter normally enters into interrelations with governments, labour, management, etc., from those countries where they establish operations. Indeed, the range of possible combinations is quite variegated.

d) Basic to the process of interrelations just mentioned is the rooting of social constituents into nationally-based social constituencies and, more generally, ensembles of technical and socio-cultural relations, which imbue their international activities with the basic tenets of both the historical character of their *raison d'etre* and the character of their integration and relative weight within the abovementioned ensembles. Thus, if we look at the role of their *raison d'etre*, it seems clear that while for some social constituents such as science and capital the international arena has increasingly become the natural and accepted ground for the unfolding of the respective processes of knowledge and capital accumulation; for others, such as government and the military - with the strengthening of national political sovereignty - the international arena has tended to become more restricted as an area of direct operations and control in pursuit of dominant national interests. On the other hand, if we look at the role of the particular character of the social constituents' integration and relative weight within nationally-based social constituencies, it seems clear that it strongly influences the practical manifestation of the trends emerging from the constituents *raison d'etre*. In particular, such constituents as science and capital may see their international activities mediated and even curtailed by requirements arising from the overriding and particular interests of other dominant constituents such as government and/or the military. The latter is a case which we have seen clearly in relation to the US's IMC, where the military, alleging national security interests in a context of re-strengthened military galvanizing forces, have curtailed the international diffusion of certain kinds of knowledge, machinery and products, thus contradicting the natural international tendency which emerge from the interests of science and capital.

e) The interlinking of nationally-based sociotechnical processes, which takes place on the basis of resource requirements and through the international expansion

and/or interaction of different countries' sociotechnical institutions, does not simply involve an international diffusion of resources or an interlinking of social interests. Ultimately, it is the very nature of ITC sociotechnical processes as ensembles of technical and socio-cultural relations which is projected internationally through the diffusion of their basic resources and the activities of their socio-institutional constituents and interests. That is to say, in the interpenetration of sociotechnical systems, the written and unwritten legislation of institutions and, indeed, societies, comes into a dynamic interaction which expresses itself in a process of adaptations and transformations whose mutual character or one-sidedness greatly depends on the relative strength of the interacting sociotechnical systems themselves and on the historical role of the galvanizing forces. In a previous section (see 5.3.3.3), we have discussed how the unfolding of sociotechnical institutions can be more clearly seen as actually transforming as much as reflecting the written and unwritten legislation, i.e., legal provisions, customs, values and attitudes prevalent in a given society. More precisely, we argued that, in such an unfolding of sociotechnical institutions, what actually takes place is a process of transformation of particular socio-cultural relations for reproduction of fundamental socio-cultural relations. The international projection of this fundamental reality has momentous implications for our conceptualization of the international dimension of sociotechnical systems. Above all, it enables us, on the one hand, to distinguish some basic conditions underlying the very possibility and character of international interlinking and, on the other, to provide a common ground for understanding the deep international socio-cultural role of the actual and variegated ways and mechanisms whereby such interlinking takes place. On the first account, assuming a two-country process of interlinking of sociotechnical processes through the intended actions of, above all, their dominant social constituents, it seems clear that a basic precondition for an interlinking of such sociotechnical processes is that, by and large, such development should imply, or be perceived as implying, the furtherance of the overriding and particular interests of the dominant parties involved, particularly, in a context of reproduction of fundamental social relations on both sides. In other words, on both sides there must be a perception of complementarity and mutual benefit, which stimulates interlinking and hence, changes in particular socio-cultural relations for reproduction of fundamental relations. This precondition would help to explain, for instance, why an international interlinking of sociotechnical systems is more readily accomplished between capitalist countries themselves, or between socialist countries themselves, than it is the case between capitalist and

socialist countries. In addition, it would help to explain why written and unwritten legislation, or changes in one country's government policies which, in the context of given historical galvanizing forces, are perceived as harmful to the interests of the other country's social constituents, normally, give rise to contradictions which may lead to showdowns and confrontations whose resolution is very much determined by the actual correlation of forces between the countries involved. On account of the second aspect, it is first necessary to point out that the variety of ways and mechanisms whereby such an interlinking can take place is in principle unlimited. Not only that, for even if we assume a two-country process, we have the additional fact that the differences between the two countries involved may assume innumerable expressions too. Thus, just to illustrate the argument about the deep socio-cultural role of interlinking mechanisms, we shall not only assume that our two countries possess similar and well-developed ITCs but, also, select the particular case, most commonly exemplified by the operations of TNCs, where institutional constituents rooted in one country's sociotechnical system operate directly within the national environment of another country's sociotechnical system. In this case, our contention is that while both parties are basically complemented in a general dynamic of reproduction of fundamental social relations, at the level of particular socio-cultural relations the situation is much more fluid. Specifically, the trend or pressure is for the subsidiaries of institutions of one country operating within the environment of the other to adapt themselves to the written and unwritten legislation of that country while, simultaneously, contributing to its transformation through the insertion of its own ensemble of technical and socio-cultural relations within the workings of the host country's sociotechnical system. Conversely, in a reversal of the inter-country flow of influences, the same institution becomes itself a vehicle for the insertion of foreign technical and socio-cultural relations back to the parent organization and hence, the home country, with the result that the flow of society-transforming changes may go from one country to another and vice-versa. Obviously, such mutual flow of influence is reinforced when institutions of both countries establish operation in the other country in a sort of, say, institutional exchange. In this context, a general rule may be suggested, namely, that in the international interlinking of sociotechnical systems through the interacting/competing activities of their respective institutions, those forms of technical and socio-cultural relations which give certain institutions an edge in terms of the realization of their overriding interests and *raison d'etre*, will tend to diffuse themselves into other similar institutions provided, of course, that such

relations are not kept secret and the latter institutions all possess the ability to appropriate them. Ultimately, if we relax our two-country assumption, this rule provides a basic explanation to Perez's process of diffusion of the general best practice frontier across firms, branches and countries (see previous section). Indeed, we can say that the greater the number of countries, the larger the scale of international diffusion of successful relations and hence, society-transforming changes.

f) Finally, the national overtones present in the previous points, for instance, in the use of terms such as particular countries' sociotechnical systems, does not imply in any sense that the interlinking of such sociotechnical systems involves, always and primarily, the simultaneous interaction and counterposition of two kinds of national blocks. This may well appear so from the standpoint of the aggregate development of a given country's sociotechnical system, or, even from the standpoint of more nationalistic social constituents such as the military, particularly, in a context of strong military galvanizing forces. In practice, however, at the socio-institutional level, the situation reveals itself to be much more flexible as we have seen in the course of this work, for instance, in our analysis of the global process of electronics capital accumulation carried out in Chapter III. There, it was found that electronics corporate capital is not at all operating on a nationalistic basis but, clearly, on a global basis which has led increasingly to alliances of electronics capitals where companies are lining up amongst themselves internationally rather than nationally. Thus, as it has normally been the case throughout this enquiry, simpler and schematic generalizations can be made only at the peril of denying the complexity and richness of the actual processes taking place.

By and large, the series of points made above constitute a basic framework for approaching the analysis of the international interpenetration of different countries' sociotechnical systems. A more impressionistic view of the complexity of the issues and interrelations involved at this level is obtained by looking at figures 5.2 and 5.3 together. Figure 5.3, in particular, depicts that, in the international interpenetration of sociotechnical systems, some or all the elements, interrelations and forces involved in the workings of the system depicted in Figure 5.3 may come into a process of interactions embracing not just two but many countries. Additionally, such countries may differ substantially in the qualitative and quantitative character and development of their respective

sociotechnical systems. In this sense, our discussion thus far has assumed a basic two-country (regions) process of interlinking with both countries (regions) possessing well developed capabilities. As we know from our discussion in previous chapters, however, this assumption relates more closely to the case of the interpenetration of most advanced countries' sociotechnical systems (e.g., the interpenetration of US and Japanese IMCs). While, as has been shown by our analysis of Mexico's electronics capabilities with their deep dependence upon the US, it does not correspond itself with the case of, let us say, DCs-UDCs interlinking of sociotechnical systems or the case of UDCs-UDCs interlinking of sociotechnical systems. In other words, in the variegated realm of international possibilities, there is not just sociotechnical interlinking between DCs themselves but, also, between DCs and UDCs and between UDCs themselves. In the remainder of this section and, indeed, the present thesis, we shall concern ourselves primarily with discussing some of the general characteristics present in the DCs-UDCs form of interlinking of sociotechnical systems. We shall do so because not only is this the case we have dealt with most in our treatment of an IMC in UDCs but, also, is the case which clearly predominates in the present stage of Third World development, where normally DCs are the actual possessors of large-scale and complex ITCs and where UDCs-UDCs forms of interrelations (i.e., the so-called South-South cooperation) for purposes of sociotechnical development are far from being a widespread reality.

Again, in the context of DCs-UDCs interlinking, the variety of possibilities is enormous with Third World countries alone differing widely between themselves. In fact, even if we take as a common general trait for TW countries the fact that they lack self-reliant ITC sociotechnical processes vis-a-vis the most advanced nations, the differences can still be enormous. For instance, they can differ not only in terms of such basic indicators as size, population, GDP, literacy, etc., but, also, in terms of broader socio-cultural and institutional characteristics such as governmental and educational systems, legislative frameworks, etc. More specifically, if we take as a point of reference the development of a given ITC sociotechnical process such as an IMC, at one end of the Third World spectrum there will be countries which possess virtually nothing in terms of the fundamental sociotechnical constituents of such a process; while, at the other end, there will be countries such as the NICs where government-supported efforts to develop an IMC have not only produced some advances but are clearly in the long-term agenda of these countries' development process. Through the case of Mexico, our concern in this thesis has mainly been



with the latter end of the Third World spectrum. As such, it is only logical that this concern should be reflected in the following discussion of the DCs-UDCs case of sociotechnical interlinking between different countries or regions. It will be the NICs, therefore, which will provide the background for the analysis of this process and, again, for the sake of simplicity, we shall assume that only two countries or regions are involved in such interlinking.

By and large, the most significant points in relation to UDCs-DCs sociotechnical interlinking find their roots in the various arguments developed above in points a) to f) and, particularly, point e). There, among other things, we said that, as two countries come together on the basis of sociotechnical interlinking, it is the written and unwritten legislation of their institutions and, indeed, societies, which comes into a process of dynamic interaction leading to technical and socio-cultural adaptations and transformations whose mutual character, or one-sidedness, greatly depends on the relative strength of the interacting sociotechnical systems themselves. We also distinguished a sort of general rule which related the diffusion of technical and socio-cultural relations to the successful realization of social constituents' and institutions' overriding interests, given, of course, that such relations are not kept secret and the institutions concerned possess the capability to appropriate them. It seems to us that these contentions offer a basis for the discussion of the sociotechnical interlinking of DCs and UDCs and hence, for the treatment of what is perhaps the most crucial issue dominating the unfolding of such interlinking, namely, the relation of *unequal interdependence* expressed in the normally commanding sociotechnical position of DCs vis-a-vis UDCs.

Let us consider for this purpose, the case of a capitalist science-based IMC and our findings relating to the sociotechnical interlinking of the US and Mexico. Here, the relevant point is that not only is the relative strength of the interacting sociotechnical systems overwhelmingly in favour of the US but, not dramatically, that in Mexico there is in fact no sociotechnical reality as that implied in a capitalist science-based IMC. Indeed, most of the intrinsic sociotechnical constituents rooted in the very nature of microtechnology, and a primarily capitalistic control of its basic resources, are systemically undeveloped in Mexico. Consequently, if we take into account that the sociotechnical interlinking between countries materializes itself in and through a complex interplay of basic resources, overriding and particular interests, institutions, galvanizing forces, etc., the fact is that, at the present stage, Mexico has very



limited leverage to influence the shape of such a complex interplay, say, within the US. In other words, from the standpoint of the interlinking of ensembles of technical and socio-cultural relations manifesting itself in the mutual or one-sided transformation of both countries written and unwritten legislation, the fact is that Mexico has very little to offer the US in terms of successful IMC technical and socio-cultural relations while being herself mostly unable to appropriate the kind of successful relations present in the IMC sociotechnical process of the US. Such combination, which is typical of the majority of the Third World countries, determines not only a greatly one-sided, or unequally interdependent, process of interpenetration of technical and socio-cultural interrelations but, above all, a process which is, from TW countries' point of view, largely shaped by the overriding and particular interests of foreign constituents and institutions and which, at least where capital is involved, tends to reproduce the conditions of unequal interdependence which enable such foreign constituents' influence in the first place. The international flow of society-transforming influences, therefore, goes primarily from DCs to UDCs and, because of the conditions (capitalistic) within which it takes place, it hardly contributes to its own negation, rather to its own reproduction.

Obviously, as we have pointed out before, in the sociotechnical interlinking of different countries, it is basically superficial to pose a view implying the counterposition of two national blocks. Also, we have established the existence of a fundamental pre-condition for such interlinking to take place, namely, that among the interacting social constituents of both countries, particularly, the dominant social constituents, there must be a perception of complementarity and mutual benefit. This means, therefore, that, within a context conditioned by the relative nature and qualitative/quantitative development of technical factors both in DCs and UDCs, it is the overriding and particular interests of both countries' social constituents and their institutions which effectively determine the shape and dynamism of their sociotechnical interlinking. Put in a different way, while it is true that the relation of unequal interdependence is generally rooted in the technical and material determinants of both countries sociotechnical processes, it is also true that the specific form of manifestation of such relation is determined by the interests of not only DCs' social constituents, but of UDCs' social constituents too. During the course of this thesis, we have seen this situation quite clearly, particularly, in the comparison between different forms of DCs-UDCs interlinking pursued by such UDCs as Mexico, Brazil and South Korea. There we saw that, within a general context of reproduction of

international capitalism and the associated need to preserve DCs-UDCs interlinking, the respective social constituents of the above countries have implemented different strategies for the development of their electronics sociotechnical processes, including, most prominently, the specific form of interlinking of these processes to those of developed countries. True, such differences in strategy have been the result of a combination of factors. Ultimately, however, there can be no denial of the fact that it has been the differences between these countries in terms of both, the nature and relative strength of their national social constituents' overriding and particular interests and the particular context of historical galvanizing forces, which have played the most dynamic part. In terms of the interlinking of these countries sociotechnical process to that of DCs, therefore, the perception of mutual advancement of interests between DCs and UDCs dominant social constituents has assumed a different expression, with the result that the very form of the relations of unequal interdependence has manifested itself differently too.

Normally, one of the most crucial and controversial areas of concern in the process of sociotechnical interlinking between DCs and UDCs relates to the role of DCs' transnational capital in the sociotechnical process of UDCs. The reason is simple, not only do TNCs constitute the main channel or mechanism of sociotechnical interlinking between DCs and UDCs, as most of the huge literature on technology transfer to the Third World bears out, but, also, as we have argued in point c) above, they tend to play a contradictory role in the national process of capital accumulation, particularly in UDCs, where frequently their superior basic-resources and technical and socio-cultural relations put them in a clear position of strength vis-a-vis national capital. It is not surprising, therefore, that in UDCs it is normally governments who strive to control the activities of TNCs social constituents with the aim of, on the one hand, enhancing their potential contribution to and hence, their complementary role in, the development of the national sociotechnical process and, on the other, curbing the negative effects of the trends implicit in the need for concentration and control which accompanies the pursuit of profit-driven capital accumulation. As we have seen in the case of Mexico, however, the latter is a path plagued with difficulties given the global nature of TNCs operations, which also explains why in other countries, like Brazil, the government constituent has sought to curtail altogether the direct presence of TNCs from those sectors of the national market where the development of national capabilities has been perceived as a matter of priority. Notwithstanding this, however, it seems clear that the issue of whether

TNCs can effectively contribute to the development of the national sociotechnical process in UDCs, and to what extent, is not something that can be answered in a black or white fashion. First of all is the fact that UDCs differ greatly between themselves in the relative strength of their social constituents vis-a-vis transnational capital. Secondly is the fact that, at the socio-institutional level of particular companies, opportunities arise not only as a result of the international competitive struggle which authors as Soete (1985) and Ernst (1985) have clearly emphasized as favourable to UDCs but, also, as a result of the different technical and socio-cultural structures of the transnational companies themselves. An example of the latter, we saw clearly in the case of Mexico where the different international structures of Ericsson and ITT were somewhat reflected in the forms of interlinking of these companies into the Mexican electronics process, with ITT entering into a bilateral arrangement technologically more favourable to Mexico than it was the case with Ericsson. The argument can be put forward, therefore, that at the level of real-life institutions, given the right set of conditions and a carefully informed approach to the participation and role of transnational capital, it may be possible for UDCs to incorporate TNCs into a framework of operation which, while being based on the perception of mutual benefits, is favourable to the development of a national ITC sociotechnical process. Obviously, a crucial issue in this connection is that of correlation of forces in the context of given historical galvanizing forces. For, while at one end of the spectrum there will be companies much more powerful than many small nations, at the other end, there will be large and more industrially diversified countries relating to a variety of sizes of TNCs. For instance, within the available range there will be countries whose dominant forces, while expecting to benefit from the presence of TNCs, will hardly be able to influence the technological role of these TNCs. In this case, regional integration seems to offer the only possible alternative, but, even then, this would mean the formation of a coherent regional social constituency. On the other hand, taking the case of stronger UDC (basically NICs), it is reasonable to think that these countries should privilege forms of interlinking with TNCs whose relative strength clearly afford them a better leverage for the favourable incorporation of transnational capital into the national ITC sociotechnical process. The difficulty with the latter alternative, however, is that it demands a strong discriminatory stand on the part of UDCs against, perhaps, the most powerful TNCs wishing to bring that country into their sphere of capital accumulation. Thus, conflict is almost certain to develop, eventually leading to the involvement of not only transnational capital but, also, of other dominant social constituents of those

countries wherefrom the discriminated TNCs originate. The reason is straightforward enough. Although we have been considering UDCs-TNCs relationships, the fact is that, in the final analysis, TNCs are basically a mechanism whereby the interlinking of two nationally-based sociotechnical processes is taking place. This means that action against powerful TNCs is in fact action against powerful fragments of the corporate capital constituent of the dominant complex of power shaping the development of an ITC sociotechnical process in a given DC. Therefore, the perception of threat to overriding interests may easily pervade all members of the DCs dominant social constituency with the result that retaliatory action may ensue. In practice, the form and content of these actions may go from simple pressures derived from threats of action to actual trade sanctions for instance and, even further, attempts to destabilize governments to alter the very nature of the dominant social constituency shaping the unfolding of the sociotechnical process in UDCs. The considerations to be taken into account in this respect are numerous and vary from every country-to-country situation, depending clearly on the countries' relative strength and particular combination of historical galvanizing forces. On the whole, however, it is clear that looking at the UDCs-DCs sociotechnical interlinking, not from the standpoint of UDCs-TNCs interrelations, but from the standpoint of the involvement of their overall social constituencies, then the correlation of strength is certainly in favour of DCs, which may go a long way to explain why UDCs wishing to involve TNCs in the unfolding of their sociotechnical systems find it hard to implement effective measures of discrimination and control. On the other hand, it has to be emphasized that, however unbalanced the sociotechnical interlinking of DCs and UDCs may be, the latter countries clearly possess sociotechnical factors which are important to the materialization of DCs sociotechnical processes and which, for the same reason, have led us to talk of a relation of unequal interdependence between DCs and UDCs, instead of using the most common term of dependence. With the term unequal interdependence, we have sought to capture the imbalance in the relation between DCs and UDCs while at the same time making it clear that the development of a DCs sociotechnical system not only depends upon, but indeed incorporates in its very shape, important sociotechnical elements from UDCs. Let us take, for instance, the development of a capitalist science-based IMC in DCs. Here, UDCs markets are crucial to the global nature of the accumulation process of DCs electronics capital and of capital as a whole for that matter. Historically, so it has been the incorporation of UDCs in the internationalization of the production process of electronic components and equipment. The latter has meant, for instance, that

not only has labour from UDCs played (under the direct control of DCs corporate capital) an integral part in the development of an IMC in DCs; also, specific UDCs socio-cultural relations such as tradeunionism, tax regulations, safety standards, etc., have been important. In addition, it is also a fact that, in some UDCs, various national companies have become market suppliers of some parts and equipment to DCs companies and have also entered into formal technical agreements with them. All these developments, suggest a clear presence of UDCs in the unfolding of an IMC in DCs. Indeed, we can go even further and argue that, from the point of view of an international interpenetration of sociotechnical systems, what we have here is undoubtedly a process whereby sociotechnical constituents from UDCs have become part of the social constituency of a DCs sociotechnical system operating on a global scale. In other words, in the same manner as this global expansion of DCs sociotechnical processes has brought the latter's products, machinery, etc., and, above all, transnational capital into the UDCs sociotechnical realms, so UDCs markets, labour, space and capital have become part of the global constituency of the DCs sociotechnical processes. The crucial point to keep in mind here is that we are no longer thinking of the action of DCs sociotechnical systems as confined to one country or region alone but truly as globally unfolding processes. When this happen, the inter-country limits begin to blur as far as the materialization of the system is concerned and factors from other countries can legitimately be seen as constituents of a DCs sociotechnical process. For instance, UDCs labour under the direct control of TNCs can be seen as both, part of the intrinsic social constituents of a UDCs sociotechnical process (just like transnational capital itself) and, simultaneously, part of the intrinsic labour constituent of a globally unfolding DCs sociotechnical process. Likewise, UDCs markets bring consumers such as governments, UDCs companies and other-likely consumers into the global constituency of DCs sociotechnical processes.

To a certain extent, therefore, we can compare this process of sociotechnical interlinking between countries with that of the interlinking of different sociotechnical system discussed above (see section 5.3.6). Certainly, there is a general analogy to be made from the fact that, in both cases, a clear interpenetration of sociotechnical systems takes place insofar as components of one system actually become part of the make up of the other system and vice-versa. The difference, of course, lies in the fact that in the case of DCs-UDCs sociotechnical interlinking, we are dealing, not with essentially different kinds of sociotechnical systems in one country, but rather, with essentially the same kind



of sociotechnical process in different countries joined by a basically unequal relation of interdependence. In such kind of relation, which need not arise in the former case, the crucial factor is that, although sociotechnical constituents of DCs and UDCs are effectively playing a direct role mainly in the production and diffusion moments of both countries sociotechnical processes, for UDCs constituents operating in the global DCs sociotechnical process the trend is to be either dominated (labour) or weak (national capital), while the DCs constituent operating within the UDCs sociotechnical processes is normally transnational capital, a very prominent member of the DCs dominant complex of power. No doubt that this situation is at the very heart of the UDCs-DCs relation of unequal interdependence.

In practice, however, unequal interdependence is clearly not a static situation. It not only varies from one UDC-DC sociotechnical relationship to another, but, equally, is continuously changing as the interacting countries alter themselves naturally in the course of their historical developments. In this context, therefore, the fundamental problem for those UDCs aiming at developing a self-reliant ITC sociotechnical process is how in their relations with DCs they can stimulate a process of transformations leading to the disappearance of the profound inequality of these relations while using in this process the reality of interdependence bringing together the social interests dominating in both countries. Obviously, there can be no universal answer to this problem but, from all we have seen in this work, it seems clear that the following general points must be taken into account by UDCs policy-makers when dealing with the potential contribution of international interlinking to the development process of UDCs sociotechnical systems.

a) Although transnational capital is by far the most important institutional channel or mechanism whereby the sociotechnical interlinking of DCs and UDCs is materialized, it is plain that, as a fresh look at figures 5.2 and 5.3 will help us to remember, there are others which must also be given careful consideration. In this respect, the variety of institutional depositories of basic resources and socio-political organizations depicted in figure 5.2, shows that there might be significant opportunities for UDCs in the interlinking through institutions controlled by social constituents other than DCs corporate capital. Therefore, intelligence about the overriding and particular interests of specific DCs institutions such as universities and other educational and scientific institutions, foundations, internationally-oriented and, above all, Third World-oriented



governmental or private institutions, and also about supranational UN-type organizations, becomes highly relevant to a well informed approach to developing fully the potential for favourable international interlinking present in the very nature of ITCs sociotechnical processes. Such an approach should of course include intelligence and ways of benefiting from forms of sociotechnical interlinking with DCs socio-political organizations such as relevant trade union organizations and scientific and professional institutions which, because of their weight at the level of aggregate social constituents, may influence the aggregate development trends of any process of sociotechnical interlinking between countries. From what we saw in our discussion on the *raison d'etre* and overriding interests of the social constituents of a capitalist science-based ITC sociotechnical process, it seems plain that it is within the ranks of the science constituent, particularly, within the institutional sphere where science interests remain dominant, that an important mechanism for sociotechnical interlinking favourable to UDCs exists. Let us not forget, however, that, under the pressures of historical galvanizing forces, the practical manifestation of science's *raison d'etre* can be mediated by the overriding interests of other social constituents in such a way that the potential implicit in its own interests can be seriously curtailed. On the other hand, although much more unlikely to happen, it is theoretically conceivable that there may be historical conjunctures when it might be in the interests of even DCs social constituents such as the military to contribute to the development of an ITC sociotechnical process in a given UDC. Although no example comes to my mind, the theoretical possibility exists and it is to UDCs policy-makers to assess whether the practical possibility is there too.

b) Within the UDCs own jurisdiction, it seems clear that the long-term pursuit of an ITC sociotechnical process for development purposes will inevitably demand a selective approach to the content and direction of the sociotechnical interlinking with DCs as a way to stimulate desired trends and developments while discouraging unwanted ones. If we again think that the interpenetration of sociotechnical processes is in fact the interpenetration of ensembles of technical and socio-cultural relations, the need for such a selective approach becomes even clearer for those countries, or dominant social constituents, aiming at encouraging the development of technical and socio-cultural relations in line with the country's ultimate development goals. In this context, a first line of policy-making and action relates to the presence and activities of transnational capital in UDCs. Here, for all we have seen in this thesis, it is plain that, if any

contribution is to be made by TNCs to the UDCs sociotechnical process, their operations can hardly be allowed to pursue, without controls and counterbalances, the dictates of their own global process of capital accumulation. Therefore, a clear policy towards transnational capital and direct foreign investment is necessary; a policy which must seek to guide the latter towards making an effective contribution to the development of the UDCs sociotechnical process. When deemed necessary such policy may certainly include selective delinking of TNCs presence through such mechanisms as the market reservation practiced in Brazil. It goes without saying that, at all times, a careful assessment of force correlation between the parties involved in the context of specific historical galvanizing forces must inform the policies actually implemented. Along with the treatment to TNCs, however, there is a second broad line of policy-making and action necessary to a selective approach to the content and direction of the sociotechnical interlinking with DCs. This relates to the very level of basic resources of an ITC sociotechnical process and, particularly, to such material resources as DCs machinery and products which penetrates the UDCs ensemble of technical and socio-cultural relations. As we have argued before, and is illustrated in Figure 5.2, such material resources are effectively crystallizations of specific combinations of financial, human, material, time and space resources and, more generally, of the very nature and workings of DCs ensembles of technical and socio-cultural relations. This means, therefore, that they carry with them potential needs and consequences which may not only discourage the growth of related UDCs basic resources, but overall, spearhead forms of technical and socio-cultural interlinking which rather than contributing to the effective development of UDCs sociotechnical process, may actually contribute to reproduce its condition of unequal interdependence by deviating resources from the priorities demanded by the strengthening of the national sociotechnical process. Consequently, a clear policy of selective interlinking through basic resources is needed to complement that related to transnational capital. Such a policy must strongly favour the diffusion of those DCs basic resources which are necessary and consistent with the strengthening of the UDCs sociotechnical realm while discouraging the diffusion of others which are superfluous or damaging to such purposes.

c) Most importantly, it is clear that the above recommendations can only be fruitful in a context of long-term policies of consistent support to the development of UDCs sociotechnical constituents. This is an absolute need for the development of an ITC sociotechnical process consistent with the development

goals of given UDCs. The international interlinking of sociotechnical systems is no solution on its own and, indeed, is a contradiction in terms to talk of ITC self-reliance without the presence of a strong social constituency to materialize it. It is only the presence of national social constituents with their sociotechnical institutions which will enable UDCs to benefit from their sociotechnical interlinking with DCs. They will constitute the necessary foundation and the means for realizing the appropriation of those DCs technical and socio-cultural relations which are consistent with both the qualitative/quantitative development of the UDCs sociotechnical process and the ultimate purposes informing the pursuit of such a development. To use Edquist's terms. in the DCs-UDCs sociotechnical interlinking, they will be the social carriers of available DCs techniques (43) into the sociotechnical process of their respective UDCs. Most crucially, for the purposes of self-reliance, however, the presence of strong UDCs constituents will enable, more than benefiting from the interlinking with DCs, the eventual creation and production of crucial basic resources such as knowledge, machinery and products not only within the confines of the UDCs sociotechnical processes themselves but, above all, in accordance with these countries' development purposes and priorities. It seems to us that the latter development would be the ultimate test in the long process leading to the overcoming of unequal interdependence.

d) Finally, and although we have not discussed them here, forms of sociotechnical interlinking between UDCs themselves undoubtedly represent an important area of policy-making and action for UDCs. Just as we have done

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(43) In the literature on technology theory, Edquist's concept of 'social carriers of techniques' is the nearest one can find to our own concept of social constituent of technological processes. 'Social carriers of techniques', however, has been developed to account for the choice of techniques already available "on the shelf" and refers primarily to what we have identified as the socio-institutional level of analysis of the unfolding of sociotechnical systems. In Edquist's words..."A social carrier of a technique is a social entity which chooses and implements a certain technique. It "carries" it into the society. It is defined in the following way. For a certain technique to be chosen and implemented in a specific context or situation, the technique must, of course, actually *exist* somewhere in the world, i.e., it must be "on the shelf". But some additional conditions must also be fulfilled:....1) A social entity that has a subjective *interest* in choosing and implementing the technique must exist...2) This entity must be *organized* to be able to make a decision and also be able to organize the use of the technique properly...3) It must have the necessary social, economic and political *power* to materialize its interest i.e., to be able to implement the technique chosen...4) The social entity must have *information* about the existence of the technique and functionally similar ones...5) It must have *access* to the technique in question...6) Finally, it must have, or be able to acquire, the necessary *knowledge* about how to handle i.e., operate, maintain and repair, the technique"...If all the six conditions listed above are fulfilled, the social entity is a *social carrier of a technique*" (Edquist, 1985, p77). See

with the DCs-UDCs form of interlinking, however, the difficulties as much as the difficulties of this path must be clearly recognized, lest the idea prevail that, in practice, Third World countries form some kind of brotherhood of interests which makes sociotechnical interlinking easier. It seems to us that, by and large, history does not bear out this assumption with the result that UDCs-UDCs interrelations are not essentially better or closer than those between DCs and DCs for instance. True enough, within specific regions sharing cultural and historical traits the chances of closer interrelations are better, as the existence of various regional common markets would testify. In the development of a regional ITC sociotechnical process, however, much more than the limited achievements of common markets are needed. As it can be implied from the previous point, the need for a consistent regional social constituency of an ITC sociotechnical process is a fundamental requisite. Thus far, there is hardly any historical precedent of a successful generation of a UDCs-UDCs social constituency. In principle, however, the possibility of its occurrence cannot be discarded for the future. It might conceivably happen that specific combinations of historical galvanizing forces may greatly stimulate national social constituents into a process of integration leading to the emergence of an effective regional social constituency. Obviously, this is a matter difficult to predict, but, from what we have seen in our discussion on overriding interests, if such a process of integration is to develop at all, the likelihood is that it must first begin with the effective interlinking -under a regional plan of action leading to the development of a regional ITC sociotechnical process- of government and science sociotechnical institutions from different UDCs. All in all, within the context of the sociotechnical characteristics of countries involved and the historical circumstances of the time, it is to policy-makers to consider all the benefits while facing the difficulties involved in the UDCs-UDCs path of sociotechnical interlinking.

In this way, therefore, with the four points just made, we now bring our discussion on the international dimension of the development of ITCs sociotechnical processes to an end. This means, therefore, that we have also come to the end of the present conclusion where we have attempted to conceptualize the workings of large-scale and complex ITC sociotechnical processes from their basic sociotechnical constituents to the international dimension of their practical materialization. Obviously, we are aware that any attempt at systematically

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theorizing on such a wide range of issues is bound to leave untouched problems which, inevitably, will appear as important to other analysts. We believe, however, that, whatever its weaknesses, the conceptual system exposed in this conclusion constitutes, not merely a well-spent effort, but, above all, a relevant contribution to the much needed theoretical systematization of the complex reality of ITC sociotechnical processes, which is so fundamental to the implementation of effective policy-making aiming at directing its path of development.

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also Edquist and Edquist (1979).

## Bibliography



## Bibliography Chapter I

- Aguirre, C. and Heredia, R. (1982). *Elements for the Formulation of a Regional Programme of Action in the Area of Microelectronics*. ID/WG.372/10, UNIDO, Vienna.
- Araoz, A. (1977). "Compras Estatales y Desarrollo Tecnológico", *Comercio Exterior*, Vol.27, No.6, pp. 654-670.
- Aslam, M. (1981). *Implications of Microelectronics in Developing Countries*. B.P.10, UNIDO, Vienna.
- Barron, I. and Curnow, R. (1979). *The Future with Microelectronics*. Frances Pinter, London.
- Bell, D. (1974). *The Coming of the Post-Industrial Society: A Venture in Social Forecasting*. Heinemann, London.
- Bell, D. (1980). "The Social Framework of the Information Society", in M. Dertouzos and J. Moses (eds.). *The Computer Age: A Twenty Years View*. The MIT Press, Camb., Mass., 1980, pp.163-211.
- Bessant, J. and Dickson, K. (1982). *Computers and Employment: A Selected Bibliography*. Heyden & Son, London.
- Bessant, J., Braun, E. and Moseley, R. (1980). "Microelectronics in Manufacturing Industry: The Rate of Diffusion" in T. Forrester (1980) editor. pp.198-218.
- Bogod, J. (1982). "The UK Council for Computing Development", *IDS Bulletin*, Vol.13, No.2, pp.52-55.
- CEPAL (1949). *Estudio Economico de America Latina*. Santiago.
- CEPAL (1974). *Progreso Tecnico y Desarrollo Socioeconomico en America Latina*. ST/CEPAL/Conf.53/L.2. Santiago.
- CIS (1979). *The New Technology*. Counter Information Service, London.
- Chudnovsky, D., Nagao, M. and Jacobsson, S. (1983). *Capital Goods Production in the Third World*. Frances Pinter, London.
- Claeys, C. (1983). *The Impact of Microelectronics on Biomedical Applications in Developing Countries*. UNIDO/IS.392, Vienna.
- Clarke, A. (1981). "Third World 2001", *South*, November, pp.13-15.
- Cross, M. (1983). "Human Cost of Cheap Electronics", *New Scientist*, 27 October, p.250.
- Dickson, K. and Marsh, J. (1978). *The Microelectronics Revolution: A Brief Assessment of the Industrial Impact with a Selected Bibliography*. Occasional Paper, Technology Policy Unit, University of Aston.
- Dray, J. and Menosky, J. (1983). "Computers and a New World Order", *Technology Review*, May/June. pp.12-16.

- Eckaus, R. (1955). "The Factor Proportions Problem in Economic Development", *The American Economic Review*, September. Reprinted in A. Agarwala and S. Singh (eds.). *The Economics of Underdevelopment*. Oxford U.P., London, 1973, pp.348-378.
- Eckaus, R. (1962). "Technological Change in the Less Developed Areas", *Development of the Emerging Countries*. The Brookling Institution, Washington D.C.
- Ernst, D. (1980). "International Transfer of Technology, Technological Dependence and Underdevelopment: Key Issues" in D. Ernst (editor) *The New International Division of Labour, Technology and Underdevelopment: Consequences for the Third World*. Campus, Frankfurt, 1980, pp.15-75.
- Ernst, D. (1981a). "Industrial Redeployment and Control over Technology - Consequences for the Third World", *Vierteljahresberichte*, No.83, March, pp.13-44.
- Ernst, D. (1981b). *Restructuring Industry in a Period of Crisis - The Role of Innovation. An Analysis of Recent Developments in the Semiconductor Industry*. UNIDO/IS.285. Vienna. Later published in 1983 under the title *The Global Race in Microelectronics. Innovation and Corporate Strategy in a Period of Crisis*. Campus, Frankfurt.
- Ernst, D. (1985). "Automation and the Worldwide Restructuring of the Electronics Industry. Strategic Implications for Developing Countries", *World Development*, Vol.13, No.3, pp.333-352.
- Fernandez de la Garza, G. (1983). *Some Considerations about a Practical Approach to the Development of Technical Infrastructure for Microelectronics*. ID/WG.401/6, UNIDO, Vienna.
- Fernandez de la Garza, G. and Octavio, M. (1986). *Report on the UNIDO Mission Preparatory to the Establishment of a Regional System for Microelectronics in Latin America (REMLAC)*. ID/WG.440/6 and ID/WG.440/6/Add.1, Vienna.
- Filipello, O. and Sagarzazu, R. (1982). *The Development of Microelectronics in Argentina*. ID/WG.372/12, UNIDO, Vienna.
- Forrester, T. (1980) editor. *The Microelectronics Revolution*. Basil Blackwell, Oxford.
- Freeman, C. (1979). "The Kondratiev Long Waves, Technical Change and Employment", in OECD. *Structural Determinants of Employment and Unemployment*. Vol.2, Paris, pp.181-196.
- Freeman, C. (1982). *Science, Technology and Employment*. SPRU/Imperial College Papers in Science, Technology and Public Policy, No.1.
- Freeman, C., Clark, J. and Soete, L. (1982). *Unemployment and Technical Innovation*. Frances Pinter, London.
- Friedrichs, G. and Schaff, A. (1982) editors. *Microelectronics and Society: For Better or For Worse*. Pergamon Press, Oxford.
- Frobel, F., Heinrichs, J. and Kreye, O. (1978). "Export-Oriented Industrialization of Underdeveloped Countries", *Monthly Review*, Vol.30, No.6, pp.22-27.

- Frobel, F., Heinrichs, J. and Kreye, O. (1980). *The New International Division of Labour*. Cambridge U.P., London.
- Galli, E. (1982). *Microelectronica y Telecomunicaciones in America Latina*. ID/WG.372/4, UNIDO, Vienna.
- Galli, E., Welch, M. and Herrera, R. (1982). *Telecommunications and Microelectronics: Some Observations*. ID/WG.372/11, UNIDO, Vienna.
- Grayson, L. (1984). *The Social and Economic Impact of New Technology 1978-1984. A Select Bibliography*. Technical Communications, Herts, England.
- Grossman, R. (1979). "Women's Place in the Integrated Circuit" in Special Joint Issue *Southeast Asia Chronicle*, No.66, Jan-Feb. 1979 and *Pacific Research*, July-Oct. 1978, pp.2-17.
- Hahn, S. (1981). *Application of Microelectronics for Development: Issues for Consideration*. M.E.2, UNIDO, Vienna.
- Heckscher, E. (1919). "The Effect of Foreign Trade on the Distribution of Income", *Economisk Tidskrift*, Vol.21, pp.497-512.
- Heden, C. (1981). *Potential Application of Computer Conferencing in Less Developed Countries*. B.P.9, UNIDO, Vienna.
- Herrera, R. (1982). *Microelectronics in Peru*. ID/WG.372/16. UNIDO, Vienna.
- Hirschman, A. (1968). *The Strategy of Economic Development*, Yale U.P., London.
- Hoffman, K. (1983). *Microelectronics and Industry in the Third World*. IDRC, Ottawa.
- Hoffman, K. (1985). "Microelectronics, International Competition and Development Strategies: The Unavoidable Issues - Editor's Contribution", *World Development*, Vol.13, No.3, pp.263-272.
- Hoffman, K. (1985a). "Clothing, Chips and Competitive Advantage: The Impact of Microelectronics on Trade and Production in the Garment Industry", *World Development*, Vol.13, No.3, pp.371-392.
- Hoffman, K. and Rush H. (1980a). "Microelectronics and Industrialization in the Third World", *Development Research Digest*, No. 3, Spring, pp.48-54.
- Hoffman, K. and Rush, H. (1980b). "Microelectronics, Industry and the Third World", *Futures*, August, pp.289-302.
- Hoffman, K. and Rush, H. (1982). "Microelectronics and the Garment Industry: Not a Perfect Fit Yet", *IDS Bulletin*, Vol.13, No.2, pp.35-41.
- Hoffman, K. and Rush, H. (1983a). *Microelectronics and Clothing: The Impact of Technical Change on a Global Industry*. ILO, Geneva.
- Hoffman, K. and Rush, H. (1983b). "From Needles and Pins to Microelectronics" in S. Jacobsson and J. Sigurdson (1983) editors. pp.71-101.
- Hurtado, M.E. (1982). "Tug of War Over Computers", *South*, January, pp.28-29.

Hutchins, D. (1986). "Having a Hard Time with Just-in-Time", *Fortune*, 9 June, pp.56-58.

Ide, T.R. (1982). "The Technology", in G. Friedrichs and A. Schaff (1982) editors. pp.37-88.

Jacobsson, S. (1979). *Microelectronics, Technical Change and Employment in Less Developed Countries*. RPI, Univ. of Lund, Sweden. Mimeo.

Jacobsson, S. (1982a). *Technical Change and Technology Policy: The Case of Numerically Controlled Lathes in Argentina*. ECLA/IDB/IDRC/UNDP Research Programme on Scientific and Technological Development in Latin America. Working Paper No.44, Buenos Aires.

Jacobsson, S. (1982b). "Electronics and the Technology Gap - The Case of Numerically Controlled Machine Tools", *IDS Bulletin*, Vol.13, No.2, pp.42-46.

Jacobsson, S. (1983). *Entry into the Production of Electronic Based Machine Tools*. R.P.I., Univ. of Lund, Sweden. Mimeo.

Jacobsson, S. (1985). "Technical Change and Industrial Policy: The Case of Computer Numerically Controlled Lathes in Argentina, Korea and Taiwan", *World Development*, Vol.13, No.3, pp.353-370.

Jacobsson, S. and Ljung, T. (1983). "Electronics, Automation and Global Comparative Advantages in the Engineering Industry" in S. Jacobsson and J. Sigurdson (1983) editors. pp.139-175.

Jacobsson, S. and Sigurdson, J. (1983) editors. *Technological Trends and Challenges in Electronics: Dominance of the Industrialized World and Responses in the Third World*. R.P.I., Univ. of Lund, Sweden.

James, G. (1982). "Microelectronics and Development", *VITA News*, July. pp.3-6.

Jamison, A. (1983). "Monitoring the Monitors: A Critique Instead of a Conclusion" in S. Jacobsson and J. Sigurdson (1983) editors. pp.293-314.

Junne, G. (1986). "New Technologies and Third World Development", *Vierteljahresberichte*, No.103, March, pp.3-10.

Kamenetzky, M. (1973). *El Poder de Compra del Estado Como Instrumento de Politica Tecnologica*. Paidos, Buenos Aires.

Kaplinsky, R. (1979). *The Impact of Microelectronics on LDCs exports of manufactures to DCs*. IDS, Univ. of Sussex, Brighton. Mimeo.

Kaplinsky, R. (1980). "Microelectronics in the Third World", *Radical Science Journal*, No.10, pp.37-51.

Kaplinsky, R. (1981). "Radical Technical Change and Export-Oriented Industrialization: The Impact of Microelectronics", *Vierteljahresberichte*, No.83, March, pp.81-100.

Kaplinsky, R. (1982a) editor. *Comparative Advantage in an Automating World*. *IDS Bulletin*, Vol.13, No.2.

- Kaplinsky, R. (1982b). "Is There a Skill Constraint in the Diffusion of Microelectronics", *ibid.* pp.47-51.
- Kaplinsky, R. (1982c). *The Impact of Electronics on the International Economic Setting - The Case of Computer-Aided Design*. UNIDO/IS.297.
- Kaplinsky, R. (1982d). *Computer-Aided Design: Electronics, Comparative Advantage and Development*. Frances Pinter, London.
- Kaplinsky, R. (1983). "Computer-Aided Design: Electronics and the Technological Gap Between DCs and LDCs" in S. Jacobsson and J. Sigurdson (1983) editors. pp.103-138.
- Kaplinsky, R. (1984a). "Trade in Technology - Who, What, Where and When?" in M. Fransman and K. King (editors). *Technological Capability in the Third World*, MacMillan, London, 1984, pp.139-160.
- Kaplinsky, R. (1984b). *Automation: The Technology and Society*. Longmans, London.
- Kaplinsky, R. (1985). "Electronics-Based Automation Technologies and the Onset of Systemofacture: Implications for Third World Industrialization", *World development*, Vol.13, No.3, pp.423-439.
- King, A. (1982a). "Introduction: A New Industrial Revolution or Just Another Technology" in G. Friedrichs and A. Schaff (1982) editors. pp.1-36.
- King, A. (1982b). "Microelectronics and World Interdependence". *ibid.* pp.311-336.
- Kleinknecht, A. (1981). "Innovation, Accumulation, and Crisis: Long Waves in Economic Development?", *Review*, Vol.4, No.4, pp.683-711.
- Kondratieff, N. (1979). "The Long-Waves in Economic Life", *Review*, Vol.2, No.4, pp.519-562. First Published in Russian in 1925 and partially in English in 1935.
- Kopetz, H. (1984). *Guidelines for Software Production in Developing Countries*. UNIDO/IS.440. Vienna.
- Kopetz, H. (1985). *The Prospects for Software Production in Developing Countries*, UNIDO ID/WG.437/4, Vienna.
- LaDou, J. (1984). "The Not-So-Clean Business of Making Chips", *Technology Review*, Vol.87, No.4, pp.22-36.
- Lahera, E. and Nochteff (1983). "La Microelectronica y el Desarrollo Latinoamericano", *Revista de la CEPAL*, Abril, pp.169-183. A previous version of this paper was published in 1982 under the title *La Microelectronica y el Desarrollo de America Latina: Problemas y Posibilidades de Accion*. E/CEPAL/R.317.
- Lalor, E. (1985). *The Use of Public Purchasing as a Tool to Develop Technological Competence in Microelectronics*, UNIDO ID/WG.440/1, Vienna.
- Lund, R. (1982a). *Las Aplicaciones de los Microprocesadores y el Desarrollo Industrial*. ID/WG.372.14. UNIDO, Vienna.



- Lund, R. (1982b). *Microprocessors and Productivity: Cashing in our Chips*. ID/WG.372/3. UNIDO, Vienna.
- McMullen, N. (1982). *The Newly Industrializing Countries: Adjusting to Success*, British-North American Committee, Canada.
- Mammana, C. (1982) *Cultural Aspects of Microelectronics Technology; Brazil*. ID/WG.372/13. UNIDO, Vienna.
- MAP (The Department of Industry Programme to Encourage the Application of Microelectronics) (1982). *Bibliography on Microelectronics Applications*, Department of Industry, London. See also various "Summary of Trade and Technical Press" produced by MAP during 1982-1983.
- Mason, J. (1984). *New Microelectronics Technologies*. ID/WG.412/1. UNIDO, Vienna.
- Mattelart, A. (1986). "Infotech and the Third World", *Radical Science Journal*, No.16, pp.27-35.
- Moravcsik, M. (1975). *Science Development: Towards the Building of Science in Less Developed Countries*. IDRC, Indiana.
- Moravcsik, M. and Ziman, J. (1975). "Paradisia and Dominitia: Science in the Developing World". *Foreign Affairs*, Vol.53, No.4, pp.699-724.
- Morehouse, W. (1979). "Chips With Everything", *Development Forum*, Vol.7, No.6; pp.1 & 6.
- Nolan, R. (1983). *Informatics for Industrial Development*. UNIDO/IS.415. Vienna.
- Norman, H. (1984). "The Information Age and the Third World", *VITA News*, July, pp.4-8.
- O'Connor, D. (1985). "The Computer Industry in the Third World: Policy Options and Constraints", *World Development*, Vol.13, No.3, pp.311-332.
- OECD (1979). *The Impact of Newly Industrializing Countries on Production and Trade in Manufactures*. Paris.
- Ohlin, B. (1933). *Interregional and International Trade*. Harvard U.P., Camb. Mass.
- Oldham, W. (1977). "The Fabrication of Microelectronics Circuits", *Scientific American*, Vol.237, No.3, pp.110-128.
- Oliphant, J. (1982a). *Potential Applications Suitable for Microprocessors Implementations: Some Illustrative Possibilities*. ID/WG.372/6. UNIDO, Vienna.
- Oliphant, J. (1982b). *Microprocessors Applications in Developing Countries*. UNIDO/IS.351. Vienna.
- Olle, W. (1986). "New Technologies and the International Division of Labour: Retransfer of Foreign Production from Developing Countries", *Vierteljahresberichte*, No.103, March, pp.11-18.



- Pinto, A. (1969). *America Latina: El Pensamiento de la CEPAL*. Editorial Universitaria, Santiago.
- Rada, J. (1980a). *The Impact of Microelectronics: A Tentative Appraisal*. ILO, Geneva.
- Rada, J. (1980b). "Microelectronics, Information Technology and Its Effects on Developing Countries" in J. Berting, S.C. Mills and H. Wintersberger (1980) editors. *Socioeconomic Impact of Microelectronics*, Pergamon Press, Oxford. pp.101-146.
- Rada, J. (1981). "The Microelectronics Revolution: Implications for the Third World", *Development Dialogue*, No.2, pp.41-67.
- Rada, J. (1982a). *The Impact of Microelectronics and Information Technology: Case Studies in Latin America*. UNESCO, Paris.
- Rada, J. (1982b). *Microelectronics: Its Impact and Policy Implications*. ID/WG.372/5. UNIDO, Vienna.
- Rada, J. (1982c). "Technology and the North-South Division of Labour", *IDS Bulletin*, Vol.13, No.2, pp.5-13.
- Rada, J. (1982d). "A Third World Perspective" in G. Friedrichs and A. Schaff (1982) editors. pp.213-242.
- Radnor, M. (1982). *Prospects of Microelectronics Application in Process and Products Development in Developing Countries*. ID/WG.372/1. UNIDO, Vienna.
- Ramaer, J. and Pijs, P. (1981). *Adapting Technology: An Example from the Electronics Industry*. ID/WG.339/6. UNIDO, Vienna.
- Ramanathan, K. (1981). *Semiconductor Industry and R and D in India*. UNIDO, B.P.5. Vienna.
- Ramanathan, K. (1981a). *Future of Electronics and Technology Transfer*. UNIDO, B.P.1. Vienna.
- Ricardo, D. (1929). *The Principles of Political Economy and Taxation*. Everyman's Library, London. (Chapter XXXI, "On Machinery").
- Rocha, S. (1983). *The Brazilian Computer Industry: Self-Reliance versus Multinational Corporations. A Project Description*. R.P.I., Univ. of Lund, Sweden. Mimeo.
- Roose, D. (1980). "Cheaper Than Machines", *New Internationalist*, No.86, April, pp.15 & 28
- Roper, C. (1983). "French Flock to Computer Centre", *New Scientist*, 10 February, pp.358-361.
- Rostow, W. (1956). "The Take-Off Into Self-Sustained Growth", *Economic Journal*, March. Reproduced in A. Agarwala and S. Singh (1973) editors. *The Economics of Underdevelopment*, Oxford U.P., London. pp.154-186.
- Rostow, W. (1960). *The Stages of Economics Growth: A Non-Communist*

*Manifesto*, Cambridge U.P. London.

Schmitz, H. (1986). "Microelectronics Based Automation and Labour Utilization in Developing Countries", *Vierteljahresberichte*, No.103, March, pp.29-41.

Schumacher, E. (1973). *Small is Beautiful*. Harper and Row, N.Y.

Schumpeter, J. (1928). "The Instability of Capitalism", *Economic Journal*, pp.361-386. Reprinted in N. Rosenberg (ed.). *The Economics of Technological Change*. Penguin Books, England, 1971, pp.13-42.

Schumpeter, J. (1939). *Business Cycles*. McGraw-Hill, N.Y.

Schumpeter, J. (1961). *Theory of Economic Development*. O.U.P., N.Y. (Chapter 4, "Enterpreneurial Profit").

Servan-Schreiber, J-J. (1980). *The World Challenge*. Simon and Schuster, N.Y.

Sethi, J. (1982). "Wanted Abroad But not at Home", *South*, September, p.18.

Sherman, B. (1979). "A Lifeline for the Third World", *New Scientist*, 8 March, p.791.

Shirkie, R. and Fleury, J-M. (1981). "Development in Miniature", *IDRC Reports*, Vol.10, April, pp.5-7.

Sivanandan, A. (1980). "Imperialism in the Silicon Age", *Monthly Review*, Vol.32, No.3, pp.24-42.

Soete, L. (1985). "International Diffusion of Technology, Industrial Development and Technological Leapfrogging", *World Development*, Vol.13, No.3, pp.409-422.

Tigre, P. (1982). "Brazil: Future in Homework Hardware", *South*, February, pp.98-99.

Tigre, P. (1983). *Technology and Competition in the Brazilian Computer Industry*. Frances Pinter, London.

UKCCD (1981). *Sharing The Wealth of Computer Technology*. UK Council for Computing Development, London.

UKCCD (1984). *A Strategy for UKCCD*. UK Council for Computing Development, London.

UNCTAD (1981). *Trade and Development Report*. N.Y.

UNESCO (1979). *An Introduction to Policy Analysis in Science and Technology*. Science Policy Studies and Documents, No.46, Paris.

UNIDO Secretariat (1981). *Implications of Micro-Electronics for Developing Countries: A Preliminary Overview of Issues*. UNIDO/IS.246. Vienna.

UNIDO Secretariat (1983a). *Microelectronics and Developing Countries: Towards an Action-Oriented Approach*. ID/WG.384/5/Rev.1. Vienna.

UNIDO Secretariat (1983b). *Policy Responses to Technological Advances: Some*

*Illustrative Cases.* ID/WG.384/3/Rev.1. Vienna.

UNIDO Secretariat (1984a). *A Silicon Foundry to Service Developing Countries' Needs: A Preliminary Approach.* UNIDO/IS.444. Vienna.

UNIDO Secretariat (1984b). *Microelectronics Applications for Developing Countries: Preliminary Issues for Concerted Action.* ID/WG.419/1. Vienna.

UNIDO Secretariat (1985). *Proposed Structure of the Regional Network for Microelectronics in the ECLAC Region,* ID/WG.440/3, Vienna.

UNIDO Secretariat (1985a). *Some Considerations on the Context and Modalities of a Programme of Work for REMLAC,* ID/WG.440/4, Vienna.

UNIDO Technology Programme (1983). *The UNIDO Programme on Technological Advances.* UNIDO/IS.411. Vienna.

UNIDO Technology Programme (1984). *The UNIDO Programme on Technological Advances: Microelectronics.* UNIDO/IS.445. Vienna.

UNIDO (1981). *Report: Exchange of Views With Experts on the Implications of Technological Advances in Micro-Electronics for Developing Countries.* UNIDO/IS.242/Rev.1. Vienna.

UNIDO (1982a). *Report: UNIDO/ECLA Expert Group Meeting on Implications of Microelectronics for the ECLA Region.* ID/WG.372/17. Vienna.

UNIDO (1982b). *The International Industrial Restructuring Process: The EEC, The European Periphery and Selected Developing Countries.* 2 Vols., UNIDO/IS.360/Add.1. Vienna.

UNIDO (1983a). *Report: Workshop on Institutional and Structural Responses of Developing Countries to Technological Advances.* ID/WG.401/7. Vienna.

UNIDO (1983b). *Selected Statistical Indicators.* ID/WG.391/1. Vienna.

UNIDO (1983c). *Industrial Development Strategies and Policies and Socio-Economic Development in Developing Countries.* UNIDO/IS.380. Vienna.

UNIDO (1984). *A Statistical Review of the World Industrial Situation-1983.* UNIDO/IS.433. Vienna.

Vernon, R. (1966). "International Investments and International Trade in the Product Cycle", *Quarterly Journal of Economics*, Vol.80, No.2, pp.190-207.

Vernon, R. (1971). *Sovereignty at Bay*, Penguin Books, England.

Wad, A. (1982). "Microelectronics: Implications and Strategies for the Third World", *Third World Quarterly*, Vol.4, No.4, pp.677-697. For a shorter version of this paper, see "The Implications of Microelectronics for the Third World", *Lund Letter on Technology and Culture*, No.5, December 1982, pp.2-6.

Wajnberg, S. (1985). *Approach to Regional Microelectronics Co-Operation Programme*, UNIDO ID/WG.440/11, Vienna.

Walsh, J. (1982). "A French Connection in High-Tech for LDC's" *Science*,

Vol.215, 19 February, pp.948-949.

Wells, L. (1969). "Test of a Product Cycle Model of International Trade: U.S. Exports of Consumer Durables", *Quarterly Journal of Economics*, Vol.83, No.1, pp.152-162.

## Bibliography Chapter II

- Abelson, P. (1982). "The Revolution in Computers and Electronics", *Science*, Vol.215, No.4534, pp.751-753.
- Abraham, E., Seaton, C. and Smith, D. (1983). "The Optical Computer", *Scientific American*, Vol.248, No.2, pp.63-71.
- Albus, J. and Evans, J. (1976). "Robot Systems", *Scientific American*, Vol.234, No.2, pp.77-86b.
- Alexander, T. (1984). "Computing with Light at Lighting Speeds", *Fortune*, 23 July, pp.74-78.
- Anderson, R. (1976). *Data Processing and Management Information Systems*. MacDonald and Evans, England.
- Asia-Pacific Technology Review* (1982). Sept.-October.
- Atherton, W. (1984). *From Compass to Computers*, San Francisco Press, San Francisco.
- AT & T on Office Automation (1985). "Stormy Weather Ahead for the Automated Office", *Technology Review*, January, pp.32-35.
- Ayres, R. and Miller, S. (1982). "Industrial Robots on the Line", *Technology Review*, May/June, pp.35-46.
- Babbage, H. (1984). *Babbage's Calculating Engines*. MIT Press, Camb., Mass.
- Babbage, C. (1970). "Of the Analytical Engine", in Pylyshyn (1970) editor. pp.16-28. Paper adapted from C. Babbage, *Passages from the Life of a Philosopher*, Longsmann and Green, London, 1864.
- Bacon, G. (1982). "Software", *Science*, Vol.215, No.4534, pp.775-779.
- Barney, C. (1983). "A 'New' Goes Back 27 Years", *Electronics*, 3 November, pp.130-131.
- Beer, S. (1971). *Cybernetics and Management*. The English University Press Ltd., London.
- Bell, D. (1980). "The Social Framework of the Information Society", in T. Forrester (1980) editor, pp.500-549.
- Bessant, J. (1980a). "Microelectronics and Manufacturing Industry", *Microprocessors and Microsystems*, Vol.4, No.3, pp.89-93.
- Bessant, J. (1980b). "Making the Most of Microelectronics", *Iron and Steel International*, August 1980, pp.209-213.
- Bessant, J. (1981). *Microelectronics and Information Technology: An Overview of the European Experience*. Paper prepared for FLACSO Seminar on Microelectronics, Buenos Aires, December 1981. Mimeo.

Bessant, J. (1982a). "The Diffusion of Microelectronics" in S. Jacobsson and J. Sigurdson (editors). *Technological Trends and Challenges in Electronics*, RPI, Univ. of Lund, Sweden, pp.31-69.

Bessant, J. (1982b). "The Microchip: What it Means for Your Firm", *Works Management*, February, pp.27-31.

Bessant, J. (1984a). *Technology and Market Trends in the Production and Application of Information Technology: A Review of Developments During the Years 1982-1983*. UNIDO/IS.438, Vienna.

Bessant, J. (1984b). *Flexible Manufacturing Systems: An Overview*. Supplement to Microelectronics Monitor No.12. December, Technology Programme of UNIDO, Vienna.

Bessant, J. and Dickson, K. (1981). "Microelectronics and Manufacturing: The Marriage That Never Was ?", *Proceedings of EEC/FAST Conference on Information Technology - Impact on the Way of Life*, Dublin, November.

Bessant, J., Bowen, J., Dickson, K. and Marsh, J. (1981). *The Impact of Microelectronics: A Review of the Literature*. Frances Pinter, London.

Bessant, J. and Dickson, K. (1982). *Issues in the Adoption of Microelectronics*, Frances Pinter, London.

Bessant, J. and Haywood, B. (1985). "Taylor Flexible Systems to Suit Your Demands", *Works Management*, November, pp.67-69.

Birnbaum, J. (1982). "Computers: A Survey of Trends and Limitations", *Science*, Vol.215, No.4534, pp.760-765.

Bodington, S. (1973). *Computers and Socialism*, Spokesman Books, England.

Bowden, B. (1971). *Faster Than Thought*, Pitman, London.

Boyle, W. (1977). "Light-Wave Communications", *Scientific American*, Vol.237, No.2, pp.40-48.

Branscomb, L. (1982). "Electronics and Computers: An Overview". *Science*, Vol.215, No.4534, pp.755-760.

Bright, J. (1977). "Automation", *McGraw-Hill Encyclopaedia of Science and Technology*, Vol.1, pp.743-746.

British Computer Society Bulletin (1979). "The Challenge of the Microprocessor". December, pp.4-9.

Brock, C. (1975). *The U.S. Computer Industry: A Study of Market Power*, Ballinger Pub. Co., Camb., Mass.

Bromley, A. (1983). "Inside the World's First Computer", *New Scientist*, 15 Sept., pp.781-784.

Brown, J. and Glazier (1975). *Telecommunications*. Chapman and Hall, London.

*Bull. Sci. Tech. Soc.* (1981). "Supermarket Automation", A Socio-Technological



Module by the Faculty and Staff Department of Technology and Society College of Engineering and Applied Sciences. SUNY at Stony Brook, N.Y., Vol.1, No.3, pp.257-288.

Burkitt, A. and Williams, E. (1980). *The Silicon Civilization*. W. Allen, London.

Burns, A. (1981). *The Microchip: Appropriate or Inappropriate Technology*. Ellis Horwood Ltd., England.

Busignies, H. (1972). "Communication Channels", *Scientific American*, Vol.227, No.3, pp.99-113. *Business Week* (1979). "The Microprocessor. A Revolution for Growth". 19 March, pp.42B-I to 42W-I.

*Business Week* (1981). "Technologies for the 80's". 6 July, pp.30-35.

*Business Week* (1982). "Artificial Intelligence: The Second Computer Age Begins". 8 March, pp.46-51.

*Business Week* (1985). 30 September.

*Business Week* (1986). 21 April.

*Business Week* (1986). 5 May.

Buzbee, B., Ewald, R. and Worlton, W. (1982). "Japanese Supercomputer Technology", *Science*, Vol.218, No.4578, pp.1189-1193.

Bylinsky, G. (1980). "Here Comes the Second Computer Revolution", in T. Forrester (1980) editor, pp.3-15.

Bylinsky, G. (1985). "GM's Road MAP to Automated Plants", *Fortune*, 28 October, pp.73-78.

Bylinsky, G. (1986). "A Breakthrough in Automating the Assembly Line", *Fortune*, 26 May, pp.60-62.

Cawkell, A. (1978). "The Paperless Revolution: Forces Controlling the Introduction of Electronic Information Systems", *Wireless World*, July and August Issues, pp.38-42 and 69-74 respectively.

*Chemical Week*, (1984). 14 March.

Colombo, U. and Lanzavecchia, G. (1982). "The Transition to An Information Society: How Do We Manage the Change? What Can R and D Contribute?", in W. Bjorn-Andersen, M. Earl, O. Holst and E. Mumford (eds.). *Information Society: For Richer, For Poorer*. North-Holland Publishing Co., London, 1982, pp.3-33.

Committee on Science, Engineering, and Public Policy of the National Academy of Sciences, National Academy of Engineering and Institute of Medicine (1983). "The Next Generation of Robots" in *Frontiers in Science and Technology* (A Report), W.H. Freeman and Co., N.Y., pp.185-209.

Cornish, B. (1981). "The Smart Machines: Implications for Society of Tomorrow", *The Futurist*, August, pp.5-19.

- Cox, G., Jacobs, D. and Matthew, J. (1973). *Energy and Atoms*. Penguin Books, England.
- Dario, P. and De Rossi, D. (1985). "Tactile Sensors and the Gripping Challenge", *IEEE Spectrum*, August, pp.46-52.
- Davis, H. (1984). "Semiconductor Pace Growth of Computers", *Electronics Week*, 8 October, pp.59-69.
- Davis, R. (1977). "Evolution of Computers and Computing", *Science*, Vol.195, No.4283, pp.1096-1102.
- Davis, R. (1986). "Knowledge-Based Systems", *Science*, Vol.231, No.4741, pp.957-963.
- Davies, J. (1979). "How Microprocessors Simplify and Extend Future of NC Machines", in M. Whitbread (1979) editor, pp.81-83.
- Derry, T. and Williams, T. (1960). *A Short History of Technology: From the Earliest Times to A.D. 1900*. Clarendon Press, Oxford.
- Dertouzos, M. and Moses, J. (1980) editors. *The Computer Age: A Twenty-Year View*. MIT Press, Camb., Mass.
- Dertouzos, M. (1986). "Harnessing Computers Together", *Technology Review*, Feb/March, pp.44-57.
- de Sola Pool, I. (1980). "Technology and Change in Modern Communications", *Technology Review*, Nov/Dec., pp.64-75.
- de Sola Pool, I. (1983). *Technologies of Freedom*, Harvard U.P., Camb., Mass.
- Dickinson, H. (1965), "The Steam Engine to 1830", in C. Singer et al (1965) editors. Vol.IV, pp.168-198.
- Dickson, K. and Bessant, J. (1982). *Issues in the Industrial Adoption of Microelectronics*, Paper presented at EEC/FAST Conference, "The Transition to an Information Society: The Distribution of Benefits and Risks Associated with Microelectronics Application", London, January, Mimeo.
- Dreyfus, H. and Dreyfus, S. (1986). "Why Computers May Never Think Like People", *Technology Review*, Vol.89, No.1, pp.42-61.
- Dunsheath, P. (1962). *A History of Electrical Engineering*. Faber and Faber, London.
- Edelson, B. (1977). "Global Satellite Communications", *Scientific American*, Vol.236, No.2, pp.58-73.
- Edelson, B. and Cooper, R. (1982). "Business Use of Satellite Communications", *Science*, Vol.215, No.4534, pp.837-842.
- Electronics* (1980). Special Commemorative Issue on the History of Electronics. April.
- Electronics* (1982), 30 November.

*Electronics Weekly* (1983), 6 April.

*Electronics Weekly* (1984), 10 October.

Elias, D. (1978). "The Possible Development of Telecommunications and Its Effects on the Telecommunication Industry", *Phil. Trans. R. Soc. Lond.*, Vol.289A, pp.19-28.

English, L. (1979). "The Hardware Revolution", *Public Finance and Accountancy*, November, pp.12-15.

Enke, C. (1982). "Computers in Scientific Instrumentation", *Science*, Vol.215, No.4534, pp.785-791.

Ernst, D. (1983). *The Global Race in Microelectronics: Innovation and Corporate Strategies in a Period of Crisis*. Campus, Frankfurt.

Ernst, M. (1982). "The Mechanization of Commerce", *Scientific American*, Vol.247, No.3, pp.111-122.

Evans, B. (1980). "Computers and Communications", in M. Dertouzos and J. Moses (1980) editors. pp.338-366.

Evans, C. (1979). *The Mighty Micro: The Impact of the Computer Revolution*. Victor Gollancz, London.

Evans, C. (1981). *The Making of the Micro: A History of the Computer*. Victor Gollancz, London.

Evans, L. (1977). "Impact of the Electronics Revolution on Industrial Process Control", *Science*, Vol.195, No.4283, pp.1146-1151.

Farowich, S. (1986). "Communicating in the Technical Office", *IEEE Spectrum*, April, pp.63-67.

*Financial Times* (1986). "Survey on Manufacturing Automation", 3 February, pp.I-VIII.

*Financial Times* (1986). "US Team Brings Out the Animal in Microchips", 17 October, p.14.

Forte, S. (1979). "Microelectronics", *Personnel Management*, May, pp.26-29.

Farber, D. and Baran, P. (1977). "The Convergence of Computing and Telecommunications Systems", *Vol.195, No.4283, pp.1166-1170*.

Feigenbaum, E. and McCorduck, P. (1984). "The Fifth Generation", in R. Muller (ed.). *Impact 1984: New Horizons from Fifth Generation Computing*, Papers for the Working Conference, 17-18 Sept. 1984. London. pp.5-16.

Fleck, G. (1973). *A Computer Perspective*. Harvard U.P., Camb., Mass.

Forrester, T. (1980). *The Microelectronics Revolution: The Complete Guide to the New Technology and Its Impact on Society*. Basil Blackwell, Oxford.

Frazer, W. (1978). *Telecommunications*. MacDonald and Jane's, London.

- Friedrichs, G. and Schaff, A. (1982) editors. *Microelectronics and Society: For Better or For Worse*. Pergamon Press, Oxford.
- Gaines, B. (1984). "Perspectives on Fifth Generation Computing", in R. Muller (ed.). *Impact 1984: New Horizons from Fifth Generation Computing*. Papers for the Working Conference. 17-18 Sept. 1984. London. pp.32-82.
- Gabriel, R. (1986). "Massively Parallel Computers: The Connection Machine and NON-VON", *Science*, Vol.231, No.4741, pp.975-978.
- Galbraith, I. (1980). "What Automation Really Means", *Management Today*, November, pp.122-130.
- Galleger, R. (1981). "Information Theory", *Encyclopaedia Britannica*, pp.574-580.
- Gibbs, S. (1977). "The First Scientific Instruments", *Technology Review*, December, pp.41-51.
- Giuliano, V. (1982). "The Mechanization of Office Work", *Scientific American*, Vol.247, No.3, pp.125-134.
- Gleiser, M. (1978). "Men and Machines Before Babbage", *Datamation*, October, pp.125-139.
- Goldstein, C. (1982). "Optical Disk Technology and Information", *Science*, Vol.215, No.4534, pp.862-868.
- Goldstine, H. (1972). *The Computer from Pascal to von Neuman*. Princeton U.P., Princeton, N. Jersey.
- Gould, L. (1985). "Computer Run the Factory", *Electronics Week*, 25 March, pp.55-60 (Part I). "Computers Get It All Together", *Electronics Week*, 1 April, pp. 55-59 (Part II).
- Greenhalgh, M. (1974). "Drum", in E. de Bono, *Eureka: An Illustrated History of Inventions from the Wheel to the Computer*. Holt, Rinehart and Winston. N.Y., p.45.
- The Guardian* (1984), 6 September.
- Gunderson, L. and Keck, D. (1983). "Optical Fibers: Where Light Outperforms Electrons", *Technology Review*, May/June, pp.32-44.
- Haas, W. (1982). "Computing in Documentation and Scholarly Research", *Science*, Vol 215, No.4534, pp.857-861.
- Hodges, A. (1983). "Alan Turing: Mathematician and Computer Builder", *New Scientist*, 15 September, pp.788-791.
- Hoffman, K. (1985). "Microelectronics, International Competition and Development Strategies: The Unavoidable Issues - Editor's Introduction", *World Development*, Vol.13, No.3, pp.263-272.
- Hollingdale, S. and Tootill, G. (1976). *Electronics Computers*. Penguin Books, England.

- Holton, W. (1977). "The Large-Scale Integration of Microelectronic Circuits", *Scientific American*, Vol.237, No.3, pp.82-94.
- Hooke, S. (1965). "Recording and Writing", in C. Singer et al (1965) editors. Vol.I, pp.744-733.
- Hopcroft, J. (1984). "Turing Machines", *Scientific American*, Vol.250, No.5, pp.86-98.
- Hudson, C. (1982). "Computers in Manufacturing", *Science*, Vol.215, No.4534, pp.818-829.
- Hughes, T. (1983). *Networks of Power*. The John Hopkins U.P., London.
- Ide, T. (1982). "The Technology", in G. Friedrichs and A. Schaff (1982) editors. pp.37-88.
- IEEE Spectrum* (1982). January.
- IEEE Spectrum* (1984). "In Pursuit of the One-Month Chip", September, pp.28-49.
- IEEE Spectrum* (1986). January.
- IEEE Spectrum* (1986). "The Quest for Ballistic Action", February, pp.36-47.
- Industrial World* (1983), January.
- Industrial World* (1986). "Automation: Industry's CIM Strategy", March, pp.2-5.
- Jack, M. (1982) editor. *The Impact of Microelectronics Technology*, Edinburgh U.P., Edinburgh.
- Jacker, C. (1964). *Man, Memory and Machine*. MacMillan, London.
- Jennings, D., Landweber, L., Fuchs, I., Farber, D. and "Computer Networking for Scientists", *Science*, Vol.231. No.4741, pp.943-950.
- Kahne, S., Lefkowitz, I. and Rose, C. (1979). "Automatic Control by Distributed Intelligence", *Scientific American*, Vol.240, No.6, pp.54-66.
- Kaminsky, M. (1986). "Protocols for Communicating in the Factory" *IEEE Spectrum*, April, pp.56-62.
- Kaplinsky, R. (1984). *Automation: The Technology and Society*. Longmans, London.
- Katz, B. and Phillips, A. (1982). "The Computer Industry" in R. Nelson (editor). *Government and Technical Progress: A Cross-Industry Analysis*, Pergamon Press, N.Y., pp.162-232.
- Kay, A. (1977). "Microelectronics and the Personal Computer", *Scientific American*, Vol.237, No.3, pp.231-244.
- Kelly, R. (1982). "Microelectronics and the Microprocessor", in M. Jack (1982) editor. pp.26-40.

- Kemeny, J. (1955). "Man Viewed As a Machine", *Scientific American*, Vol.192, No.4, pp.58-66.
- Kent, E. and Shneier, M. (1986). "Eyes for Automatons", *IEEE Spectrum*, March, pp.37-45.
- Krouse, J. (1984). "Automation Revolutionizes Mechanical Design", *High technology*, Vol.4, No.3, pp.36-45.
- Kuck, D., Davidson, E., Lawrie, D. and Sameh, A. (1986). "Parallel Supercomputing Today and the Cedar Approach", *Science*, vol.231, No.4741, pp.967-974.
- Larsen, E. (1977). *Telecommunications: A History*. Frederick Muller, London.
- Laurie, P. (1980). *The Microrevolution*. Futura Publications, London.
- Layton, C. (1972). *Ten Innovations: An International Study on Technological Development and the Use of Qualified Scientists and Engineers in Ten Industries*. Allen and Unwin, London.
- Lefrancois, G. (1983). *Psychology*. Wadsworth Pub. Co., California.
- Leopold, G. (1984). "Factory Nets Follow a MAP", *Electronics Week*, 17 December, pp.20-21.
- Levine, R. (1982). "Supercomputers", *Scientific American*, Vol.246, No.1, pp.112-125.
- Lima, I. (1981). "The International Break-Away Effort", *Computing*, October, pp.22-23.
- Lindgren, M. and Lindqvist, S. (1982). "Scheutz's First Difference Engine Rediscovered", *Technology and Culture*, Vol.23, No.2, pp.207-213.
- Lineback, R. (1984). "AI Transforms CAD/CAM to CIM", *Electronics Week*, 17 December, pp.17-18.
- Luff, P. (1978). "The Electronic Telephone", *Scientific American*, Vol.238, No.3, pp.58-64.
- Lupton, T. (1986). "The Management of Change to Advanced Manufacturing Systems", *Technology Innovation and Society*, Vol.2, No.1, pp.12-18.
- Mackie, R. (1982). "Microprocessors in Industrial Process Control", in M. Jack (1982) editor. pp.82-90.
- MacIntosh, I. (1978). "Large-Scale Integration: Intercontinental Aspects", *IEEE Spectrum*, June, pp.51-56.
- Manuel, T. and Ivanczuk, S. (1983). "Commercial Products Begin to Emerge from Decades of Research", *Electronics*, 3 November, pp.127-129.
- Marsh, P. (1980a). "Communications for the Information Age", *New Scientist*, 23 October, pp.235-238.



- Marsh, P. (1980b). "Towards the Unmanned Factory". *New Scientist*, 31 July, pp.373-377.
- Marsh, P. (1981). *The Silicon Chip Book*. Abacus, London.
- Marsh, P. (1982). *The Robot Age*. Abacus, London.
- Marsh, P. and Naraine, M. (1983). "Satellites Jostle for Space". *New Scientist*, 9 June, pp.707-711.
- Marshack, A. (1972). *The Roots of Civilization*. McGraw-Hill, N.Y.
- Martin, S. (1970). *Numerical Control of Machine Tools*. The English Universities Press, London.
- Mavor, J. (1982). "Microelectronics: The Scene Today", in M.Jack (1982) editor. pp.1-11.
- Mayall, W. (1980). *The Challenge of the Chip*. HMSO, London.
- Maynard, J. (1975). *Dictionary of Data Processing*. Newness-Butterworth, London.
- Mayo, J. (1982). "Evolution of the Intelligent Telecommunications Network", *Science*, Vol.215, No.4534, pp.831-837.
- Meindl, J. (1977). "Microelectronic Circuit Elements", *Scientific American*, Vol.237, No.3, pp.70-81.
- Merdinger, A. (1977). "Numerical Control", *McGraw-Hill Encyclopaedia of Science and Technology*, Vol.13, pp.692-699.
- Mertes, L. (1981). "Doing Your Office Over -Electronically", *Harvard Business Review*, March-April, pp.127-135.
- Meyer, E. (1985). "Survey of Multiprocessors", *VLSI System Design*, November, pp.30-39.
- Mitroff, I. and Turoff, M. (1973). "The Whys Behind the Hows", *IEEE Spectrum*, March, pp.62-71.
- Morrison, P. and Morrison, E. (1961) editors. *Charles Babbage and His Calculating Engines: Selected Writings by Charles Babbage and Others*. Dover Publications, N.Y.
- Morrison, D., Snow, R. and Lamoureux, J. (1982). "Advances in Process Control", *Science*, Vol.215, No.4534, pp.813-818.
- New Scientist* (1984), 23 February.
- New Scientist* (1985), 21 March.
- New Scientist* (1986). 30 January.
- Newell, A. and Sproull, F. (1982). "Computer Networks: Prospects for Scientists", *Science*, Vol.215, No.4534, pp.843-852.

- Norman, C. (1981). *The God That Limp*s. W.W. Norton and Co., N.Y.
- Noyce, R. (1977a). "Microelectronics", *Scientific American*, Vol.237, No.3, pp.63-69.
- Noyce, R. (1977b). "Large-Scale Integration: What Is Yet to Come", *Science*, Vol.195, No.4283, pp.1102-1106.
- Oldham, W. (1977). "The Fabrication of Microelectronics Circuits". *Scientific American*, Vol.237, No.3, pp.111-128.
- Oliver, B. (1977). "The Role Of Microelectronics in Instrumentation and Control", *Scientific American*, Vol.237, No.3, pp.180-190.
- Osborne, A. (1979). *Running Wild*. Osborne/McGraw-Hill, California.
- Overman, M. (1974). *Understanding Telecommunications*. Lutterworth Press, London.
- Pask, G. and Curran, S. (1982). *Microman: Living and Growing with Computers*. Century Pub. Co., London.
- Petre, P. (1985). "How GE Bobbled the Factory of the Future", *Fortune*, 11 November, pp.46-54.
- Pierce, J. (1972). "Communication", *Scientific American*, Vol.227, No.3, pp.31-41.
- Pierce, J. (1977). "Electronics: Past, Present and Future", *Science*, Vol.195, No.4283, pp.1092-1095.
- Ploch, M. (1984). "Micros Flood Campuses", *High Technology*, Vol.4, No.3, pp.47-49.
- Pylyshyn, Z. (1970) editor. *Perspectives on the Computer Revolution*, Prentice-Hall, London.
- Reid-Green, K. (1978). "A Short History of Computers", *Byte*, Vol.3, No.7, pp.84-94.
- Renmore, C. (1980). *Silicon Chips and You*. Sheldon Press, London.
- Robertson, G. (1980). "Industrial Robots", *McGraw-Hill Yearbook of Science and Technology*. pp.1-11.
- Robertson, J. (1982). "Microelectronic Circuit Fabrication", in M. Jack (1982) editor. pp.12-25.
- Robinson, A. (1977). "Impact of Electronics on Employment: Productivity and Displacement Effects", *Science*, Vol.195, No.4283, pp.1179-1184.
- Rosenberg, J. (1969). *The Computer Prophets*. MacMillan, London.
- Rudall, B. (1985). "Towards Automatic Software Generation", *Robotica*, Vol.3, pp.31-34.
- Schaller, C. (1978). "The Revolution of EFTS", *The Journal of Accountancy*.

October, pp.74-80.

*Science Age* (1984) September.

*Sci-Tech Report* (1984), edited by John Turner. Pluto Press, London.

*Semiconductor International Magazine* (1986), May.

Shaiken, H. (1985). "The Automated Factory: The View from the Shop Floor", *Technology Review*, Vol.88, No.1, pp.16-27.

Shannon, C. (1969), "Information Theory", *Encyclopaedia Britannica*. pp.246-249.

Shurkin, J. (1983). "Expert Systems: The Practical Face of artificial Intelligence", *Technology Review*, Vol.86, No.6, pp.72-78.

Silver, J. (1979). *The Social Impact Of Computers*. Harcourt Brace Jovanovich, N.Y.

Simon, H. (1980). "What Computers Mean for Man and Society", in T. Forrester (1980) editor. pp.420-433.

Singer, C. (1965). "East and West in Retrospect", in C. Singer et al (1965) editors. Vol.II, pp.753-776.

Singer, C., Holmyard, E. and Hall, A. (1965) editors. *A History of Technology*. Clarendon Press, Oxford.

Skinner, F. (1965). "Measures and Weights", in C. Singer et al (1965) editors. Vol.I, pp.774-784.

Smith, T. (1970). "Some Perspectives on the Early History of Computers", in Pylyshyn (1970) editor. pp.7-15.

Spinrad, R. (1982). "Office Automation", *Science*, Vol.215, No.4534, pp.808-813.

Stewart, D. (1967) editors. *Automaton Theory and Learning Systems*, Academic Press, London.

Suydam, W. (1986). "AI Becomes the Soul of the New Machines", *Computer Design*, Vol.5, No.4, pp.55-70.

*Technology Ireland* (1983), January.

*Technology Update* (1986). 10 March.

Terman, L. (1977). "The Role of Microelectronics in Data Processing", *Scientific American*, Vol.237, No.3, pp.163-167.

*The Economist* (1983). 26 February.

*The Economist* (1984). 11 August.

*The Economist* (1986). "The Factory of the Future", 5 April, pp.83-85.

*Time* (1978), "The Age of Miracle Chips", 20 February, pp.38-52.

- Toong, H-M. (1977). "Microprocessors", *Scientific American*, Vol.237, No.3, pp.146-152.
- Trakhtenbrot, B. (1970). "Algorithms", in Z. Pylyshyn (1970) editor. pp.69-86.
- Tribus, M. and McIrvine, E. (1971). "Energy and Information", *Scientific American*, Vol.224, No.3, pp.179-188.
- Truxal, J. "Control Systems", *McGraw-Hill Encyclopaedia of Science and Technology*, Vol.3, pp.488-491.
- Turing, A. (1970). "Computing Machinery and Intelligence", in Z. Pylyshyn (1970) editor. pp.224-245.
- Turner, G. (1980). *Antique Scientific Instruments*, Blandford, England.
- Turski, W. (1984). *Software Engineering: A Survey*. UNIDO/IS.446. Vienna.
- UNIDO Secretariat (1983). *Problems in Software Development in Developing Countries*. UNIDO/IS.383. Vienna.
- Van Riemsdijk, J. and Brown, K. (1980). *The Pictorial History of Steam Power*, Octopus, London.
- Waddington, C. (1977). *Tools for Thought*. Jonathan Cape, London.
- Wailes, R. (1965). "Windmills", in C. Singer et al (1965) editors. Vol.III, pp.89-109.
- Wedlake, G. (1973). *S.O.S.: The Story of Radiocommunications*. David and Charles, Newton-Abbot, England.
- Whitbread, M. (1979) editor. *Microprocessor Applications in Business and Industry*. Castle House Pubs., London.
- White, R. (1980). "Disk-Storage Technology", *Scientific American*, Vol.243, No.2, pp.112-121.
- Williamson, J. (1981). "The Challenge of Fibre Optics", *New Scientist*, 23 July, pp.216-218.
- Winston, P. and Prendergast, K. (1984) editors. *The AI Business: Commercial Uses of Artificial Intelligence*. MIT Press, Camb., Mass.
- Zermeno, R., Moseley, R. and Braun, E. (1980). "The Robots Are Coming -Slowly", in T. Forrester (1980) editor. pp.184-197.

### Bibliography Chapter III

- Abegleen, J. and Etori, E. (1983). "Japanese Technology Today" (Special Report), *Scientific American*, Vol 249, No 4, pp.J-1 to J-24.
- Abernathy, W. (1982). "The Competitive Decline in U.S. Innovation: The Management Factor" in H. Fusfeld and R. Langlois (editors). *Understanding R & D Productivity*, Pergamon Press, NY, pp.55-72.
- Adam, J. and Fischetti, M. (1985). "SDI: The Grand Experiment", *IEEE Spectrum*, September, pp.34-35.
- Adam, J. and Horgan, J. (1985). "Debating the Issues", *IEEE Spectrum*, September, pp.55-64.
- Adam, J. and Wallich, P. (1985). "Mind-Boggling Complexity", *IEEE Spectrum* (1985), September, pp.36-46.
- Adams, G. (1982). *The Politics of Defense Contracting: The Iron Triangle*. Transaction Books, London.
- Aftergood, S. (1986). "Nuclear Space Mishaps and Star Wars", *Bulletin of the Atomic Scientists*, October, pp.40-43.
- Albury, D. and Schwartz, J. (1982). *Partial Progress: The Politics of Science and Technology*, Pluto Press, London.
- Allison, D. (1980). *The Origins of Radar at the Naval Research Laboratory: A Case Study of Mission-Oriented Research and Development*. Ph.D. Thesis, Princeton University.
- Anderson, H. (1977). "IBM Versus Bell in Telecommunications", *Datamation*, May, pp.91-95.
- Athanasίου, T. (1985). "High-Tech Alternativism: The Case of the Community Memory Project", *Radical Science*, No 16, pp.37-51.
- Atherton, W. (1984). *From Compass to Computer*, San Francisco Press, San Francisco.
- Aviation Week & Space Technology* (1981). "Technical Survey: Very High Speed Integrated Circuits", 16 February, pp.48-85.
- Bacon, F. (1900). *The New Atlantis*, Edited by G.C. Moore Smith, Cambridge U.P., Cambridge.
- Baran, P. and Sweezy, P. (1975). *Monopoly Capital*, Penguin Books, England.
- Barber, B. (1970). *Science and the Social Order*, Collier Books, NY.
- Barker, J. and Downing, H. (1979). *Office Automation: Word Processing and the Transformation of Patriarchal Relations*. Paper presented to the Annual Conference of the CSE, 13-16 July 1979, Leeds University, Mimeo.
- Barlett, H. (1941). "The Development of Industrial Research in America" in National Resource Planning Board (1941) editors, pp. 19-77.

- Barnes, B. and Edge, D. (1982). "The Interaction of Science and Technology" in B. Barnes and D. Edge (editors). *Science In Context*, The Open University Press, England, pp.147-154.
- Battelle-Colombus Division (1984). *Probable Levels of R & D Expenditures in 1985: Forecast and Analysis*, Battelle, Ohio.
- Beresford, R. (1983). "VHSIC: Redefining the Mission", *VLSI Design*, November, pp.16-21.
- Berger, M. (1984). "Japanese Firms Boots Spending for Short- and Long-Term Projects", *Electronics Week*, 24 September, pp.32-36.
- Berger, M. (1985). "Why U.S. Wants Military Technology from Japan", *Electronics*, 29 July, pp.34-35.
- Bernal, J. (1944). *The Social Function of Science*, George Routledge, London.
- Bernal, J. (1969). *Science in History: The Natural Science in Our Time (Vol 3)*, Penguin Books, England.
- Bessant, J. (1984). *Technology and Market Trends in the Production and Application of Information Technology: A Review of Developments During the Years 1982-1983*. UNIDO/IS.438, Vienna.
- Birr, K. (1966). "Science in American Industry" in D. van Tassel and M. Hall (1966) editors, pp.35-80.
- Birr, K. (1979). "Industrial Research Laboratories", in N. Reingold (1979) editor, pp.193-207.
- Bohme, G., van Den Daele, W. and Krohn, W. (1978). "The 'Scientification' of Technology" in W. Krohn et al (1978) editors, pp.219-250.
- Borrus, M., Millstein, J. and Zysman, J. (1982). *International Competition in Advanced Industrial Sectors: Trade and Development in the Semiconductor Industry*, U.S. Government Printing Office, Wash., D.C.
- Botkin, J. and Dimancescu, D. (1984). "The DARPA Exception" in J. Tirman (1984) editor, pp.222-225.
- Botkin, J., Dimancescu, D. and Stata, R. (1982). *Global Stakes: The Future of High Technology in America*, Ballinger Pub. Co., Camb., Mass.
- Brand, C. (1941). "Technical Research by Trade Associations" in National Resources Planning Board (1941) editor, pp.88-97.
- Braun, E. (1980). "From Transistors to Microprocessors" in T. Forrester (1980) editor, pp.72-102.
- Braun, E. and MacDonald, S. (1978). *Revolution in Miniature: The History and Impact of Semiconductor Electronics*, Cambridge U.P., London.
- Braverman, H. (1974). *Labor and Monopoly Capital: The Degradation of Work in the Twentieth Century*, Monthly Review, NY.



- Brock, G. (1975). *The U.S. Computer Industry: A Study Of Market Power*, Ballinger Pub. Co., Camb., Mass.
- Brock, G. (1981). *The Telecommunications Industry: The Dynamics of Market Structure*, Harvard U.P., Camb., Mass.
- Brooks, J. (1976). *Telephone: The First Hundred Years*, Harper and Row, NY.
- Brown, H. (1985). "Star Wars Once Funny, Now Frightening", *Bulletin of the Atomic Scientists*, Vol 41, No 5, p.3.
- Bueche, A. (1979). "The Economy" in H. Fushfeld and C. Haklisch (1979) editors, pp.138-153.
- Burke, J. and Eakin, M. (1979) editors. *Technology and Change*, Boyd and Fraser, San Francisco.
- Burnham, J. (1941). *The Managerial Revolution: What is Happening in the World*, The John Day Co., NY.
- Business Week* (1979). "The Microprocessors: A Revolution for Growth" (Special Report), 19 March, pp.42B-I to 42W-I.
- Business Week* (1979). "Can Semiconductor Survive Big Business" (Special Report), 3 December, pp.66-86.
- Business Week* (1984). "Software: The New Driving Force" (Special Report), 27 February, pp.54-71.
- Business Week* (1984a) "GM Moves Into a New Era", 16 July, pp.70-75.
- Business Week* (1984b). "Reshaping the Computer Industry" (Special Report), 16 July, pp.48-68.
- Business Week* (1984). 7 November.
- Bylinsky, G. (1984). "The Holes in AT & T's Computer Strategy", *Fortune*, 13 September, pp.50-62.
- Charlish, G. (1985). "Sperry Links Manufacture to Design", *Financial Times*, 20 February, p.14.
- Charlish, G. (1985b). "Profits Become Harder to Find in CAD Industry", *Financial Times*, 5 November, p.18.
- Chemical Economy and Engineering Review* (1985), March.
- Chomsky, N. (1980). "The Cornerstone of the American System" in Y. Fitt, A. Faire and J-P Vigier (1980), pp.1-12 (foreword).
- Chronicle of Higher Education* (1983). "Defense Department to Encourage Industry-University Ties", 4 May, p.20.
- Coben, S. (1979). "American Foundation As Patrons of Science: The Commitment to Individual Research" in N. Reingold (1979) editor, pp.229-247.

- Connolly, R. (1978). "Pentagon to Fund major IC Program", *Electronics*, 14 September, pp.81-82.
- Cooley, M. (1976). "Contradictions of Science and Technology in the Productive Process" in H. Rose and S. Rose (1976) editors, pp.72-95.
- Cooley, M. (1980a). *Architect or Bee: The Human/Technology Relationship*, Langley Technical Series, England.
- Cooley, M. (1980b). "The Designer in the 1980s - The Deskiller Deskilled", *Design Studies*, Vol 1, No 4, pp.197-201.
- Coon, H. (1939). *American Tel & Tel: The Story of a Great Monopoly*, Longmans, NY. Reprinted in 1981, University Microfilms International, London.
- Cooper, C. (1971). "Science, Technology and Development", *Economic and Social Review* (Dublin), Vol 2, No 2, pp.165-189.
- Cooper, F. (1941). "Location and Extent of the Industrial Research Activity in the United States" in National Resources Planning Board (1941) editor, pp.173-187.
- CSE Microelectronics Group (1980). *Capitalist Technology and the Working Class*, CSE Books, London.
- Datamation* (1982). "IBM-AT & T: The Coming Collision" (Special Issue), July.
- Datamation* (1982). "Japan's Top Ten", December, pp.164-3 to 164-6.
- Datamation* (1984), 1 October.
- David, E. (1979). "Science Futures: The Industrial Connection", *Science*, Vol 203, No 4383, pp.837-840.
- De Grasse (1984). "The Military and Semiconductors" in J. Tirman (1984) editor, pp.77-104.
- de Jonquieres, G. (1980). "Decade of the Silicon Chip", *Financial Times*, 12 September, p.11.
- de Jonquieres, G. (1980a). "Europe Heavily Dependent on Overseas Suppliers", *Financial Times*, 12 September, p.12.
- de Jonquieres, G. (1981). "High Investments Despite Fall in Growth", *Financial Times*, 1 July, p.17.
- de Jonquieres, G. (1982). "Squaring Up For a Fight", *Financial Times*, 18 January, p.12.
- de Jonquieres, G. (1983a). "IBM & AT & T: Now It's Eyeball to Eyeball", *Financial Times*, 18 January, p.22.
- de Jonquieres, G. (1983b). "AT & T Sets Out to Take the World", *Financial Times*, 17 January, p.8.
- de Jonquieres, G. (1983c). "Ma Bell is Coming", *Newsweek*, 23 May (special

section on computers & communications).

de Jonquieres, G. (1985). "Looking for Strength to Jump Over the Barrier", *Financial Times*, 12 July, p.18.

de Jonquieres, G. and Bett, P. (1983). "The Breaking and Making of Ma Bell", *Financial Times*, 10 January, p.12.

de Sola Pool, I. (1977) editor. *The Social Impact of the Telephone*, The MIT Press, Camb., Mass.

de Sola Pool, I. (1983). *Technologies of Freedom*, Harvard U.P., Camb., Mass.

Dickson, D. (1984). *The New Politics of Science*, Pantheon Books, NY.

Diebold, J. (1952). *Automation: The Advent of the Automatic Factory*, D. van Nostrand Co., NY.

Diebold, J. (1964). *Beyond Automation: Managerial Problems of an Exploding Technology*, McGraw-Hill Book Co., NY.

Dinneen, G. and Frick, F. (1977). "Electronics and National Defense", *Science*, Vol 195, No 4283, pp.1151-1155.

Dos Santos, T. (1972). "Las Contradicciones del Imperialismo Contemporaneo", *Sociedad y Desarrollo*, Enero/Marzo 1972, pp.9-34.

Druckrer, P. (1961). "The Technological Revolution: Notes on the Relationship of Technology, Science and Culture", *Technology and Culture*, Vol 2, No 4, pp.342-351.

Dumas, L. (1984). "University Research, Industrial Innovation, and the Pentagon" in J. Tirman (1984) editor, pp.123-151.

Dumas, L. (1986). "The Military Burden on the Economy", *Bulletin of the Atomic Scientists*, October, pp.22-25.

Duncan, M. (1981). "The Information Technology Industry in 1981", *Capital and Class*, No 17, pp.78-113.

Dunsheath, P. (1962). *A History of Electrical Engineering*, Faber and Faber, London.

Dupree, A. (1957). *Science in the Federal Government*, Harvard U.P., Camb., Mass.

*Electronics* (1978). "VHSI Proposal Finds Willing Audience", 28 September, pp.89-90.

*Electronics* (1980). Special Commemorative Issue on the History of Electronics, April.

*Electronics* (1980). "1980 World Markets Forecast", 3 January, pp.125-148.

*Electronics* (1981). "1981 World Markets Forecast", 13 January, pp.121-144.

- Electronics* (1982). "1982 World Markets Forecast". 13 January, pp.121-152.
- Electronics* (1983). "1983 World Markets Forecast". 13 January, pp.125-156.
- Electronics* (1984). "1984 World Markets Forecast". 12 January, pp.123-154.
- Electronics* (1984). 9 February.
- Electronics Week* (1984). "World Markets Show a Renewed Vigor As U.S. Leads the Way" (Special Report), pp.85-108.
- Electronics Week* (1985). "Bright Gains in 1985 for Major Markets", 1 January, pp.61-82.
- Elliot, D. and Elliot, R. (1976). *The Control of Technology*, Wykeham Pub., London.
- Ellul, J. (1967). *The Technological Society*, Alfred Knopf, NY.
- Ellul, J. (1981). "Science, Technology, Society in France Today", *Bull. Sci. Tech. Soc.*, Vol 1, No 1/2, pp.17-21.
- Emme, E. (1967). "The Contemporary Spectrum of War" in M. Kranzberg and C. Pursell (1967) editors, pp.578-590.
- Ernst, D. (1981). *Restructuring World Industry in a Period of Crisis: The Role of Innovation*. UNIDO/IS.285, Vienna.
- Fagen, M. (1975) editor. *A History of Engineering and Science in the Bell System: The Early Years (1875-1925)*. Bell Telephone Laboratories, U.S.A.
- Farber, D. and Baran, P. (1977). "The Convergence of Computing and Telecommunications Systems", *Science*, Vol 195, No 4283, pp.1166-1170.
- Fedoseyev, P. (1977). "Social Significance of the Scientific and Technological Revolution" in ISA (1977) collection of papers, pp.83-107.
- Federal Register* (1980). "Initial Military Critical Technologies List", Vol 45, No 192, pp.65014-65019.
- Fegurson, C. (1983). "The Microelectronics Industry in Distress", *Technology Review*, Vol 86, No 6, pp.24-37.
- Feibleman, J. (1961). "Pure Science, Applied Science, Technology, Engineering: An Attempt at Definitions", *Technology and Culture*, Vol 2, No 4, pp.305-317.
- Feickert, D. (1979). *Microprocessor-Based Technology in Production: Design Choice*. Paper presented to the Annual Conference of the CSE, 13-16 July 1979. University of Leeds. Mimeo.
- Feigenbaum, E. and McCorduck, P. (1983). *Challenge to the World*, Pan Books, London.
- Fels, R. (1972). *The Second Crisis of Economic Theory*, General Learning Press, N. Jersey.

- Finan, W. (1981). "The Semiconductor Industry's Record on Productivity" in SIA, *American Prosperity and Productivity: Three Essays on the Semiconductor Industry*, SIA, Cupertino, Calif., 1981, pp.19-28.
- Finn, B. (1967). "Electronics Communications" in M. Kranzberg and C. Pursell (1967) editors, pp.293-309.
- Fischetti, M. (1985). "Exotic Weaponry", *IEEE Spectrum*, September, pp.47-54.
- Fisher, F., McKie, J. and Mancke, R. (1983). *IBM and the U.S. Data Processing Industry: An Economic History*, Praeger, NY.
- Fishman, K. (1981). *The Computer Establishment*, McGraw-Hill Book Co., NY.
- Fitt, Y. (1980). "Two Tools for Domination: Industry and Agriculture" in Y. Fitt, A. Faire and J-P Vigier (1980), pp.13-67.
- Fitt, Y., Faire, A. and Vigier, J-P. (1980). *The World Economic Crisis: U.S. Imperialism at Bay*, Zed Press, London.
- Fleck, G. (1973). *A Computer Perspective*, Harvard U.P., Camb., Mass.
- Fleming, A. (1917). *Industrial Research in the United States of America*, HMSO, England.
- Foremski, T. (1984). "AT & T: Can It Do Battle With IBM", *Computing*, 12 January, p.16.
- Forrester, T. (1980). *The Microelectronics Revolution*, Basil Blackwell, Oxford.
- Forrester, T. (1985). *The Information Technology Revolution*, Basil Blackwell, Oxford.
- Freeman, C. (1974). *The Economics of Industrial Innovation*, Penguin, England.
- Freeman, C. (1977). "Economics of Research and Development" in I. Spiegel-Rosing and D. de Solla Price (1977) editors, pp.223-275.
- Freeman, C. (1982). "The Economics Implications of Microelectronics" in C. Cohen (1982) editor, pp.53-88. *Agenda for Britain 1: Micro Policy, Choices for the 1980s*, Phillip Allan, Oxford, 1982, pp.
- Freeman, C. (1985). "The Economics of Innovation", *IEE Proceedings*, Vol 132, Pt. A, No 4, July, pp.213-221.
- Freeman, C., Clark, J. and Soete, L. (1982). *Unemployment and Technical Innovation: A Study of Long Waves and Economic Development*. Frances Pinter, London.
- Friedman, A. (1977). *Industry and Labour: Class Struggle at Work and Monopoly Capitalism*, MacMillan, London.
- Friedrichs, C. and Schaff, A. (1982) editors. *Microelectronics and Society: For Better or For Worse*, Pergamon Press, Oxford.
- Fusfeld, H. and Haklisch, C. (1979). *Science and Technology Policy: Perspectives*

for the 1980s, The New York Academy of Sciences, NY.

Galbraith, J. (1978). *The New Industrial State*, Penguin Books, England.

Galbraith, J. (1974). *Economics and the Public Purpose*, Andre Deutsch, London.

Gansler, J. (1980). *The Defense Industry*, The MIT Press, Camb., Mass.

Gibbons, M. and Johnson, C. (1970). "Relationship Between Science and Technology", *Nature*, Vol 227, 11 July, pp.125-127.

Gibbons, M. and Wittrock, B. (1985) editors. *Science as a Commodity: Threats to the Open Community of Scholars*, Longman, England.

Golding, A. (1971). *The Semiconductor Industry in Britain and the United States: A Case-Study in Innovation, Growth and Diffusion of Technology*, D. Phil. Dissertation, University of Sussex.

Goldstine, H. (1972). *The Computer From Pascal to Von Neumann*, Princeton U.P., N. Jersey.

Gregory, G. (1983). "Japan Challenges the Computer Giant", *New Scientist*, 6 January, pp.28-30.

Hales, M. (1982). *Science or Society? The Politics of the Work of Scientists*, Pan Books, London.

Hazewindus, N. (1982). *The U.S. Microelectronics Industry: Technical Change, Industry Growth and Social Impact*, Pergamon Press, NY.

Hobsbawn, E. (1978). *Industry and Empire*, Penguin Books, England.

Hoddeson, L. (1981). "The Emergence of Basic Research in the Bell Telephone System, 1875-1915", *Technology and Culture*, Vol 22, No 3, pp.512-544.

Hogan, L. (1977). "Reflections on the Past and Thoughts About the Future of Semiconductor Technology", *Interface Age*, Vol 2, No 4, pp.24-36.

Howard, R. (1985). "UTOPIA: Where Workers Craft New Technology", *Technology Review*, Vol 88, No 3, pp.43-49.

Hudson, C. (1982). "Computers in Manufacturing", *Science*, Vol 215, No 4534, pp.818-825.

Hughes, T. (1983). *Networks of Power: Electrification in Western Society 1880-1930*, John Hopkins U.P., Baltimore.

Hymer, S. (1979). "The Multinational Corporation and the Law of Uneven Development" in H. Radice (1979) editor, pp.37-62.

Inaba, M. (1983). "Japan Mfrs. Seek Tech. Feedback via U.S. Sales", *Electronics News*, 7 March (Supplement), pp.10 and 22-23.

Irwin, M. and Johnson, S. (1977). "The Information Economy and Public Policy", *Science*, Vol 195, No 4283, pp.1170-1174.



- ISA (International Sociological Association) (1977) collection of papers. *Scientific-Technological Revolution: Social Aspects*, Sage Pub., London.
- Iversen, W. (1984). "VHSIC-Insertion Program Begin to Pay Dividends", *Electronics Week*, 17 December, pp.57-66.
- Iversen, W. (1985). "Motorola and NCR Team Up in Semicustoms Chips", *Electronics*, 29 July, pp.20-21.
- Jacobsson J. (1982). *Problems and Issues Concerning the Transfer, Application and Development of Technology in the Capital Goods and Industrial Machinery Sector*. UNCTAD, TD/B/C.6/AC.713.
- Johnson, J. (1982). "Strategies in the Services Realm", *Datamation*, July, pp.24-30.
- Kaldor, M. (1985). "The Armament Process" in D. MacKenzie and J. Wajcman (1985) editors, pp.263-269.
- Kaplinsky, R. (1982). *Computer-Aided Design: Electronics, Comparative Advantage and Development*, Frances Pinter, London.
- Kaplinsky, R. (1984). *Automation: The Technology and Society*, Longman, London.
- Katz, B. and Phillips, A. (1982). "The Computer Industry" in R. Nelson (1982) editor, pp.162-232.
- Kay, G. (1977). *Development and Underdevelopment: A Marxist Analysis*. MacMillan, London.
- Kehoe, L. (1985a). "Semiconductor Industry: Roller-Coaster Derailed", *Financial Times*, 6 December, p.15.
- Kehoe, L. (1985b). "US Chipmakers Fear Extinction in Japan Trade War", *Financial Times*, 6 December, p.16.
- Kilby, J. (1976). "Invention of the Integrated Circuit", *IEEE Transactions on Electron Devices*, Vol ED-23, No 7, pp.648-654.
- Kirkland, R. (1984). "Ma Blue: IBM's Move Into Communications", *Fortune*, 15 October, pp.36-40.
- Kranzberg, M. and Pursell, C. (1967) editors. *Technology in Western Civilization*, Vol II, Oxford U.P., London.
- Krohn, W., Layton, E. and Weingart, P. (1978) editors. *The Dynamics of Science and Technology*, D. Reidel Pub. Co., Dordrecht, Holland.
- Kozma, R. (1985). "AT & T's Global Plan to Score in Computer Market", *Electronics*, 5 August, pp.26-29.
- Kulish, V. (1976). "Science and Warfare", *Impact of Science on Society*, Vol 26, No 1/2, pp.53-61.
- Kurth, J. (1972). "The Political Economy of Weapons Procurement: The Follow-On Imperative" in R. Fels (1972) editor, pp.304-311.

- Lakoff, S. (1977). "Scientists, Technologists and Political Power" in I. Spiegel-Rosing and D. de Solla Price (1977) editors, pp.355-391.
- Lamb, J. (1985). "Star Wars' Software Will Not Work", *New Scientist*, 5 September, p.19.
- Lamborghini, B. (1982), "The Impact on the Enterprise" in G. Friedrichs and A. Schaff (1982) editors, pp.119-156.
- Landes, D. (1969). *The Unbound Prometheus*, Cambridge U.P., Camb.
- Lasby, C. (1966). "Science and the Military" in D. van Tassel and M. Hall (1966) editors, pp.251-282.
- Layton, E. (1977). "Conditions of Technological Development" in I. Spiegel-Rosing and D. de Solla Price (1977) editors, pp.197-222.
- Lenin, V. (1944). *Imperialism, the Highest Stage of Capitalism*, Lawrence and Wishart, London.
- Leopold, G. (1984). "Study Sees Few Commercial Spinoffs from VHSIC", *Electronics Week*, 17 December, p.60.
- Leopold, G. (1985). "CMU Starts DoD Software Center", *Electronics Week*, 4 February, 9.27.
- Levin, R. (1982). "The Semiconductor Industry" in R. Nelson (1982) editor, pp.9-100.
- Levin, R. (1982a). "R & D Productivity in the Semiconductor Industry: Is a Slowdown Imminent?" in H. Fusfeld and R. Langlois (editors). *Understanding R & D Productivity*, Pergamon Press, NY, 1982, pp.37-54.
- Lewis, W. (1967). "Industrial Research and Development" in M. Kranzberg and C. Pursell (1967) editors, pp.615-634.
- Lin, H. (1985). "The Software for Star Wars: An Achilles Heel?", *Technology Review*, Vol 88, No 5, pp.16-18.
- Lindsay, R. (1973). *The Role of Science in Civilization*, Greenwood Press, Westport, Connecticut.
- Lineback, R. (1984). "Ford Sees Silicon Through Colorado Facility", *Electronics*, 26 January, p.106.
- Linville, J. and Hogan, L. (1977). "Intellectual and Economic Fuel for the Electronics Revolution", *Science*, Vol 195, No 4283, pp.1107-1113.
- Louis, A. (1984). "The Great Electronic Mail Shootout", *Fortune*, 20 August, pp.149-152.
- MacDonald, S., Collingridge, D. and Braun, E. (1981). "From Science to Technology: The Case of Semiconductors", *Bull. Sci. Tech. Soc.*, Vol 1, No 1/2, pp.173-201 and No 3, pp.289-320.
- MacKenzie, D. (1985). *Behind the News: The Military, the Computer and Artificial*

*Intelligence*, University of Edinburgh, April. Mimeo.

MacKenzie, D. and Wajcman, J. (1985) editors. *The Social Shaping of Technology*, Open University Press, England.

Mandel, E. (1979). "International Capitalism and 'Supranationality'" in H. Radice (1979) editor, pp.143-157.

Mandel, E. (1977). *Marxist Economic Theory*, Merlin Press, London.

Marbarch, W. et al (1985). "The Race to Build A Supercomputer" in T. Forrester (1985) editor, pp.60-70.

Mark, H. (1982). "Technology and the Strategic Balance", *Technology in Society*, Vol 4, No 1, pp.15-32.

Mansfield, E. (1969). *The Economics of Technological Change*, Longmans, London.

Mansfield, E. (1972). *Research and Innovation: The Modern Corporation*, MacMillan, London.

Marsh, P. (1985). "The Heroic Obstacles Still to Be Overcome", *Financial Times*, 25 June, p.16.

Marshall, E. (1981). "William Perry and the Weapons Gamble", *Science*, Vol 211, No 4483, pp.681-683.

Marx, C. (1977a). *Capital*, Vol I, Lawrence and Wishart, London.

Marx, C. (1977b). *Capital*, Vol III, Lawrence and Wishart, London.

Marx, C. (1977c). *Grundrisse*, Penguin Books, England.

Mason, S. (1962). *A History of the Sciences*, Collier Books, NY.

Mason, J. (1980). "VLSI Goes to School", *IEEE Spectrum*, November, pp.48-52.

Mc Cartney, L. (1978). "Exxon: Another Computer Giant?", *Datamation*, July, pp.169-173.

Mc Claurin, R. (1949). *Invention and Innovation in the Radio Industry*, The MacMillan Co., NY.

Melman, S. (1986). "Swords Into Plowshares: Converting from Military to Civilian Production", *Technology Review*, Vol.89, No.1. pp.62-71.

Merrifield, D. (1983). "Forces of Change Affecting High Technology Industries", *National Journal*, 29 January, pp.253-256.

Meynaud, J. (1968). *Technocracy*, Faber and Faber, London.

Miller, H. (1966). "Science and Private Agencies" in D. van Tassel and M. Hall (1966) editors, pp.191-221.

Molina, H. (1986). "The US Revalues its Electronics Patents", *New Scientist*, 1 May, pp.40-43.

- Mowery, D. (1983). "Innovation, Market Structure, and Government Policy in the American Semiconductor Electronics Industry: A Survey", *Research Policy*, Vol 12, No 4, pp.183-197.
- Mulkay, M. (1977). "Sociology of the Scientific Research Community" in I. Spiegel-Rosing and D.de Solla Price (1977) editors, pp.93-148.
- Mumford, E. and Henshall, D. (1979). *A Participative Approach to Computer Systems Design: A Case Study of the Introduction of a New Computer System*, Associated Business Press, London.
- Mumford, E., Land, F. and Hawgood, J. (1978). "A Participative Approach to the Design of Computer Systems", *Impact of Science on Society*, Vol 28, No 3, pp.235-253.
- Mumford, E. and Weir, M. (1979). *Computer Systems in Work Design - The ETHICS Method: Effective Technical and Human Implementation of Computer Systems*, Associated Business Press, London.
- Mumford, L. (1967). *Technics and Civilization*, Routledge and Kegan Paul, London.
- Mumford, L. (1970). *The Myth of the Machine: The Pentagon of Power*, Harcourt Brace Jovanovich, NY.
- NAE/NRC (National Academy of Engineering/National Research Council) (1983). *The Competitive Status of the U.S. Machine Tool Industry*, National Academy Press, Wash., D.C.
- NAE/NRC (1984). *The Competitive Status of the U.S. Electronics Industry*, National Academy Press, Wash., D.C.
- National Resource Planning Board (1941). *Research - A National Resource*, Vol II, NRPB, Wash., D.C.
- National Science Board (1984). *Science Indicators 1980*, NSF, Wash., D.C.
- National Science Foundation (NSF) (1971). *Research and Development in Industry, 1970*, NSF, Wash., D.C.
- National Science Foundation (NSF) (1984). *Research and Development in Industry, 1982*, NSF, Wash., D.C.
- Nelson, R. (1962). "The Link Between Science and Invention: The Case of the Transistor" in National Bureau of Economic Research. *The Rate and Direction of Inventive Activity*, Princeton U.P., Princeton, 1962, pp.549-583.
- Nelson, R. (1979). "Technical Advance and Economic Growth: Present Problems and Policy Issues" in H. Fusfeld and C. Haklisch (1979) editors, pp.47-57.
- Nelson, R. (1982) editor. *Government and Technical Progress: A Cross-Industry Analysis*, Pergamon Press, NY.
- Newsweek* (1982). "Japan's High-Tech Challenge", 9 August, pp.20-34.
- Niosi, J. and Faucher, P. (1985). "The Decline of North American Industry", *IDS*

*Bulletin*, Vol 16, No 2, pp.12-19.

Noble, D. (1977). *America by Design: Science, Technology, and the Rise of Corporate Capitalism*, Alfred Knopf, NY.

Noble, D. (1979). "Social Choice in Machine Design: The Case of Automatically Controlled Machine Tools" in A. Zimbalist (editor). *Case Studies on the Labour Process*, Monthly Review, NY, 1979, pp.18-50.

Noble, D. (1982). "The Selling of the University", *The Nation*, 6 February, pp.129 and 143-148.

Noble, D. (1984). *Forces of Production*, Alfred Knopf, NY.

Norman, C. (1979). *Knowledge and Power: The Global Research and Development Budget*, Worldwatch Paper 31, Wash., D.C.

Norman, C. (1981). *The God That Limp: Science and Technology in the Eighties*, W. Norton, NY.

Norman, C. (1982). "Electronics Firms Plug Into the Universities", *Science*, Vol 217, No 4559, pp.511-514.

OECD (1968). *Reviews of National Science Policy: United States*, OECD, Paris.

OECD (1968b). *Gaps in Technology: Electronics Components*, OECD, Paris.

OECD (1971). *Science, Growth and Society*, OECD, Paris.

OECD (1976). *The Measurement of Scientific and Technical Activities: "Frascati Manual"*, OECD, Paris.

Ornstein, S., Smith, B. and Suchman, L. (1984). "Strategic Computing", *Bulletin of the Atomic Scientists*, Vol 40, No 10, pp.11-15.

Panofsky, W. (1985). "The Strategic Defense Initiative: Perception vs Reality", *Physics Today*, June, pp.34-45.

Pappademos, J. (1983). "Militarized Science and the Crisis of Capitalism Today", *Science and Nature*, No 6, pp.6-20.

Pavitt, K. and Worboys, M. (1977). *Science, Technology and the Modern Industrial State*, Butterworth, London.

Penick, J., Pursell, C., Sherwood, M. and Swain, D. (1972). *The Politics of American Science: 1939 to the Present*, MIT Press, Camb., Mass.

Perez, C. (1985). "Microelectronics, Long Waves and World Structural Change: New Perspectives for Developing Countries", *World Development*, Vol 13, No 3, pp.441-463.

Perry, W. and Roberts, G. (1982). "Winning Through Sophistication: How to Meet the Soviet Military Challenge", *Technology Review*, July, pp.27-35.

*Physics Today* (1980). "Centers to Fund Academic-Industrial Research", December, p.55.

- Physics Today* (1980a). "DoD Encourages Industry to Subcontract Research", December, p.54.
- Platzek, R. and Kilby, J. (1964). "Minuteman Integrated Circuits: A Study of Combined Operations", *IEEE Proceedings*, Vol 52, pp.1669-1678.
- Ploch, M. (1983). "University Invest in Research Centers", *High Technology*, May, pp.15-18.
- Prager, D. and Ommen, G. (1980). "Research, Innovation, and University-Industry Linkages", *Science*, Vol 207, No 4429, pp.379-384.
- Price, D. (1965). *The Scientific Estate*, Oxford U.P., London.
- Pugh, E. (1984). *Memories That Shaped an Industry: Decisions Leading to IBM System/360*, The MIT Press, Camb., Mass.
- Pursell, C. (1966). "Science and Government Agencies" in D. van Tassel and M. Hall (1966) editors, pp.223-249.
- Rada, J. (1980). "Microelectronics, Information Technology and Its Effects on Developing Countries" in J. Berting, S. Mills and H. Wintersberger (editors). *The Socioeconomic Impact of Microelectronics*, Pergamon Press, Oxford.
- Rada, J. (1982). "Technology and the North-South Division of Labour" *IDS Bulletin*, Vol 13, No 2, pp.5-13.
- Rae, J. (1968). *Climb to Greatness: The American Aircraft Industry 1920-1960*, The MIT Press, Camb., Mass.
- Radice, H. (1979) editor. *International Firms and Modern Imperialism*, Penguin Books, England.
- Recabarren, J. (1980). *Latin America: Dependence and Trade Unionism*, M. Phil Dissertation, University of Bradford, England.
- Reich, M. (1972). "Does the U.S. Economy Require Military Spending" in R. Fels (1972) editor, pp.296-303.
- Reich, L. (1977). "Research, Patents, and the Struggle to Control Radio: A Study of Big Business and the Use of Industrial Research", *Business History Review*, No 51, pp.208-235.
- Reingold, N. (1979) editor. *The Sciences in the American Context: New Perspectives*, Smithsonian Institution Press, Wash., D.C.
- Reppy, J. (1983). "The United States" in N. Ball and M. Leitenberg (1983) editors. *The Structure of the Defense Industry*, Croom Helm, London, pp.21-49.
- Richta, R. (1977). "The Scientific and Technological Revolution and the Prospects of Social Development" in ISA (1977) collection of papers, pp.25-72.
- Robinson, A. (1980a). "Giant Corporations From Tiny Chips Grow", *Science*, Vol 208, No 4443, pp.480-484.
- Robinson, A. (1980b). "Perilous Times for U.S. Microcircuit Makers", *Science*, Vol



208, No 4444, pp.582-586.

Rose, H. and Rose, S. (1976) editors. *The Political Economy of Science*, MacMillan, London.

Rose, H. and Rose, S. (1976a). "The Production of Science in Advanced Capitalist Society" in H. Rose and S. Rose (1976) editors, pp.14-31.

Rose, H. and Rose, S. (1977). *Science and Society*, Penguin Books, England.

Rosenberg, N. (1974). "Karl Marx on the Economic Role of Science", *Journal of Political Economy*, Vol 82, No 4, pp.56-77.

Rosenberg, N. (1980). "The Economic Implications of the VLSI Revolution", *Futures*, October, pp.358-369.

Rosenberg, N. (1983). *Inside the Black Box: Technology and Economics*, Cambridge U.P., Camb.

Rosenbrock, H. (1977a). "Interactive Computing: A New Opportunity", *Control Systems Center Report No 388*, University of Manchester (UMIST), September.

Rosenbrock, H. (1977b). "The Future of Control", *Automatica*, Vol 13, pp.389-392.

Rothblatt, S. (1985). "The Notion of an Open Scientific Community in Historical Perspective" in M. Gibbons and B. Wittrock (1985) editors, pp.21-76.

Rothschild, K. (1983a). "U.S., Japan Equipment Mfrs. Vie for R & D Edge", *Electronics News*, 7 March (Supplement), pp.4-5.

Rothschild, K. (1983b). "U.S. Suppliers Enter Production Deals in Japan", *Electronics News*, 7 March (Supplement), pp.6, 18-19 and 26.

Sabato, J. (1975). "Using Science to 'Manufacture' Technology", *Impact of Science on Society*, Vol 25, No 1, pp.37-44.

Saint-Simon, H. (1964). *Social Organization, the Science of Man and Other Writings*, edited by F. Markham, Harper and Row, NY.

Saint-Simon, H. (1966). *L' Organisateur in Ouvres de Claude-Henri de Saint-Simon*, editions Anthropos, Paris, in particular pp.50-61 corresponding to "L' auteur a ses compatriotes", sixieme lettre.

Salomon, J-J. (1977). "Science Policy Studies and the Development of Science Policy" in I. Spiegel-Rosing and D. de Solla Price (1977) editors, pp.43-70.

Salomon, J-J. (1985). "Science as A Commodity - Policy Changes, Issues and Threats" in M. Gibbons and B. Wittrock (1985) editors, pp.78-98.

Sanders, R. (1975). "The Dimensions of Research and Development" in R. Sanders (1975) editor. *Science and Technology: Vital National Resources*, Lomond Books, Mt. Airy, Maryland.

Sapolsky, H. (1977). "Science, Technology and Military Policy" in I. Spiegel-Rosing and D. de Solla Price (1977) editors, pp.443-471.

- Sciberras, E. (1980). "The UK Semiconductor Industry" in K. Pavitt (editor). *Technical Innovation and British Economic Performance*, MacMillan, London, 1980, pp.282-296.
- Sciberras, E. and Payne, B. (1984). *Technical Change and International Competitiveness: A Study of the Machine Tool Industry*, The Technical Change Centre, London, Mimeo.
- Schnee, J. (1978). "Government Programs and the Growth of High-Technology Industries", *Research Policy*, No 7, pp.2-24.
- Schlesinger, T. (1984). "Labour, Automation and Regional Development" in J. Tirman (1984a) editor, pp.181-213.
- Schmitt, R. (1984). "National R & D Policy: An Industrial Perspective", *Science*, Vol 224, No 4654, pp.1206-1209.
- Schroeder-Gudehus, B. (1977). "Science, Technology and Foreign Policy" in I. Spiegel-Rosing and D. de Solla Price (1977) editors, pp.473-506.
- Schroerer, D. (1972). *Physics and Its Fifth Dimension: Society*, Addison-Wesley Pub. Co., London.
- Shapley, D. (1978). "Electronics Industry Takes to "Potting" Its Products for Market", *Science*, Vol 202, No 4370, pp.848-849.
- Sharpe, W. (1969). *The Economics of Computers*, Columbia U.P., NY.
- Sherwood, M. (1967). "Technology and Public Policy" in M. Kranzberg and C. Pursell (1967) editors, pp.487-498.
- SIA (Semiconductor Industry Association) (1981). *The International Microelectronic Challenge: The American Response by the Industry, the Universities and the Government*, SIA, Cupertino, Calif.
- Silk, L. (1960). *The Research Revolution*, McGraw-Hill, NY.
- SIPRI (1985). "Gasto y Produccion Militares en el Mundo", *Comercio Exterior*, Vol 35, No 3, pp.268-281.
- Skole, R. (1984). "Merger Makes Electronic Giant", *Electronics*, 9 February, pp.84 and 88.
- Skorov, G. (1978) editor. *Science, Technology and Economic Growth in Developing Countries*, Pergamon Press, Oxford.
- Smith, J. (1983). "Soviet Lag in Key Weapons Technology", *Science*, Vol 219, No 4590, pp.1300-1301.
- Smith, M. (1985) editor. *Military Enterprise and Technological Change: Perspectives on the American Experience*. The MIT Press, Camb., Mass.
- Snoddy, R. (1985). "Blunder Gave IBM a World Lead in Factory Automation Sales", *Financial Times*, 16 July, p.16.
- Soma, J. (1978). *The Computer Industry: An Economic-Legal Analysis of Its*

*Technology and Growth*, Lexington Books, Mass.

Soukup, M. (1976). "The Scientific-Technical Revolution and a Comprehensive Disarmament Programme", *Impact of Science on Society*, Vol 26, No 1/2, pp.91-99.

Spiegel-Rosing, I. and de Solla Price, D. (1977) editors. *Science, Technology and Society: A Cross-Disciplinary Perspective*, Sage Pub., London.

Staat, E. (1979). "The Economy: Introductory Remarks" in H. Fusfeld and C. Haklisch (1979) editors, pp.135-137.

Stanfield, R. (1980). "Campuses and Corporations: Industry Offers Money, But Not Without Strings", *National Journal*, 29 November, pp.2021-2024.

Sturmev, S. (1958). *The Economic Development of Radio*, Gerald Duckworth, London.

Sumney, L. (1980). "VLSI with a Vengeance", *IEEE Spectrum*, April, pp.24-27.

Sun, M. (1983). "The Pentagon's Ambitious Computer Plan", *Science*, Vol 222, No 4629, pp.1213-1215.

Sundaram, G. (1981). "Is Military R & D a Necessary Evil?", *Impact of Science on Society*, Vol 31, No 1, pp.5-13.

Svorykin, A. (1963). "Science as A Direct Productive Force", *Impact of Science on Society*, Vol 13, No 1, pp.49-60.

Swain, D. (1967). "Organization of Military Research" in M. Kranzberg and C. Pursell (1967) editors, pp.535-548.

Sweezy, P. (1970). *The Theory of Capitalist Development*, Modern Reader, London.

Sweezy, P. (1972). *Modern Capitalism and Other Essays*, Monthly Review, NY.

Teal, G. (1976). "Single Crystals of Germanium and Silicon - Basic to the Transistor and the Integrated Circuit", *IEEE Transaction on Electron Devices*, Vol ED-23, No 7, pp.621-629.

*The Chronicle of Higher Education* (1983). "Defense Dept. to Encourage Industry-University Ties", 4 May, p.20.

*The Economist* (1980). "The Megabattle for Microchip Market Shares", 8 November, pp.93-96.

*The Economist* (1982). "A Survey of Japanese Technology", 19 June, pp.1-36.

*The Economist* (1983). "Robot Industry: Sunburnt at Sunrise", 4 June, pp.65-66.

*The Economist* (1984). "Now IBM's Mainframes Has Only Japanese Challengers", 16 June, pp.53-54.

*The Economist* (1984). "Semiconductors: The Party's Over for Now", 8 December, pp.74 and 78.

- The Economist* (1984). "NEC: A Lightning Semiconductor". 15 December, pp.73 and 75.
- Thee, M. (1981). "Significancy of Military R & D: The Impact of the Arms Race on Society", *Impact of Science on Society*, Vol 31, No 1/2, pp.49-59.
- Thurow, L. (1985). "A World-Class Economy: Getting Back Into the Ring". *Technology Review*, Vol 88, No.6, pp.27-37.
- Tilton, J. (1971). *International Diffusion of Technology: The Case of Semiconductors*, The Brookings Institution, Wash. D.C.
- Tirman, J. (1984). "The Defense-Economy Debate" in J. Tirman (1984) editor, pp.1-32.
- Tirman, J. (1984a). *The Militarization of High Technology*, Ballinger, Camb., Mass.
- Tucker, J. (1985). "The Strategic Computer Initiative", *Science for the People*, Vol 17, No 1/2, pp.21-25.
- Tugendhat, C. (1981). *The Multinationals*, Penguin Books, England.
- UNIDO RCSB (Regional and Country Studies Branch) (1985). *Survey of Government Policies in Informatics*, UNIDO/IS.526, Vienna.
- U.S. Department of Commerce. Bureau of Census (1960). *Statistical Abstract of the United States 1960*, Wash., D.C.
- U.S. Department of Commerce. Bureau of Census (1965). *Statistical Abstract of the United States 1965*, Wash., D.C.
- U.S. Department of Commerce. Bureau of Census (1975). *Historical Statistics of the United States: Colonial Times to 1970*, Part 2, Wash., D.C.
- U.S. Department of Commerce. Bureau of Census (1983). *Statistical Abstract of the United States 1984*, Wash., D.C.
- U.S. Department of Commerce. Industry and Trade Administration (1979). *A Report on the U.S. Semiconductor Industry*, September, Wash., D.C.
- Uttal, B. (1984). "Japan's Latest Assault on Chipmaking", *Fortune*, 3 September, pp.58-65.
- Utterback J. and Murray, A. (1977). *Influence of Defense Procurement and Sponsorship of Research and Development on the Development of the Civilian Electronics Industry*, Center for Policy Alternatives, MIT, Camb., Mass., June.
- van Tassel, D. and Hall, M. (1966) editors. *Science and Society in the United States*, The Dorsey Press, Illinois.
- Veblen, T. (1964). *The Vested Interests and the Common Man*, Augustus Kelly, NY.
- Veblen, T. (1965). *Engineers and the Price System*, Augustus Kelly, NY.
- Vernon, R. (1971). *Sovereignty at Bay: The Multinational Spread of US Enterprise*,

Penguin Books, England.

Vigier, J-P. (1980). "The Crisis and the Third World War" in Y. Fitt, A. Faire and J-P. Vigier (1980), pp.111-177.

von Hippel, F. (1985). "Attack on Stars War Critic: A Diversion", *Bulletin of the Atomic Scientists*, Vol 41, No 4, pp.8-10.

Wainwright, H. and Elliot, D. (1982). *The Lucas Plan: A New Trade Unionism in the Making*, Allison and Busby, London.

Waller, L. (1985). "U.S. Semiconductor Firms Step Up Pace of Deals with Japanese", *Electronics Week*, 6 May, pp.34-35.

Walsh, J. (1977). "International Trade in Electronics: US-Japan Competition", *Science*, Vol 195, No 4283, pp.1175-1179.

Walsh, J. (1981). "DoD Funds More Research in Universities", *Science*, Vol 212, No 4498, pp.1003-1004.

Walsh, J. (1982). "Japan-US Competition: Semiconductors Are the Key", *Science*, Vol 215, No 4534, pp.825-829.

Walton, R. (1982). "Social Choice in the Development of Advanced Information Technology", *Technology in Society*, Vol 4, No 1, pp.41-49.

Warman, J. (1982). *Perspectivas de Desarrollo Para la Industria Electronica de Mexico*, SEPAFIN (Mexico), Mimeo.

Webster, F. and Robin, K. (1979). "Mass Communications and 'Information Technology'", *Socialist Register*, pp.285-316.

Webster, F. and Robins, K. (1981). "Technological Determination or Demystification?", *New Universities Quarterly*, Vol 35, No 3, pp.315-322.

Wedlake, G. (1973). *S.O.S.: The Story of Radio Communications*, David and Charles, Newton Abbot, England.

Weinberger, C. (1985). *Annual Report to the Congress, Fiscal Year 1986*, Wash., D.C.

Weiner, C. (1979). "How the Transistor Emerged" in J. Burke and M. Eakin (1979) editors, pp.251-261.

Weingart, P. (1978). "The Relation Between Science and Technology - A Sociological Explanation" in W. Krohn et al (1978) editors, pp.251-286.

Weisberg, L. (1978). "DoD Directions in Electronic Device R & D", *Proceedings of IEEE Conference on U.S. Technological Policy*, pp.24-25.

Weinzenbaum, J. (1985). "Computers in Uniform: A Good Fit?", *Science for the People*, Vol 17, No 1/2, pp.26-29.

Whittington, F. (1982). "Sizing Each Other Up", *Datamation*, July, pp.8-16.

Wilson, R., Ashton, P. and Egan, T. (1980). *Innovation, Competition, and*

*Government Policy in the Semiconductor Industry*, Lexington Books, Lexington, Mass.

Winner, L. (1977). *Autonomous Technology: Technics-Out-of-Control As a Theme in Political Thought*, MIT Press, Camb., Mass.

Wohl, A. (1982). "Office Automation: The Next Battlefield", *Datamation*, July, pp.34-39.

Wolff, M. (1976). "The Genesis of the Integrated Circuit", *IEEE Spectrum*, August, pp.45-53.

Yonas, G. (1985). "Strategic Defense Initiative: The Politics and Science of Weapons in Space", *Physics Today*, June, pp.24-32.

Zinberg, D. (1985). "The Legacy of Success: Changing Relationships in University-Based Scientific Research in the United States" in M. Gibbons and B. Wittrock (1985) editors, pp.107-127.



## Bibliography Chapter IV

- Aguirre, C. and Heredia, R. (1982). *Elements for the Formulation of a Regional Programme of Action in the Area of Microelectronics*. UNIDO ID/WG.372/10, Vienna.
- Ahn, Y-O. (1985). *Commercialization of Research and Development Results - Korean Experience*, UNIDO ID/WG.435/11, Vienna.
- Almada, I. (1982). "Muertos que no Hacen Ruido" in *Nexos* editors, pp.33-48.
- Alvarez, E. et al (1982). "El Desarrollo de la Ciencia y la Tecnologia en Mexico" in E. Flores et al (1982), pp.39-116.
- Alvarez, J. (1982). "La Nueva Ley Sobre Transferencia de Tecnologia: Aciertos y Limitaciones de la Politica Gubernamental", *Comercio Exterior*, Octubre, pp.1117-1124.
- Amadeo, E. (1979). "National Science and Technology Councils in Latin America: Achievements and Failures of the First Ten Years" in M. Wionczek (1979) editor, pp.149-166.
- American Machinist* (1985). "Locals Only to Supply CAD/CAM: Brazil", May 1985, p.43.
- Aspra, A. (1977). "Import Substitution in Mexico: Past and Present", *World Development*, Vol.5, Nos.1/2, pp.111-123.
- Assereto, A. (1984). "Perfil de las Crisis Recientes del Sistema Financiero Mexicano", *Comercio Exterior*, Octubre, pp.953-969.
- Ayala, J., Blanco, J., Cordera, R., Knochenhauer, G. and Labra, A. (1983). "La Crisis Economica: Evolucion y Perspectivas" in P. Gonzalez Casanova and E. Florescano (1983) editors, pp.17-94.
- Balassa, B. (1983). "La Politica de Comercio Exterior de Mexico", *Comercio Exterior*, Marzo, pp.210-222.
- Barclays Bank* (1984). Abecor Country Report: Mexico. July.
- Barkin, D. (1975). "Mexico's Albatross: The United States Economy", *Latin American Perspectives*, Vol.2, No.2, pp.64-80.
- Bellinghausen, H. (1982). "Ciencia Mexicana: Entre la Inmovilidad y la Esquizofrenia" in *Nexos* ( editors, pp.349-354.
- Berger, M. (1985). "Korean Chip Makers Aren't Backing Off", *Electronics*, 2 December, pp.28-29.
- Berney, K. (1985). "Asia: The Four Dragons Rush to Play Catch-Up Game", *Electronics Week*, 6 May, pp.48-56.
- Beltran del Rio, A. and Klein, L. (1984). "El Problema Mundial de la Deuda: Existe una Solucion?", *Comercio Exterior*, Octubre, pp.931-938.
- Bennett, R. (1975). "IBM in Latin America" in J. Gunneman (editor), *The Nation*

*State and Transnational Corporations in Conflict: With Special Reference to Latin America.* Praeger, N.Y., 1975, pp.224-237.

Bhaduri, A. (1985). *The Impact of External Debt and Financial Crisis on the Process of Industrialization: A Case Study of Mexican Manufacturing Sector.* UNIDO/PC.110, Vienna.

Blomstrom, M. and Persson, H. (1983). "Foreign Investment and Spillover Efficiency in an Underdeveloped Economy: Evidence from the Mexican Manufacturing Industry", *World Development*, Vol.11, No.6, pp.493-501.

Briceno, L. and Rivera, E. (1981). *La Industria Electronica en Mexico: Diagnostico y Perspectivas*, Fundacion Javier Barros Sierra, Mexico D.F., Mimeo.

Brundenius, C. and Goransson, B. (1986). "Technology Policies in Developing Countries - The Case of Telecommunications in Brazil and India", *Vierteljahresberichte*, No.103, Marz, pp.43-64.

Brzoska, M. (1986). "Other Countries: The Smaller Arms Producers" in M.Brzoska and T. Ohlson (1986) editors, pp.251-277.

Brzoska, M. and Ohlson, T. (1986). *Arms Production in the Third World*, Taylor and Francis, London.

*Business Week* ( 1982). "Mexico: U.S. Computer Makers Rush to Set Up Plants", 17 May, p.50.

*Business Week* 9 1982a). "Mexico Rattles the Multinationals", 4 October, p.56.

*Business Week* ( 1983). "U.S. Computer Makers Are feeling at Home", 14 November, p.64.

*Business Week* ( 1984). "What Made Apple Seek Safety in Numbers", 12 March, p.30.

Calderon, E. (1982). "El Estado de la Computacion en Mexico" in CONACYT (1982). *Diagnostico de la Situacion Tecnologica de los Sectores de Electricidad, Electronica y Computacion.* CONACYT, Mexico D.F. Mimeo.

Calvert, P. (1972). "Mexico: Second Thoughts on the Mexican Experiment", *Bulletin of the Society for Latin American Studies*, No.15, October, pp.11-13.

Campos, M. (1972). "Relacion Entre la Ciencia y la Tecnologia y el Comercio Exterior" in K-H Stanzick and H. Godoy (1972) editors, pp.61-90.

Campos, M. (1975). "La Politica Mexicana Sobre Transferencia de Tecnologia: Una Evaluacion Preliminar" in M. Wionczek (1975) editor, pp.169-199.

Carrillo, J. (1986). "Conflictos Laborales en la Industrial Maquiladora de Exportacion", *Comercio Exterior*, Enero, pp.46-57.

CEPAL (Comision Economica para America Latina) (1983). "Rasgos Generales de la Economia Mexicana en 1983", *Comercio Exterior*, Agosto, pp.751-754.

CEPAL (1985). "Evolucion de la Economia Mexicana en 1984", *Comercio Exterior*, Julio, pp.727-730.

- Chavez, A. (1983). "Nutricion: Problemas y Alternativas" in P. Gonzalez Casanova and E. Florescano (1983) editors, pp.220-229.
- Chavez, F., de la Vega, A. and Nadal, A. (1974). "Caracteristicas del Sistema Cientifico y Tecnologico de Mexico, *Demografia y Economia*, Vol.8, No.5, pp.269-306.
- Choi, H. (1983). *Bases for Science and Technology Promotion in Developing Countries*, Asian Productivity Organization, Tokyo.
- Chon, K. (1984). *State-of-the-Art Series on Microelectronics: Republic of Korea*, UNIDO/IS.490, Vienna.
- Chudnovsky, D. (1982). "Las Filiales Estadounidenses en el Sector Manufacturero de America Latina", *Comercio Exterior*, Julio, pp.748-753.
- Cockcroft, J. (1981). "Subordinated Technological Development: The Case of Mexico" in L. Kriesberg (editor). *Research in Social Movements, Conflict and Change*, JAI Press, London, 1981, pp.253-282.
- Cockcroft, J. (1983). *Class Formation, Capital Accumulation and the State*, Monthly Review Press, N.Y.
- Comercio Exterior* ( 1978). "In-Bond Plants: The Industry's Recent Developments and Present Perspectives", May, pp.202-210.
- Comercio Exterior* ( 1985). Julio.
- Comercio Exterior* ( (1985a). "No a la IBM", Febrero, p.131.
- Comercio Exterior* ( (1985b). "La IBM Fabricara Computadoras", Agosto, pp.770-771.
- Correa, C. (1983). "Importacion de Tecnologia en America Latina: Algunos Resultados de un Decenio de Intervencion Estatal", *Comercio Exterior*, Enero, pp.20-33.
- Dahlman, C. and Cortez, M. (1984). "Mexico", *World Development*, Vol.12, Nos.5/6, pp.601-624.
- Davidson, I. (1986). "The Dilemma of the Other Arms Race", *Financial Times*, 17 March, p.17.
- de la Madrid, M. (1985). "El Pueblo, Riqueza Fundamental de Mexico", *Comercio Exterior*, Septiembre, pp.845-847.
- de la Madrid, M. (1985a). "La Politica Economica para 1986", *Comercio Exterior*, Diciembre, pp.1179-1188.
- Dillman, C. (1983). "Assembly Industry in Mexico: Contexts of Development", *Journal of Interamerican Studies and World Affairs*, Vol.25, No.1, pp.31-58.
- Echeverria, L. (1972). "To Harness What Nature Gives Us", *Impact of Science on Society*, Vol.22, Nos.1/2, pp.43-53.
- Eckstein, S. (1977). "The State and the Urban Poor" in J. Reyna and R. Weinert

(1977) editors, pp.23-46.

*Electronics* (1985). "Mexico Approves IBM Microcomputer Manufacturing Plan", 29 July, p.14.

Erber, F. (1985). "The Development of the 'Electronics Complex' and Government Policies in Brazil", *World Development*, Vol.13, No.3, pp.293-309.

Evans, P. and Gereffi, G. (1980). "Inversion Extranjera y Desarrollo Dependiente: Una Comparacion Entre Brazil y Mexico", *Revista Mexicana de Sociologia*, Vol.42, No.1, pp.9-70.

Fajnzylber, F. (1975). "Las Empresas Transnacionales y el Sistema Industrial de Mexico", *El Trimestre Economico*, Vol.42, No.168, pp.903-931.

Fernandez, G. (1985). *Research and Development in Microelectronics in Argentina, Brazil, Mexico and Venezuela*. UNIDO ID/WG.440/5, Vienna.

Fernandez, G. and Octavio, M. (1985). *Report of the UNIDO Mission Preparatory to the Establishment of a Regional System for Microelectronics in Latin America (REMLAC)*. UNIDO ID/WG.440/6, Vienna.

*Financial Times* ( 1986). 3 February and 17 February.

Flores, E. (1982). "El Desarrollo de la Ciencia y la Tecnologia en la Actualidad", *Ciencia y Desarrollo*, Vol.8, No.43, pp.107-111.

Flores, E. (1983). "Science and Technology in Mexico: Towards Self-Determination", *Science*, Vol.219, No.4591, pp.1398-1401.

Flores, E. et al (1982). *La Ciencia y la Tecnologia en Mexico*, CONACYT, Mexico D.F.

Frobel, F., Heinrichs, J. and Kreye, O. (1981). *The New International Division of Labour*, Cambridge U.P., Cambridge.

Fuentes, O. (1983). "Educacion Publica y Sociedad" in P. Gonzalez Casanova and E. Florescano (1983) editors, pp.230-265.

Furtado, C. (1970). *Economic Development of Latin America: A Survey from Colonial Times to the Cuban Revolution*. Cambridge U.P., Cambridge.

Galli, E. (1982). *Microelectronica y Telecomunicaciones en America Latina*, UNIDO ID/WG.372/4, Vienna.

Goldblat, J. and Millan, V. (1982). "Militarization and Arms Control in Latin America" in *SIPRI Yearbook, 1982*, Taylor and Francis, London, pp.393-425.

Gonzalez Casanova, P. (1970). "Mexico: La Dinamica de Una Revolucion Agraria y 'Semicapitalista'" in J. Petras and M. Zeitlin (editors), *America Latina: Reforma o Revolucion?*, Editorial Tiempo Contemporaneo, Argentina, 1970, pp.415-430.

Gonzalez Casanova, P. (1980). "The Economic Development of Mexico", *Scientific American*, Vol.243, No.3, pp.154-163.

Gonzalez Casanova, P. and Florescano, E. (1983). *Mexico, Hoy, Siglo Veintiuno*

Editores, Mexico.

Goransson, B. (1984). "Una Política para Fortalecer la Capacidad Tecnológica Nacional: El Caso de las Telecomunicaciones en Brazil", *Comercio Exterior*, Diciembre, pp.1214-1231.

Goulet, D. (1983). *Mexico: Development Strategies for the Future*, University of Notre-Dame Press, Notre-Dame.

Granados, O. (1982). "Regreso a las Armas?" in *Nexos* (1982) editors, pp.125-135.

Grapa, E. (1984). "Perspectivas de la Computación en los Próximos Cinco Años", *Ciencia y Desarrollo*, Vol.9, No.54, pp.12-21.

Grayson, G. (1981). "The Mexican Oil Boom" in S. Purcell (1981) editor, pp.146-157.

Green, R. (1981). "Mexico's Economic Dependence" in S. Purcell (1981) editor, pp.104-114.

Green, R. (1982). "El Callejón de las Decisiones" in *Nexos* (1982) editors, pp.111-118.

Green, R. (1983). "Mexico: Crisis Financiera y Deuda Externa", *Comercio Exterior*, Febrero, pp.99-107.

Grunwald, J. (1985). "The Assembly Industry in Mexico" in Grunwald, J. and Flamm, K. (editors). *The Global Factory: Foreign Assembly in International Trade*, The Brookings Institution, Wash., D.C., 1985, pp.137-179.

Gutierrez, R. (1981). "Cambio de Matiz en la Estrategia Económica de México: Los Años Setenta y Ochenta", *Comercio Exterior*, Agosto, pp.864-875.

Hamilton, N. (1975). "Mexico: The Limits of State Autonomy", *Latin American Perspectives*, Vol.2, No.2, pp.81-108.

Hobday, M. (1985). *Telecommunications and Information Technology in Latin America: Prospects and Possibilities for Managing the Technology Gap*. UNIDO ID/WG.440/2, Vienna.

Hobday, M. (1985a). *The Brazilian Telecommunications Industry: Accumulation of Microelectronics Technology in the Manufacturing and Service Sectors*. UNIDO/IS.511, Vienna.

Hobday, M. (1986). "Telecommunications - A "Leading Edge" in the Accumulation of Digital Technology? Evidence from the Case of Brazil", *Information Technology for Development*, Vol.1, No.1, pp.23-43.

Iglesias, E. (1983). "La Evolución Económica de América Latina en 1982", *Comercio Exterior*, Febrero, pp.162-185.

Iglesias, E. (1985). "Balance Preliminar de la Economía de América Latina en 1984", *Comercio Exterior*, Febrero, pp.171-190.

Islas, H. (1984). "Un Retrato Reciente de México: El Último Censo", *Comercio*

*Exterior*, Julio, pp.586-592.

Jacobsen, M. (1983). "Mexico's Computer Decree: The Problem of Performance Requirements and a U.S. Response", *Law and Policy in International Business*, Vol.14, No.4, pp.1159-1195.

Jenkins, R. (1978). "Manufactured Exports - Development Strategy or Internationalization of Capital?", *Bulletin of the Society for Latin American Studies*, No.28, April, pp.64-82.

Jenkins, R. (1979). *Foreign Firms, Export of Manufactures and the Mexican Economy*, Monograph in Development Studies No. 7, School of Development Studies, University of East Anglia. September.

Jung-nam, C. (1984). "South Korea Chips Into a Jackpot", *South*, July 1984, p.80,83.

Katz, J. and Ablin, E. (1978a). *Technology and Industrial Exports. A Micro-Analysis of Argentina's Recent Experience*, IDB/ECLA Programme in Science and Technology, Working Paper No.2, Buenos Aires.

Katz, J. and Ablin, E. (1978b). *From Infant Industry to Technology Exports: The Argentine Experience in the International Sale of Industrial Plants and Engineering Works*. IDB/ECLA Research Programme in Science and Technology, Working Paper No.14, Buenos Aires.

Kaplinsky, R. (1986). "The Electronics Industry in Developing Countries", *Vierteljahresberichte*, No.103, Marz, pp.19-28.

Kucinski, B. (1983). "Brazil's Bold Leap Into the Light-Speed Age", *South*, April 1983, pp.64-65.

Lahera, E. and Nochteff, H. (1982). *La Microelectronica y el Desarrollo de America Latina: Problemas y Posibilidades de Accion*", UNIDO ID/WG.372/15, Vienna.

Lall, S. (1980). "Developing Countries as Exporters of Industrial Technology", *Research Policy*, January, pp.24-52.

Lall, S. (1983). "Los Paises en Desarrollo y un Nuevo Orden Tecnologico Internacional", *Comercio Exterior*, Enero, pp.7-13.

*Latin America Weekly Report* ( 1981). "Entering the Microcomputer Age", WR-81-46, 20 November, pp.9-10.

Layton, L. (1985). "How Funes Swung the IBM-Mexico Deal", *Electronics*, 5 August, p.38.

Lazcano, A. (1982). "Politica Cientifica: Una Tradicion a Construir", *Nexos* ( 1982) editors, pp.339-347.

Leal, J. (1975). "The Political Economy of the Mexican State", *Latin American Perspectives*, Vol.2, No.2, pp.48-63.

Leff, E. (1983). "Dependencia Cientifico-Tecnologica y Desarrollo Economico" in P. Gonzalez Casanova and E. Florescano (1983) editors, pp.266-285.



- Levi de Lopez, S. (1980). "Industrial Development in Mexico", *Bulletin of the Society for Latin American Studies*, No.32, October, pp.6-23.
- Lock, P. (1986). "Brazil: Arms for Exports" in M. Brzoska and T. Ohlson (1986) editors, pp.79-104.
- Lomnitz, L. (1977). "Conflict and Mediation in a Latin American University", *Journal of Interamerican Studies and World Affairs*, Vol.19, No.3, pp.315-338.
- Lomnitz, L. (1979). "Hierarchy and Peripherality: The Organization of a Mexican Research Institute", *Minerva*, Vol.17, No.4, pp.526-548.
- Lopez, D. (1983). "Salud y Seguridad Social: Problemas Recientes y Alternativas" in P. Gonzalez Casanova and E. Florescano (1983) editors, pp.177-219.
- Lorentzen, A. (1984). *The Capital Goods Sector in Mexico - Significance and Conditions of Development*. Centre for Development Research, CDR Project Papers A.84.3., Copenhagen.
- Marquez, M. (1982). *10 Anos del Consejo Nacional de Ciencia y Tecnologia*, CONACYT, Mexico.
- Martinez, M. (1983). "Ventajas e Inconvenientes de la Actividad Maquiladora en Mexico: Algunos Aspectos de la Subcontratacion Internacional", *Comercio Exterior*, Febrero, pp.146-151.
- McCrone, A. (1985). "US Challenges Brazil Over Protectionism", *Computing*, 28 November, p.24.
- Mendoza, E. (1984). "Petroleo y Gas en Mexico: Politicas y Resultados", *Comercio Exterior*, Mayo, pp.444-447.
- Meyer, L. (1977). "Historical Roots of the Authoritarian State in Mexico" in J. Reyna and R. Weinert (1977) editors, pp.3-22.
- Minian, I. (1981). *Progreso Tecnico e Internacionalizacion del Proceso Productivo: El Caso de la Industria Maquiladora de Tipo Electronica*, CIDE, Mexico.
- Moreno, J. (1982). "Sector Electronico" in CONACYT (1982). *Diagnostico de la Situacion Tecnologica de los Sectores Electricidad, Electronica y Computacion*, CONACYT, Mexico. Mimeo.
- Mucino, V. (1984). "CAD/CAM Technology and Industrial Automation in Mexico" in UNIDO/IO.575, Vienna. p.26.
- Nadal, A. (1977). "Multinational Corporations and Transfer of Technology: The Case of Mexico" in Germidis, D. (editor). *Transfer of Technology by Multinational Corporations*, Vol.I, OECD, Paris, pp.219-250.
- Nadal, A. (1977a). *Instrumentos de Politica Cientifica y Tecnologica en Mexico*. El Colegio de Mexico, Mexico D.F.
- NAFINSA (Nacional Financiera S.A.) (1979). *La Industria Electronica Profesional en Mexico*. Proyecto Conjunto de Bienes de Capital NAFINSA-ONUDI, NAFINSA, Mexico D.F.

- NAFINSA (1981). *La Economía Mexicana en Cifras*, NAFINSA, Mexico D.F.
- NAFINSA (1984). *La Economía Mexicana en Cifras*, NAFINSA, Mexico D.F.
- Nam, C. (1986). "Política Comercial y Desarrollo Económico en Corea", *Comercio Exterior*, Enero, pp.13-22.
- Narro, J., Urbina, M., Castro, R., Palma, J. and Palma, Y. (1984). "Evolución Reciente de la Mortalidad en México", *Comercio Exterior*, Julio, pp.636-646.
- Nexos (1982) editors. *El Desafío Mexicano*, Ediciones Oceano, Mexico D.F.
- Nochteff, H. (1985). *Government Policies for the Data Processing Industries in Argentina, Brazil and Mexico*. UNIDO ID/WG.440/7, Vienna.
- Nolan, J. (1986). "South Korea: An Ambitious Client of the United States" in M. Brzoska and T. Ohlson (1986) editors, pp.215-231.
- Ortiz, S. and Torres, F. (1975). "Necesidad de una Política de Ciencia y Tecnología en México" in M. Wionczek (1975) editor, pp.237-274.
- Park, U. (1984). *The Development of the Electronics Industry in Korea: The Case of Samsung Electronics*. Paper presented at Korea Development Institute the Forum on Industrialization and Trade Promotion, Seoul, Korea, May 15-24. Mimeo.
- Parthasarathi, A. (1978). *Electronics in Developing Countries: Issues in Transfer and Development of Technology*. UNCTAD, Geneva.
- Perez Tamayo, R. (1982). "Para Desmontar el CONACYT" in Nexos (1982) editors, pp.319-337.
- Plaetzer, K. (1984). *The Capital Goods Industry in Latin America: Present Situation and Prospects*. Sectoral Working Papers Series No.19, UNIDO 115.478, Vienna.
- Poder Ejecutivo Federal (1983). *Plan Nacional de Desarrollo, 1983-1988*. Published as a Supplement of *Comercio Exterior*, Junio 1983.
- Poder Ejecutivo Federal (1984). *Programa Nacional de Desarrollo Tecnológico y Científico, 1984-1988*. CONACYT, Mexico D.F.
- Purcell, J. (1981). "Mexican Social Issues" in S. Purcell (1981) editor, pp.45-54.
- Purcell, S. (1981) editor. *Mexico-United States Relations*. Proceedings of the Academy of Political Science, Vol.34, No.1, N.Y.
- Raddavero, B. (1985). "Posibilidades de Empresas Conjuntas en el Ambito Iberoamericano", *Comercio Exterior*, Febrero, pp.134-137.
- Ramirez, M. and Galicia, R. (1972). "La Penetración Imperialista en México", *Problemas del Desarrollo*, Vol.3, No.12, pp.101-138.
- R & D Mexico (1982). "Mexico Invest in Its Future", March, p.38.
- Reyna, J. (1977). "Redefining the Authoritarian Regime" in J. Reyna and R.

Weinert (1977) editors, pp.155-171.

Reyna, J. and Weinert, R. (1977) editors. *Authoritarianism in Mexico*, Inst. for the Study of Human Issues, Philadelphia.

Reynolds, C. (1978). "Why Mexico's 'Stabilizing Development' Was Actually Destabilizing (With Some Implications for the Future)", *World Development*, Vol.6, Nos.7/8, pp.1005-1018.

Rivas, S. (1985). "La Industria Maquiladora en Mexico: Realidades y Falacias". *Comercio Exterior*, Noviembre, pp.1071-1084.

Sagasti, F., Chaparro, F., Paredes, C. and Jaramillo, H. (1984). "Ciencia y Tecnologia en America Latina", *Comercio Exterior*, Diciembre, pp.1163-1179.

Salehizadeh, M. and Garza-Adame, J. (1984). "Mexican Protectionist Policies and Their Implications for the Computer Industry", *Inter-American Economic Affairs*, Vol.38, No.1, pp.85-101.

Schoijet, M. (1979). "The Condition of Mexican Science", *Minerva*, Vol.17, No.3, pp.381-412.

Schteingart M. (1984). "El Sector Inmobiliario y la Vivienda en Crisis", *Comercio Exterior*, Agosto, pp.739-750.

SECOFI (Secretaria de Comercio y Fomento Industrial) (1985). *Estrategia de Desarrollo de la Industria Electronica*. SECOFI, Mexico D.F. Mimeo.

SECOFI (1985a). *Evaluacion de Resultados del PND y de Pronafice en la Industria Electronica*. SECOFI, Mexico D.F. Mimeo.

SEPAFIN (Secretaria de Patrimonio y Fomento Industrial) (1981). *Programa de Fomento para la Manufactura de Sistemas Electronicos de Computo, sus Modulos Principales y sus Equipos Perifericos*. SEPAFIN, Mexico D.F. Mimeo.

Serrano, A. (1984). "Los Factores Externos de la Crisis: Una Evaluacion", *Comercio Exterior*, Octubre, pp.970-979.

Serrano, A. (1984a). "Poverty: A Lacerating Reality", *Comercio Exterior*, Agosto, pp.755-764.

Smith, P. (1977). "Does Mexico have a Power Elite" in J. Reyna and R. Weinert (1977) editors, pp.129-151.

Soberon, G. and Poveda, A. (1973). "Mexico's Scientific and Technological Gap and the Program of Scientific Development of the Universidad Nacional Autonoma de Mexico" in R. Esquenazi-Mayo, K. Shahani and S. Treves (editors). *Symposium on the Scientific and Technological Gap in Latin America*. University of Nebraska-Lincoln, Nebraska, 1973, pp.181-191.

Soriano, M. and Lemaitre, C. (1985). "Primera Decada de la Computacion en Mexico: 1958-1968", First part in *Ciencia y Desarrollo*, Vol.10, No.60, pp.133-140; second part in *Ciencia y Desarrollo*, Vol.11, No.1, pp.170-177.

Spaey, J. (1970). *El Desarrollo por la Ciencia*, UNESCO, Paris.

- SPP (Secretaria de Programacion y Presupuesto) (1980). *Diagnostico de la Informatica en Mexico, 1980*. SPP, Mexico D.F.
- SPP/INEGI (Secretaria de Programacion y Presupuesto/Instituto Nacional de Estadistica e Informatica) (1981a). *Mexico: System of National Accounts (Vol I). General Summary, 1970-1978*. SPP/INEGI, Mexico D.F.
- SPP/INEGI (1981b). *Sistema de Cuentas Nacionales de Mexico, 1978-1980: Resumen General*. Vol I, SPP/INEGI, Mexico D.F.
- SPP/INEGI (1983a). *Sistema de Cuentas Nacionales de Mexico: Principales Variables Macroeconomicas. Periodo 1970-1982*. SPP/INEGI, Mexico D.F.
- SPP/INEGI (1982b). *10 Anos de Indicadores Economicos y Sociales de Mexico*, SPP/INEGI, Mexico .D.F.
- SPP/INEGI (1984). *Sistema de Cuentas Nacionales de Mexico, 1981-1983*. SPP/INEGI, Mexico D.F.
- Stanzick, K-H, and Godoy, H. (1972) editors. *Inversiones Extranjeras y Transferencia de Tecnologia en America Latina*. ILDIS/FLACSO, Santiago, Chile.
- Szuprowicz, B. (1981). "The World's Top 50 Computer Import Markets", *Datamation*, January, pp.141-146.
- Tigre, P. (1983). *Technology and Competition in the Brazilian Computer Industry*, Frances Pinter, London.
- Tullberg, R. and Millan, V. (1983). "Military Expenditures Series: A Comparison of Five Latin American Countries" in *SIPRI Yearbook, 1983*. International Publications Service, N.Y., pp.181-189.
- Turner, R. (1984). "PABX Suppliers Quitting Brazil", *Electronics Week*, 17 December, pp.40-41.
- UNCTAD (1975). *International Subcontracting Arrangements in Electronics Between Developed Market-Economy Countries and Developing Countries*. UNCTAD, N.Y.
- UNCTC (United Nations Centre on Transnational Corporations) (1983). *Transnational Corporations in the International Semiconductor Industry*. N.Y.
- UNESCO (1978). "Mexico" in *La Politica Cientifica y Tecnologica en America Latina y el Caribe*. Estudios y Documentos de Politica Cientifica y Tecnologica No.42, UNESCO, Paris.
- UNESCO (1979). *An Introduction to Policy Analysis in Science and Technology*. Science Policy Studies and Documents No.46, UNESCO, Paris.
- UNESCO (1981). *Statistical Yearbook, 1981*. UNESCO, Paris.
- Unger, K. (1985). "El Comercio Exterior de Manufacturas Modernas en Mexico: El Papel de las Empresas Extranjeras", *Comercio Exterior*, Mayo, pp.431-443.
- UNIDO (1982). *Proceedings of the First Meeting on Co-operation Between Scientific and Industrial Sectors in Microelectronics*. UNIDO/IS.338, Vienna.

- UNIDO RCSB (1983). *Role of the Public Industrial Enterprise Sector in Mexico*. UNIDO IS/428, Vienna.
- UNIDO Secretariat (1985a). *Some Considerations on the Content and Modalities of a Programme of Work for REMLAC*. UNIDO ID/WG.440/4, Vienna.
- UNIDO Secretariat (1985b). *Proposed Structure of the Regional Network for Microelectronics in the ECLAC Region*, UNIDO ID/WG.440/3, Vienna.
- U.S. Department of Commerce. Industry and Trade Administration (1979). *A Report on the U.S. Semiconductor Industry*. September. U.S. Gov. Printing Office, Wash., D.C.
- Velasco, J. (1983). *Impacts of Mexican Oil Policy on Economic and Political Development*. Lexington Books, Lexington, Mass.
- Villarreal, R. (1977). "The Policy of Import-Substituting Industrialization, 1929-1975" in J. Reyna and R. Weinert (1977) editors, pp.67-107.
- Villarreal, R. and Villarreal, R. (1981). "Mexico's Development Strategy" in S. Purcell (1981) editor, pp.97-103.
- Villela, G. (1981). *The Mexican Experience in the Electronics Industry*, UNIDO ID/WG.339/10, Vienna.
- Waissbluth, M. and Gutierrez, I. (1982). "Elementos para una Estrategia de Desarrollo Científico y Tecnológico" in E. Flores et al (1982), pp.117-135.
- Wajnberg, S. (1985). *Approach to Regional Microelectronics Co-Operation Programme*, UNIDO ID/WG.440/11, Vienna.
- Warman, J. (1981). *Participación del Gobierno Federal en el Desarrollo de la Industria Electronica*. NAFINSA, Mexico D.F.
- Warman, J. (1982). "Nuestro Limbo Electronico", *Nexos, No.?, pp.35-39*.
- Warman, J. (1984). "Marcos de Referencias y Opciones de Política para el Desarrollo de la Industria Electronica en Mexico", *Comercio Exterior*, Enero, pp.67-76.
- Weinert, R. (1977). "The State and Foreign Capital" in J. Reyna and R. Weinert (1977) editors, pp.109-128.
- Westphal, L., Rhee, Y. and Pursell, G. (1984). "Sources of Technological Capability in South Korea" in M. Fransman and K. King editors. *Technological Capability in the Third World*, MacMillan, London, pp.279-300.
- Whitehead, L. (1981). "On 'Governability' in Mexico", *Bulletin of Latin American Research*, Vol.1, No.1, pp.28-47.
- Whiting, V. (1981). "La Política y la Reglamentación de las Empresas Transnacionales en Mexico", *Revista Mexicana de Sociología*, Vol.42, No.1, pp.71-92.
- Wionczek, M. (1972). "La Inversión Extranjera Privada y la Transferencia de Tecnología a Mexico" in K-H Stanzick and H. Godoy (1972) editors, pp.493-514.

Wionczek, M. (1973). "La Transferencia de Tecnologia en el Marco de la Industrializacion Mexicana" in M. Wionczek (editor). *Comercio de Tecnologia y Subdesarrollo Economico, UNAM, Mexico, 1973*, pp.241-272.

Wionczek, M. (1975) editor. *Politica Tecnologica y Desarrollo Socio-Economico*, Secretaria de Relaciones Exteriores, Tlatelolco, Mexico.

Wionczek, M. (1979). "Science and Technology Planning Problems in a Large Circum-Caribbean Country (Mexico)" in D. Thomas and M. Wionczek (editors). *Integration of Science and Technology with Development: Caribbean and Latin American Problems in the Context of the United Nations Conference on Science and Technology for Development*. Pergamon Press, N.Y., 1979, pp.220-232.



## Bibliography Chapter V

Bessant, J. and Haywood, B. (1985). "Taylor Flexible Manufacturing Systems to Suit Your Demands", *Works Management*, November, pp.67-69.

*Business Week* (1985). "Are You Creative", 30 September, pp.46-52.

*Business Week* (1986). "Rocket Scientists' Are Revolutionizing Wall Street", 21 April, pp.84-88.

*Business Week* (1986a). "When Will the Slump End for the Computer Industry", 21 April, pp.92-95.

Callon, M. (1980). "The State and Technical Innovation: A Case Study of the Electrical Vehicle in France", *Research Policy*, Vol.9, pp.358-376.

Callon, M. and Latour, B. (1981). "Unscrewing the Big Leviathan, or How do Actors Macrostructure Reality?" in K. Knorr-Cetina and A. Cicourel (editors). *Advances in Social Theory and Methodology: Toward an Integration of Micro- and Macro-Sociologies*. Routledge and Kegan Paul, London, 1981, pp.277-303.

Callon, M. and Law, J. (1982). "On Interests and Their Transformation: Enrolment and Counter-Enrolment", *Social Studies of Science*, Vol.12, No.4, pp.615-625.

Childe, G. (1965). "Early Forms of Society" in C. Singer et al (editors). *A History of Technology*, Vol I, Clarendon Press, Oxford, 1965, pp.

*Computing* (1985). "Imperial Scientists Rally in Protest at 'Unfeasible' SDI", 28 November, p.32.

Cooper, C. (1971). "Science, Technology and Development", *Economic and Social Review* (Dublin), Vol.2, No.2, pp.165-189.

Cooper, C. and Maxwell, P. (1980). "Machinery Suppliers and the Transfer of Technology: A View of 'Packaging' and 'Learning By Doing'", *Development Research Digest*, No.3, Spring, pp.27-30.

Dahlman, C. and Cortez, M. (1984). "Mexico", *World Development*, Vol.12, Nos.5/6, pp.601-624.

de Bono, E. (1971). *The Use of Lateral Thinking*, Penguin Books, England.

de Bono, E. (1978). *Teaching Thinking*, Penguin Books, England.

Derry, T. and Williams, T. (1975). *A Short History of Technology*, Oxford U.P., London.

Desai, A. (1984). "Achievements and Limitations of India's Technological Capability" in M. Fransman and K. King (1984) editors, pp.245-261.

Dickson, D. (1974a). "Technology and Construction of Social Reality", *Radical Science Journal*, No.1, January, pp.29-50.

Dickson, D. (1974b). *Alternative Technology and the Politics of Technical Change*, Fontana/Collins, Glasgow.

- Dore, R. (1984). "Technological Self-Reliance: Sturdy Ideal or Self-Serving Rhetoric" in M. Fransman and K. King (1984) editors, pp.65-80.
- Dosi, G. (1982). "Technological Paradigms and Technological Trajectories", *Research policy*, Vol.11, pp.147-162.
- Drucker, P. (1970). "Work and Tools" in P. Drucker (editor), *Technology, Management and Society*, Heinemann, London.
- Edquist, C. (1985). *Capitalism, Socialism and Technology: A Comparative Study of Cuba and Jamaica*, Zed Books, London.
- Edquist, C. and Edquist, D. (1979). "Social Carriers of Technique for Development", *Journal of Peace Research*, Vol.16, No.4, pp.313-331.
- Electronics* (1980). Special Commemorative Issue on the History of Electronics, April.
- Ellul, J. (1963). "The Technological Order", *Technology and Culture*, Vol.3, No.4, pp.394-421.
- Ellul, J. (1965). "The Biology of Technique", *The Nation*, 24 May.
- Ellul, J. (1967). *The Technological Society*, Alfred Knopf, N.Y.
- Ellul, J. (1972). *Hope in Time of Abandonment*, The Seabury Press, N.Y.
- Ellul, J. (1981). "Science, Technology, Society in France Today", *Bulletin of Science, Technology and Society*, Vol.1, No.1/2, pp.17-21.
- Ernst, D. (1980a) editor. *The New International Division of Labour, Technology and Underdevelopment: Consequences for the Third World*, Campus, Frankfurt.
- Ernst, D. (1980b). "International Transfer of Technology, Technological Dependence and Underdevelopment: Key Issues" in D. Ernst (1980a) editor, pp.15-78.
- Feibleman, J. (1966). "Technology as Skills", *Technology and Culture*, Vol.7, No.3, pp.318-328.
- Fransman, M. (1984). "Some Hypotheses Regarding Indigenous Technological Capability and the Case of Machine Production in Hong Kong" in M. Fransman and K. King (1984) editors, pp.301-316.
- Fransman, M. and King, K. (1984) editors. *Technological Capability in the Third World*, MacMillan, London.
- Freeman, C. (1985). "The Economics of Innovation", *IEE Proceedings*, Vol.132, Pt.A, No.4, pp.213-221.
- Freeman, C. (1986). *Induced Innovation, Diffusion of Innovations and Business Cycles*, Paper prepared for the Centre of Canadian Studies Conference on Technology and Social Change. Edinburgh University, June 12th-13th, 1986.
- Galbraith, J. (1952). *American Capitalism*, Hamish Hamilton, London.

- Galbraith, J. (1958). *The Affluent Society*, Penguin Books, England.
- Galbraith, J. (1963). *Economic Development in Perspective*, Harvard, U.P., Camb., Mass.
- Galbraith, J. (1967). *The New Industrial State*, Penguin Books, England.
- Galbraith, J. (1971). "Economics a System of Belief" in J. Galbraith. *A Contemporary Guide to Economics, Peace and Laughter*, Andre Deutsch, London, 1971, pp.60-87.
- Galbraith, J. (1974). *Economics and the Public Purpose*, Andre Deutsch, London.
- Goulet, D. (1975). *On the Ethics of Development Planning: General Principles and Special Application to Value Conflicts*, University of California, Los Angeles.
- Goulet, D. (1977). *The Uncertain Promise: Value Conflicts in Technology Transfer*, IDOC/North America, N.Y.
- Goulet, D. (1983). "Value Orientation in Technology Policy", *Bulletin of Science, Technology and Society*, Vol.3, No.4, pp.299-310.
- Habermas, J. (1971). "Technology and Science as 'Ideology'" in J. Habermas. *Towards a Rational Society: Student Protest, Science and Politics*, Heinemann Educational Books, 1971, London.
- Herrera, A. (1972). "Social Determinants of Science Policy in Latin America", *The Journal of Development Studies*, Vol.9, No.1, pp.19-37.
- Herrera, A. (1978). "Tecnologías Científicas y Tradicionales en los Países en Desarrollo", *Comercio Exterior*, Diciembre, pp.1462-1476.
- Hobday, M. (1985). *Telecommunications and Information Technology in Latin America: Prospects and Possibilities of Managing the Technology Gap*. UNIDO ID/WG.440/2, Vienna.
- Hobday, M. (1986). "Telecommunications —A "Leading Edge" in the Accumulation of Digital Technology ? Evidence from the case of Brazil, *Information Technology for Development*, Vol.1, No.1, pp.23-43.
- Hughes, T. (1969). "Technological Momentum in History: Hydrogenation in Germany 1898-1933", *Past and Present*, No.44, August, pp.106-132.
- Hughes, T. (1979). "The Electrification of America: The System Builders", *Technology and Culture*, Vol.20, No.1, pp.124-161.
- Hughes, T. (1981). "Convergent Themes in the History of Science, Medicine, and Technology", *Technology and Culture*, Vol.22, No.3, pp.550-558.
- Hughes, T. (1983). *Networks of Power: Electrification in Western Society, 1880-1930*, The John Hopkins U.P., Baltimore.
- Hughes, T. (1986). "The Seamless Web: Technology, Science, Etcetera, Etcetera", *Social Studies of Science*, Vol.16, No.2, pp.281-292.
- Iacocca, L. (1984). *Iacocca: An Autobiography*, Bantam Books, N.Y.

- Kaplinsky, R. (1985). "Electronics-Based Automation Technologies and the Onset of Systemofacture: Implications for Third World Industrialization", *World Development*, Vol.13, No.3, pp.423-439.
- Kuhn, T. (1962). *The Structure of Scientific Revolutions*, The University of Chicago Press, Chicago.
- Latour, B. (1983). "Give Me a Laboratory and I Will the World" in K. Knorr-Cetina and M. Mulkey (editors). *Science Observed: Perspectives on the Social Study of Science*, Sage Publications, London, pp.141-170.
- Latour, B. (1986a). "The Powers of Association" in J. Law (editor). *Power, Action and Belief: A New Sociology of Knowledge?* Routledge & Kegan Paul, London, 1986.
- Latour, B. (1986b). *How to Write 'The Prince' for Machines as well as for Machinations*, Paper presented to the Conference on Technology and Social Change, Edinburgh University, 12-13 June. Mimeo.
- Law, J. (1986). *The Anatomy of a Sociotechnical Struggle: The Design of the TSR.2*, Paper presented at the Conference on Technology and Social Change, University of Edinburgh, 12-13 June. Mimeo.
- Layton, E. (1977). "Conditions of Technological Development" in I. Spiegel-Rosing and D. de Solla Price (editors). *Science, Technology and Society: A Cross-Disciplinary Perspective*, Sage Publications, London, 1977, pp.197-222.
- Leikind, M. and Miles, W. (1975). "The Nature of Science and Technology" in R. Sanders (editor). *Science and Technology: Vital National Resources*, Lomond Books, Mariland.
- Leys, C. (1984). "Relations of Production and Technology" in M. Fransman and K. King (1984) editors, pp.175-184.
- MacDermott, J. (1969). "Knowledge is Power", *The Nation*, 14th April, pp.458-462.
- MacDermott, J. (1972). "Technology: The Opiate of the Intellectuals" in A. Teich (editor). *Technology and Man's Future*, St. Martin's Press, N.Y., 1972, pp.151-178.
- MacKenzie, D. (1984). "Marx and the Machine", *Technology and Culture*, Vol.25, No.3, pp.473-502.
- Makange, A. (1980). "Strategies to Overcome Technological Dependence" in D. Ernst (1980a) editor, pp.556-575.
- Mansfield, E. (1969). *Economics of Technological Change*, Longmans, London.
- Marcuse, H. (1941). "Some Social Implications of Modern Technology", *Studies in Philosophy and Social Science*, Vol.9, pp.414-439.
- Marcuse, H. (1964). *One Dimensional Man: Studies in the Ideology of Advanced Industrial Societies*, Routledge and Kegan Paul, London.
- Marx, K. (1977a). *Capital*, Lawrence and Wishart, London.

- Marx, K. (1977b). *Grundrisse*, Penguin Books, England.
- Mesthene, E. (1970). *Technological Change: Its Impact on Man and Society*, Harvard U.P., Camb., Mass.
- Mishra, R. (1979). "Technology and Social Structure in Marx's Theory: An Exploratory Analysis", *Science and Society*, Vol.43, No.2, pp.132-157.
- Morehouse, W. (1980). "Technological Autonomy and Delinking in the Third World: Confronting the Unholy Alliance of Power, Privilege and Technology in Rich and Poor Countries", in D. Ernst (1980a) editor, pp. 529-555.
- Muller, J. (1980). *Liquidation or Consolidation of Indigenous Technology*, Aalborg U.P., Denmark.
- Mumford, L. (1934). *Technics and Civilization*, Routledge and Kegan Paul, London.
- Mumford, L. (1957). *The Transformation of Man*, George Allen and Unwin, London.
- Mumford, L. (1960). "Tools and the Man", *Technology and Culture*, Vol.1, No.4, pp.320-334.
- Mumford, L. (1964). "Authoritarian and Democratic Techniques", *Technology and Culture*, Vol.5, No.1, pp.1-8.
- Mumford, L. (1966). "Technics and the Nature of Man", *Technology and Culture*, Vol.7, No.3, pp.303-317.
- Mumford, L. (1967). *The Myth of the Machine: Technics and Human Development*, Secker and Warburg, London.
- Mumford, L. (1970). *The Myth of the Machine: The Pentagon of Power*, Harcourt Brace Jovanovich, N.Y.
- Nelson, R. and Winter, S. (1977). "In Search of a Useful Theory of Innovation", *Research Policy*, Vol.6, pp.36-76.
- Noble, D. (1977). *America By Design: Science, Technology and the Rise of Corporate Capitalism*, Alfred Knopf, N.Y.
- Noble, D. (1979). "Social Choice in Machine Design: The Case of Automatically Controlled Machine Tools" in A. Zimbalist (editor). *Case Studies on the Labour Process*, Monthly Review Press, N.Y., 1979, pp.18-50.
- Noble, D. (1984). *Forces of Production: A Social History of Industrial Automation*, Alfred Knopf, N.Y.
- Noble, D. (1985). "Command Performance: A Perspective on the Social and Economic Consequences of Military Enterprise" in M. Smith (editor). *Military Enterprise and Technological Change: Perspectives on the American Experience*, The MIT Press, Camb., Mass, 1985, pp.329-346.
- Noble, D. (1986). "Automation Madness: Progress Without People", *Science for the People*, Vol.18, No.1, pp.22-26.



- Perez, C. (1983a). *Towards a Comprehensive Theory of Long-Waves*, Paper presented at the IIASA Meeting on "Long Waves, Depression and Innovation", Siena-Florence, October 26-29. Mimeo.
- Perez, C. (1983b). "Structural Change and Assimilation of New Technologies in the Economic and Social Systems", *Futures*, October, pp.357-375.
- Perez, C. (1985). "Microelectronics, Long Waves and World Structural Change: New Perspectives for Developing Countries", *World Development*, Vol.13, No.3, pp.441-463.
- Pinch, T. and Bijker, W. (1984). "The Social Construction of Facts and Artefacts: or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other", *Social Studies of Science*, Vol.14, No.3, pp.399-441.
- Pinch, T. and Bijker, W. (1986). "Science, Relativism and the New Sociology of Technology: Reply to Russell", *Social Studies of Science*, Vol.16, No.2, pp.347-360.
- Pinch, T. (1986). *Understanding Technology: Some Possible Implications of Work in the Sociology of Science*, Paper presented to the Conference on Technology and Social Change, Edinburgh University, June 12-13. Mimeo.
- Rosenberg, N. (1974). "Marx on the Economic Role of Science", *Journal of Political Economy*, Vol.82, No.4, pp.713-728.
- Rosenberg, N. (1976). "Marx as a Student of Technology", *Monthly Review*, Vol.28, No.3, pp.56-77.
- Rosenberg, N. (1977). *Perspectives on Technology*, Cambridge University Press, Cambridge.
- Rosenberg, N. (1977a). "Factors Affecting the Diffusion of Technology" in N. Rosenberg (1977) editor, pp.189-210.
- Rosenberg, N. (1977b). "The Direction of Technological Change: Inducement Mechanisms and Focusing Devices" in N. Rosenberg (1977) editor, pp.108-128.
- Russell, S. (1986). "The Social Construction of Artefacts: A Response to Pinch and Bijker", *Social Studies of Science*, Vol.16, No.2, pp.331-346.
- Sabato, J. (1975). "Ciencia, Tecnologia, Desarrollo. Algunos Comentarios Generales" in M. Wionczek (1975) editor, pp.60-72.
- Sagasti, F. (1975). "Subdesarrollo, Ciencia y Tecnologia: El Punto de Vista de los Paises Subdesarrollados" in M. Wionczek (1975) editor, pp.25-37.
- Sagasti, F. (1976). "Technological Self-Reliance and Cooperation Among Third World Countries", *World Development*, Vol.4, Nos.10/11, pp.939-946.
- Sagasti, F. (1978). "Hacia un Desarrollo Cientifico-Tecnologico Endogeno en America Latina", *Comercio Exterior*, Diciembre, pp.1498-1504.
- Sagasti, F. (1980). "Towards Endogenous Science and Technology for Another Development" in D. Ernst (1980a) editor, pp.592-607.
- Schonberger, R. (1982). *Japanese Manufacturing Techniques: Nine Hidden Lessons*



*in Simplicity*, The Free Press, N.Y.

Shulman, S. (1986). "Stopping Star Wars". *Science for the People*, Vol.18, No.1, pp.10-15.

Soete, L. (1985). "International Diffusion of Technology, Industrial Development and Technological Leapfrogging", *World Development*, Vol.13, No.3, pp.409-422.

Stewart, F. (1978). *Technology and Underdevelopment*, MacMillan Press, London.

Stewart, F. (1984). See below (\*)

UNESCO (1979). *An Introduction to Policy Analysis in Science and Technology*, Science Policy Studies and Documents No. 46, UNESCO, Paris.

UNIDO (1981). *Technological Self-Reliance of the Developing Countries: Towards Operational Strategies*, Development and Transfer of Technology Series No.15, UNIDO, Vienna.

Vidal-Hall, J. (1982). "It's Time to Reach the Sky", *South*, September, pp.8-10.

Whitehouse, D. (1986). "A Quiet Move Into Space", *New Scientist*, 23 October, pp.46-50.

Winner, L. (1977). *Autonomous Technology: Technics-Out-of-Control as a Theme in Political Thought*, The MIT Press, Camb., Mass.

Winner, L. (1979). "The Political Philosophy of Alternative Technology: Historical Roots and Present Prospects", *Technology in Society*, Vol I, pp.75-86.

Winner, L. (1985). "Do Artifacts Have Politics ?" in D. MacKenzie and J. Wajcman (editors). *The Social Shaping of Technology*, Open University Press, England, 1985, pp.26-38.

Wionczek, M. (1975) editor. *Politica Tecnologica y Desarrollo Socioeconomico*, Secretaria de Relaciones Exteriores, Tlatelolco, Mexico.

Wolfe, D. (1986). *Socio-Political Contexts of Technological Change: Some Conceptual Models*, Paper presented to the Conference on Technology and Social Change, University of Edinburgh, June 12-13. Mimeo.

(\*) Stewart, F. (1984). "Facilitating Indigenous Technical Change in Third World Countries" in M. Fransman and K. King (1984) editors, pp. 81-94.

## Appendices

## Appendix I

### The Science-Related Nature of an Indigenous Microelectronics Capability.

The one aspect which is immanent to the origin of the microtechnology is scientific knowledge. Both the science of electromagnetism and quantum theory are generally acknowledged as having laid the foundations for the present-day microtechnological revolution (1). In Atherton's words,

"From the discovery of electromagnetism it is possible to trace a continuous development of understanding spanning more than a century that incorporates the electromagnetic theory of light, the beginning of relativity, and quantum theory and quantum mechanics. From the latter came our understanding of semiconductors and the path to the silicon chip" (Atherton,p.14).

Electromagnetism and the advances made in the 19th century had open the way for electronics telecommunications as well as for the generation of

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(1) Electricity and magnetism, thought as separate phenomena, had already attracted the attention of the ancient Greeks. But according to Mason (1962), their study in modern times "may be said to have begun with the researches of William Gilbert of Colchester during the sixteenth century" (Mason,p.474). On the other hand, Atherton (1984) relates the beginning of modern electrical science to the discovery of conduction by Stephen Gray in 1729. However, the science of electromagnetism as such may be said to have started only in 1820 with Hans Christian Oersted's announcement of the existence of the unified phenomenon of electromagnetism. Thereafter, during the 19th century, other great names contributed to establish the foundations of this science. Among others, Andre Marie Ampere with his mathematical work on electrodynamics (1820-1822), George Ohm with his work on the relationship between current, voltage and resistance (1826-1827), Michael Faraday with his work on electrolysis and electromagnetic induction (1831) and James C. Maxwell with his mathematical formulation of the theory of electromagnetism [Dunsheath(1962), Atherton(1984)]. The latter theory was first published between 1855 and 1864 and a definite version was published in 1873 in a book entitled *Treatise on Electricity and Magnetism*. Later, during 1877, Heinrich Hertz was to prove the validity of Maxwell's theory while simultaneously building a rudimentary transmitter and detector of electromagnetic waves which first demonstrated the basis of communications across the space. This scientific work during the 19th century laid the foundations for further scientific advances during the 20th century. Thus, in 1900, Max Planck postulated the principles of quantum theory, and Einstein in 1905 suggested that light and electromagnetic radiations in general had both, a particle- and a wave-nature. In 1924, Louis de Broglie extended this concept and suggested that all matter has dual wave/particle properties. De Broglie's work was furthered by other scientists, notably, Werner Heisenberg, Erwin Schrodinger and Paul Dirac, and, in 1926, Schrodinger gave mathematical formulation to the wave behaviour of the electron [Mason(1962), Atherton(1984), Bernal(1969)]. In this way, mostly since the 19th century, scientists gradually produced the knowledge base leading to the understanding of matter and energy and hence, to the understanding of the semiconducting phenomenon at the base of the

electricity. The discovery of the Edison effect in 1883 (2) had established the basis for the development of the vacuum diode by John Fleming in 1904 and later the vacuum triode by Lee de Forest in 1906. Both elements, acting as detector and as amplifier and switch respectively, became the elementary active components of all electronics (e.g., telecommunications devices and computers) up to the advent of semiconductor devices based on the scientific knowledge of the 20th century.

The scientific base of solid-state electronics is a well-documented fact, particularly, in relation to the epoch-making discovery of the transistor (3). The roots of its invention are often traced far back to Faraday's discovery in 1833 that the conductivity of silver sulfide increases with temperature (while metals display an opposite effect) and to the observation of other phenomena which in the 19th century puzzled the minds of great scientists (4) and found explanation only with the 20th century development of quantum theory. Thus, in 1932, A.H. Wilson published his work on the quantum theory of semiconductors which culminated the work of other scientists like F. Bloch and A. Sommerfeld (5). By 1933, as the same Wilson claimed, "all the basic principles concerning the solid state had been established" (Quoted by MacDonald et al, 1981, p.177).

The transistor, however, was developed only in 1948, ushering the era of solid-state electronics and the process of convergence of signal systems. That its development took fifteen years from the date referred by Wilson shows that scientific knowledge does not lead automatically into technology and hence, that in the case of the transistor, it was not the only ingredient necessary for its

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microrevolution.

(2) "In that year Thomas Alva Edison, in his effort to increase the life of his early carbon-filament lamps, introduced a metal electrode into the vacuum envelope containing the glowing filament. He discovered that when a positive voltage was applied to the electrode, a current flowed across the vacuum between it and the filament. This phenomenon - the great inventor's only fundamental scientific discovery - is the basis of all electron tubes and of all electronics up to the solid-state era" (*Electronics*, 1980, p.60).

(3) See Gibbons and Johnson (1970), Braun and MacDonald (1977), MacDonald et al (1981), Nelson (1962), Brooks (1976), Weiner (1979).

(4) In 1839, Alexander Becquerel discovered that he could generate a voltage by illuminating the junction of an electrolyte. A century later, the latter would be termed a semiconductor. In 1873, Willoughby Smith discovered photoconductivity by observing the reduction in the resistance of illuminated selenium. Finally, in 1874, Ferdinand Braun discovered the rectifying property of contacts between metals and semiconductors [Gibbons and Johnson(1970), *Electronics*( 1980)].

(5) Wilson put forward a band theory of conduction in semiconductors and explained the existence of both positive and negative highly mobile charge carriers (holes and electrons) as

materialization. Indeed, social and technical factors such as the need for equipment to control the level of impurities in semiconductor materials and the spur of commercial or military interests did play a crucial role in explaining the advent of the transistor. Without science, however, there would have been no transistor. As Braun and MacDonald (1977) have so forcefully argued,

"More than most innovations, the transistor was born out of scientific discovery. No doubt the science was aided by a whole gamut of techniques and instruments, but these served as the tools of science. Many innovations are based on technology, often aided by science at many stages. The transistor is one of the supreme examples of an invention truly based on science" (Braun and MacDonald,p.167).

In the transistor, therefore, there was an integral participation of science in the technological process in the same way as the science of electromagnetism had been the base leading to the early developments in telecommunications. Indeed, as we have indicated already, such a science-related factor is a permanent feature in the development of microtechnology and the one that has made R & D the most decisive element in a microelectronics capability (6). The latter whether to push the frontiers of microtechnology or, more simply, to command autonomy in its possession and application.

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well as the effect of impurities on conductivity (Gibbons and Johnson,1970).

(6) It is also the feature that has made microtechnology an advanced or high technology, that is, a technology which is at the very frontier of science.

## Appendix II

### Concepts Relating to the Post-World War II Social Complex of Power.

L. Mumford's Pentagon of Power controlling the modern Megamachine is the ensemble of social interests formed by the military-industrial-scientific elite plus the bureaucratic and the educational establishments. This Megamachine emerged under the pressure of World War II but, in the aftermath of the war, according to Mumford, "it did not give up its absolute weapons or the scheme for universal domination by threat of total destruction that had given a coalition of scientific and military agencies such inordinate power. Far from it. Though nominally the older organs of industry and government resumed their diverse activities, the militarized 'elite' fortified themselves in an inner citadel...cut off from inspection or control by the rest of the community. With the pusillanimous aid of Congress, they extended their tentacles throughout the industrial and the academic world, through fat subsidies for 'research and development', that is, for weapons expansion, which made these once-independent institutions willing accomplices in the whole totalitarian process...[Thus A.M.]... In a short time, the original military-industrial-scientific elite became the supreme Pentagon of Power, for it incorporated likewise both the bureaucratic and the educational establishments" (Mumford,1970,pp.226 and 269).

J. Ellul's techno-bureaucracy is the welding of the technologist, bureaucracy and politicians on the basis of a rationality of science-based technology and progress which absorbs science and is supported by the public and those in power. In Ellul's words, "...Politicians and administrators are completely convinced that the entire life of society, its economic development, and so on, is bound up with scientific "research", with the growth of our laboratories, with the result of the sciences...the bureaucrats exactly have the same conceptions as the technologists. It is true, moreover, that they themselves have become the technologists of the administration. More and more close ties are been knit between the group of technologists and the bureaucratic organisms of power. Finally, all research projects are made possible only by these administrations" (Ellul,1981,p.19). This social ensemble of power will exert total control over the development of science and technology. Thus, in relation to data processing, for instance, Ellul



thinks that "it is quite true that data processing (virtually) could be an instrument of humanization, decentralization, a flexible organization of work, of a real economy of time, etc...but *in fact* this possibility does not exist because the issue has already been decided in advance. Information processing is taken over by the techno-bureaucracy which only wishes to maintain its own conception of progress and growth. Said in another way, it will serve as an instrument of centralization, control, and rigidity" (ibid.,p.21). For an in-depth treatment of Ellul's concept of technology, see his famous work *The Technological Society* (1967).

J. Galbraith's systemic view of the technostructure-state-scientific- and-educational-estate interrelations.- According to Galbraith (1978,1974), the big corporations governed by the technostructure and the state are now deeply enmeshed in a network of common interests and goals. Thus, "...No sharp line separates government from the private firm; the line becomes very indistinct and even imaginary. Each organization is important to the other; members are intermingled in daily work; each organization comes to accept the other's goals; each adapt the goals of the other to its own... [thus A.M.]...The state is strongly concerned with the stability of the economy. And with its expansion or growth. And with education. And with technical and scientific advance. And most notably, with the national defence. These are the national goals;...[whereas A.M.]... The technostructure requires stability in demand for its planning. Growth bring promotion and prestige. It requires trained manpower. It needs government underwriting of research and development. Military and other technical procurement support its most developed forms of planning. At each point the government has goals with which the technostructure can identify itself. Or, more plausibly, these goals reflect adaptation of public goals to the goals of the technostructure" (Galbraith,1978,pp.309 and 313). But, it is with the military where the big corporations finds the best conditions to fulfill their goals. "The Department of Defense supports...the most highly developed planning in the industrial system. It provides contracts of long duration calling for large investments of capital in areas of advanced technology...This leads the technostructure to identify itself clearly with the goals of the Armed Services" (ibid.,p.310). Finally, the interlinking of the scientific and educational estate within the above complex of social interests takes place through two interrelated processes. First, "...the educational and scientific estate is no longer small;... it is very large. It is no longer dependent on private income and wealth for its support; most of its sustenance is provided by the state...[Second A.M.]...the

technostructure has become deeply dependent on the educational and scientific estate for its supply of trained manpower. It needs also to maintain a close relation with the scientific sector of this estate to ensure that it is safely abreast of scientific and technological innovations" (ibid.,p.289-290). Another author who has written in similar lines to Galbraith is D. Price. See *The Scientific Estate* (1965).

The military-industrial(-scientific) complex.- Pavitt and Worboys (1977) define the military-industrial(-scientific) complex (MIC) "as a coalition of certain industrial interests, the military, big science and technology, and others who profit from the proliferation of war and have an interests in preparations for such eventuality" (Pavitt and Worboys,p.26). Various explanations have been provided as regards the fundamental reasons for the existence of the MIC. Reich (1977), for instance, argues that the "growth and persistence of a high level of military expenditure is a natural outcome in an advanced capitalist society that both suffers from the problem of inadequate private aggregate demand and plays a leading role in the preservation and expansion of the international capitalist system" (Reich,p.296). This explanation follows Sweezy and Baran's argument of monopoly capitalism's need for a military machine in order to absorb the surplus and to confront the socialist system. As regards the latter aspect, the authors state that "the need of the American oligarchy for a large and growing military machine is a logical corollary of its purpose to contain, compress, and eventually destroy the rival world socialist system" (Baran and Sweezy,1975,p.190). See also Soukup (1976). The crucial economic role of the MIC is also emphasized by Mandel (1977). For him, "...Armaments economy, war economy, represent the essential replacement markets which the capitalist system of production has found in its age of decline...[it A.M.]...is indispensable for making profitable use of the capital of heavy industry and the "overcapitalized" big monopolies. But the arms economy makes the state the chief customer of this industry. The special ties between the state and monopoly capital...thus assume a more specific form" (Mandel,pp.522-523). Finally, the reproduction of the MIC has found in Kurth's follow-on imperative a different explanation. In Kurth's view, the military production lines are seen as national resources by all the interested parties involved. Thus, the "Defense Department would find it risky and even reckless to allow...large production lines to wither and die for lack of a large production contract...Such a contract renovates both the large and established ...corporation that produces the weapons systems and the large and established military organization that deploys it"

(Kurth,1972,p.308).

## Appendix III

### The Roots of the Social Constituency of the US's IMC: Corporate Capitalism and R & D System During the Late-19th and Early-20th Centuries.

By the late-19th century, the process of concentration and centralization of capital, which Marx described in *Capital*, had taken capitalism into its monopoly stage (1) and related stage of imperialism [Lenin(1944), Sweezy(1970)] (2). That is to say, within the most advanced capitalist nations the rise of monopolies, which Baran and Sweezy (1975) date from about 1870, had signalled the end of the predominantly competitive stage of capitalism.

In the new stage, the dominant economic unit was to be the corporation, a powerful instrument of centralization and accumulation of capital (3) which

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(1) As Recabarren (1980) put it, "...The emergence of monopolies was a natural result of the dynamics of concentration and centralization intrinsic to the process of capital accumulation", but, at the same time, in a dialectical fashion, "with the development of monopolies an acceleration of the very same process that was its cause, that is to say, capital accumulation, had to take place" (Recabarren,p.19).

(2) "Imperialism is capitalism in that stage of development in which the dominance of monopolies and finance capital has established itself; in which the export of capital has acquired pronounced importance; in which the division of all territories of the globe among the great capitalist powers has been completed" (Lenin,1944,p.77). In its most succinct definition, for Lenin, "imperialism is the monopoly stage of capitalism" (ibid.).

(3) The corporation, under the name of joint-stock company, had begun its development in Marx's time. Among its consequences, Marx saw in the corporation an "enormous expansion of the scale of production and of enterprises, that was impossible for individual capitals"...[and also a]... "transformation of the actually functioning capitalist into a mere manager, administrator of other people's capital, and of the owner of capital into a mere owner, a mere money capitalist" (Marx,1977b,p.436). The latter issue of the transformation of the role of the capitalist has been the focus of a great deal of attention, since it concerns directly with the problem of power within the capitalist enterprise and, indeed, society at large. By and large, there seems to be agreement that in the mature corporation control no longer rests in the hands of the capitalist but in those of management [Baran and Sweezy(1975),Kay(1977),Braverman(1974),Elliot and Elliot(1976)], or, in Galbraith's view, in the hands of the technostructure, that is, the organization embracing "all who bring specialized knowledge, talent or experience to group decision-making" (Galbraith,1974,p.86). However, while for Galbraith (1974,1978), the technostructure rather than capital has become the depository of power, for other authors this is a questionable proposition. Elliot and Elliot (1976) and Friedman (1977), for instance, argue that senior management and not the broader technostructure is the actual policy-making centre of the firm. In a similar vein, Sweezy (1972)states, "...The technostructure is hired and fired by top management" (Sweezy,p.36). On the other hand, Braverman (1974) points to the basic unity of interests between owner and top manager of capital to the extent that both "are drawn, by and large, from the same class" (Braverman,p.258). A somewhat similar point is raised by

would eventually grow into the present-day giant corporation commanding large economies of scale and exercising oligopolistic control of extensive markets (4). In Baran and Sweezy's words, under monopoly capital, the "dominant element, the prime mover, is Big Business organized in giant corporations" (Baran and Sweezy,1975,p.62) (5).

Briefly, this was the industrial-economic set up which saw the rise of the first science-based technologies and industries, namely, the electrical and chemical industries based on scientific knowledge of electromagnetism and chemistry respectively (6). As we shall presently see, from the beginning the monopolistic advantages associated to the possession of inventions protected by patents found in the application of scientific knowledge a most powerful source of inventions and hence, a means of constantly ensuring and extending such monopolistic advantages. In the science-based industries, therefore, a symbiotic relationship developed whereby scientific knowledge became effectively pressed into the service of corporate capital providing it with a constant source of productive growth and expansion, while corporate capital, in turn, became the social framework actually shaping and materializing the specific form of integration of the basic social constituents of the science-based technological and industrial

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Winner (1977), who suggests that the technostructure may in fact be directed by tacit limits and understandings reflecting the influence of the financial and business elite. Finally, Kay (1977) does accept the loss of power by the capitalist but sees it not as the end of capital but rather the unfolding of a new and superior stage of its historical development. In the last analysis, all this discussion is intricately related to the issue of who holds the reins of power in society. In this respect, the rise and spread of management to all spheres of society, particularly government, has fueled the basic technocratic idea that power may now rest in the hands of a technocratic or managerial class based on scientific and technical knowledge and expertise. We shall not discuss this issue here and shall content ourselves with directing the attention of the reader towards some important work on the roots of the concept of technocracy. See Bacon (1900), Saint-Simon (1964,1966), Veblen (1964,1965), Burnham (1941), Meynard (1968).

(4) The big corporation came into its own in the second half of the nineteenth century, first in the fields of finance and railways spreading to industry around the turn of the century, and later invading most other branches of the national economy" (Baran and Sweezy,1975,p.40). See also Braverman (1974).

(5) For instance, "...Between 1896 and 1905 the size of the hundred largest American companies quadrupled and by 1905 they controlled 40 percent of America's industrial capital" (Friedman,1977,p.38).

(6) In his explanation of the transformation of industry by the late-19th century, Hobsbawn (1978) argues that among the most important changes, the "first and in the long run most profound change was in the role of science in technology...The major technical advances of the second half of the nineteenth century were...essentially scientific;...Two major growth industries of the new phase of industrialism, the electrical and the chemical, were entirely based on scientific knowledge...The last major change was the increase in the *scale* of economic enterprise, the concentration of production and ownership, the rise of an economy comprised of a handful of great lumps of rock -trusts, monopolies, oligopolies- rather than a

activity. As Noble (1977) put it in relation to the US, "...the history of modern technology in America is of a piece with that of the rise of corporate capitalism. Both contributed to a transformation of the *modus operandi* of industrial capitalism - the one providing the wherewithal for unlimited productive growth by implicating science in the production process, the other offsetting the destructive tendencies in an unchecked competitive market economy by making possible the regulation of production, distribution and prices" (Noble,pp.xii-xiii)

### *The Emergence of the R & D System.*

Along with the process of incorporation of science into the sphere of technological and industrial activity there emerged a set of institutions whose purpose was to enable and materialize such a process of science incorporation and which has become known as the research and development (R & D) system. The origins of this system may be traced back to the 18th century to the formation of the first technical schools in France and Germany (7) and, more directly, to the introduction of the experimental technical laboratory at the *Technische Hochschule* in Munich in 1868 (8). With the emergence of the laboratory, technology finally became a field of research in itself (Weingart,1978), incorporating science to supply the needs of the emergent science-based industrialization.

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large number of pebbles" (Hobsbawn,pp.172 and 177).

(7) The first specialized technical schools emerged in France and they were organized by the absolutist state "strictly to meet the needs of transportation, mining, the military and the Navy (Bohme et al,1978,p.227). In this sense, as Weingart (1978) suggests, they "seem to have been the result of an early utilization of science by the state" (Weingart,p.270). Among some of the early schools in France were, the *Ecole des Ponts et Chaussees* ( 1750), the *Ecole du Corps des Ingenieurs des Mines* ( 1778), the *Ecole Royale Militaire* ( 1753), the *Ecole du Corps Royal du Genie* ( 1765). In England, similar institutions were the Mechanics Institutes, and in Germany the Mining Academies in Berlin (1775), in Freiberg (1765), and the Schools of Agronomy (Bohme et al,1978). In France, the movement of technical schools led in 1794 to the formation of the *Ecole Polytechnique*, which, according to Drucker (1961), marked the establishment of the profession of engineer. The main focus of these schools was technical training, but they incorporated the fundamentals of mathematics and natural science in their curriculum. Hence, Weingart's statement that "they were not limited to purely technical training function but also fostered natural sciences" (Weingart,1975,p.270).

(8) According to Hales (1982), "...The systematic application of research effort to problems relevant to commercial practice took off most notably in Germany, where the chemistry teaching laboratory of Justus von Liebig (founded at Giessen 1824) became a model of future development" (Hales,p.89).



Historically, it was in Germany where the incorporation of science into industry achieved its most developed expression, during the last decades of the 19th century. There, a policy of fostering science and its industrial application was to develop in a way which was unknown to other contemporary industrial powers, notably Britain which remained very much in the grip of empiricism (Bohme et al,1978). As Braverman (1974) has described,

"...at a time when British and American industry used university-trained scientists only sporadically, for help on specific problems, the German capitalist class had already created the total and integrated effort which organized, in the universities, industrial laboratories, professional societies and trade associations, and in government-sponsored research a continuous scientific-technological effort as the new basis for modern industry" (Braverman,p.162).

The clearest demonstration of the situation above was the rise of Germany as the undisputed world leader in the chemical science-based industry by the turn of the century. In effect, although, as Landes (1969) has argued, the first years of the new branch of chemical manufacturing belonged to Britain with France in second place (9), by the late 1870s the German industry had captured about half the world market and, by the turn of the century, its share was around 90 percent (10). The large extent to which such a monopolistic supremacy depended upon the systematic integration of science into the industrial process is confirmed by Freeman (1974),

"The German industry in the 1870s had already established the new pattern of in-house R & D leading to the introduction of new products and processes. Bayer, Hoechst and BASF (Badische Anilin and Soda Fabrik) were among the first firms in the world to organize their own professional R & D laboratories" (Freeman,p.48) (11).

The impact of the experience of the chemical industry, and also that of the

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(9) Braverman (1974) points out that the leadership in chemistry and its industrial applications first belonged to France and it was forged during the Napoleonic Wars as a result of the cutting of supplies of soda, sugar and other products. In Bernal's view, the birthplace of chemical research was 18th century Britain. But starting with Lavoisier, France gained and kept a 70-years supremacy in chemical research. Later, the leadership would slip to Germany (Bernal,1969).

(10) As Bernal (1944) has stated, "in a few years the chemistry of dye-stuffs and explosives, for which the foundation had been laid largely in France and Britain had been captured as part of a new German industry which held the virtual monopoly of the world market" (Bernal,p.29).

(11) "The six largest German firms for coal-tar products took out 948 patents between 1886 and 1990, as compared with 86 by the corresponding English firms" (Landes,1969,pp.352-353). Also, "the six largest German chemical works employed more than 650 chemists and engineers, while the entire British coal tar industry had no more than thirty or forty" (Braverman,1974,p.162). See also Barber (1970).

other science-based industry of the 19th century: the electrical industry, had momentous significance. In short, it definitely established the importance of science for industry and capital accumulation. Indeed, in Hobsbawn's view,

"...by the end of the nineteenth century it was already clear...that the output of technological progress was a function of the input of scientifically qualified manpower, equipment and money into systematic research projects" (Hobsbawn,1978,p.174).

In other words, by the end of the 19th century, the integration of human, material and financial resources intrinsic to all technological development began to revolve, as never before, around the systematic production and/or application of scientific knowledge through the R & D system (12). More importantly, as this process was actually mediated by the unfolding context of corporate capitalism, it is true that, as Noble (1977) argued, from its inception, the development of the R & D system and, more generally, of the science-related technologies, came to play a major part in the process of capital accumulation and monopoly power. In turn, in a dynamic of reciprocal compulsions, the latter process also helped to shape the development of the R & D system itself.

Historically, however, the economic sphere was only the most immediate place where the importance of the R & D system manifested itself in practice. For, in time, the role of such a system was to reach deeply into other spheres of society, thus bringing other powerful social interests (e.g., military, government) to bear their influence upon its development. In the latter context, as we shall see below, the control of basic human, financial and material resources of the R & D system will effectively outgrow the prerogative of industry in such a way that its actual shape and dynamism will be the result as much of the relative strength as of the convergence and contradictions characterizing the interrelations between all the social interests involved. Undoubtedly, the main tendencies emanating from the industrial sphere of capital will still shape the development of the R & D system, but now in interaction and interrelation with other social interests through the shared

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(12) "Whatever the situation in the early nineteenth century, formal links between science and industry were increasingly forged in the form of a distinct organization within the firm - the research and development laboratory. Moreover, the specialization of inventive and innovative activity was not restricted to modern, science-related industries; it was also found in established industries like iron and steel...it became increasingly dangerous for firms to be left behind by technical change and in turn more profitable for them to invest in the exploration of new products and processes" (Pavitt and Worboys,1977,p.17). In the same vein, Noble (1977) defines modern science-based industry as "industrial enterprise in which ongoing scientific investigation and the systematic application of scientific knowledge to the

control of the R & D system's basic resources.

In the following by focusing on the particular case of the US, we shall look at the social forces, and their interrelations, which have been involved in the origins and development of the R & D system and hence, of science-based technology. In so doing, we shall illustrate our discussion with particular evidence from the science-based industries most directly related to today's microtechnology. Thus, we expect to gain an insight into the historical roots of the social constituency of an indigenous microelectronics capability. In line with the historical development of the R & D system, we shall start by focusing our attention on those forces and tendencies emanating from within the industrial and productive sphere. For, it was here where the R & D system and science-related technologies actually began its development in earnest.

*The Emergence and Development of the US's R & D System: Corporate Capital as Its Dominant Social Constituent.*

In the US, where the industrial R & D system has achieved a leading position during the 20th century, the first research laboratory set up for the specific purpose of systematic invention was organized by T.A. Edison at Menlo Park, New Jersey, in 1876. According to Lindsay (1973),

"This was the forerunner of the modern industrial research laboratory, which has revolutionized the relations between science and technology in the twentieth century...[however A.M.]...Edison's laboratory was not a laboratory for scientific research. His sole purpose was to dream up and then produce gadgets which would have economic value, i.e., could be sold at a profit to a public which found them useful or exciting...Nevertheless, his laboratory had a well-defined program and pursued it systematically" (Lindsay,p.216) (13).

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process of commodity production have become routine parts of the operation" (Noble,p.5).

(13) Although not engaged in fundamental research, Edison's laboratory made full use of the fundamental laws of electromagnetism. Thus, "...Having...defined the purpose, Edison achieved it through the systematic application of the scientific discoveries which had been made by Ohm, Oersted, Laplace, Joule, Faraday and others" (Sabato,1975,p.39). In his *Networks of Power*, Hughes has dealt extensively with the characteristics of Edison's laboratory. According to him, "...The Edison laboratory at Menlo Park was probably one of the best electrical laboratories in the world. Moreover, Edison also equipped it, at great expense, as a chemical research laboratory...Edison assembled a community of craftsmen and appliers of science and the tools and scientific instruments they needed in order to work on problems of a systemic nature" (Hughes,1983,pp.24-25).

Later, towards the end of the 19th century and beginning of the 20th century the number of commercial research laboratories began to increase as gradually the importance of R & D began to be recognized. In 1886, Arthur D. Little, an applied scientist, started his independent firm. Others followed, Eastman Kodak (1893), B.F. Goodrich (1895), General Electric (1900), and Du Pont (1902) were some of the earliest manufacturing firms to establish laboratories; and the Bell Telephone System (1907) was among the first utilities to do so (Mansfield,1969). Also, the first government laboratories were in 1887 by the Department of Agriculture (Braverman,1974).

Before the 20th century, however, most scholars coincide in that R & D activity in industry put little emphasis on fundamental research. Indeed, it is a matter of agreement that organized industrial research, involving fundamental research, actually began in 1900 at General Electric's (GE) laboratory at Schenectady, New York, as a result of a conscious policy by the company to bring scientific knowledge to play a major role in its future development [Barlett(1941),Lewis(1967),Allison(1980)]. In Lewis's words,

"Here under the leadership of Willis R. Whitney, formerly a chemistry professor at M.I.T., a large staff of scientist and technical personnel was formed and kept constantly at work on a variety of problems involving electrical phenomena. By engaging in continuous education, the company helped to keep abreast of any new developments in its area of commercial interests, thus maintaining its dominance and guarding against future competition" (Lewis,1967,p.626).

The laboratories organized by Du Pont in 1902 and Bell in 1907 followed GE's path, as did other industrial laboratories set up later on (14). The reasons behind such change were both technical and socio-economic but an immediate one was the fear that the stock of scientific knowledge which had underlain the rise of the science-based industries in the 19th century was no longer sufficient for the demands of further technological progress (15). Thus, the frontiers of scientific knowledge had to be pushed forward and, as it was apparent that they could be done so indefinitely with obvious implications for the future of the companies, a policy of in-house R & D activity, including fundamental research, came to be perceived by corporate capital as an important asset in the long-term

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(14) For a brief historical review of early laboratories in different industrial fields, see Barlett (1941) and Fleming (1917).

(15) "A few people feared that technological improvement might be hampered by a lack of scientific information. Some leaders at General Electric at the end of the century feared that the industry was rapidly "using up" its scientific capital. The organization of the General Electric Research Laboratory was one step in an attempt to rectify that situation"

commercial strategy of science-based industries (16).

The industrial laboratories materializing a policy of in-house R & D, however, demanded sizeable financial resources and, in practice, could be afforded by only a handful of powerful industrial concerns, namely, the large corporations. Such development clearly marked the end of the early period of the industrial laboratory dominated by the figure of the inventor-entrepreneur. The latter had been the original form and it had clearly established the foundations of science-based activity (17), but, by the early 20th century, as Birr (1966) put it, it "was left to the large corporations developing everywhere in the American scene... to introduce organized industrial research" (Birr,p.68). The reason was quite simple: it was these large corporations where there was "sufficient financial resources and stability to support the laboratories and where there was a rapidly changing, competitive technology which made successful research imperative for the sponsoring firm "(ibid.) (18).

In the early 20th century US, therefore, large corporate capital effectively became the dominant social constituent behind the development of the R & D system. This meant that the latter's shape and dynamism became largely influenced by the tendencies and needs flowing from the particular interests of corporate capital. In this respect, profits, competition and the search for

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(Birr,1979,p.197).

(16) For instance, in reference to GE's decision to set up the Schenectady laboratory in 1900, Lindsay (1973) says, "...It was soon recognized by the directors of this new company that the amount of technological development which could be drawn out of the scientific knowledge already accumulated during the nineteenth century, though large, was finite and that there would be a greater chance of ingenious developments if there were more science to work with" (Lindsay,p.216).

(17) As one scholar has described, "the industrial research laboratory... grew up almost imperceptibly from the workshop or private testing place of the inventor turned business man, such as Siemens or Edison" (Bernal,1969,p.569). The names of Alexander Bell and Guglielmo Marconi are of particular relevance for the present study on electronics as they were the inventor-entrepreneurs who did most in relation to the telephone and radio respectively.

(18) "Nearly all of the basic research done by industry, as well as the bulk of applied research, was restricted to large firms with ample financial resources, since they alone were able to provide researchers with a relatively stable working situation and adequate facilities" (Noble,1977,p.111). Also, "only corporations of great wealth... can afford large research organizations. Good industrial research of any kind, and specially relatively fundamental research, is expensive for a number of reasons. In the first place, good research talent and good research facilities are not cheap...In the second place, research is expensive because there may be a period of anywhere from five to ten years between the original scientific conception or "hunch" and its application in an actual industrial process or product...And, last of all, the development work which lies between pure research and industrial application is also very costly, not only in equipment but in engineering talent" (Barber,1970,pp.220-221).



monopoly positions through patenting and innovation, all became prominent factors in accounting for the particular form of development of the science-based technology. Let us try to systematize the process whereby all these factors came together, mostly within the industrial sphere of society. The following major developments can be distinguished.

a) The incorporation of science into the industrial sphere of society was naturally pioneered by those industries which from the outset had depended upon science for its development. These were the chemical and electrical industries which, as we have seen earlier, were the first to incorporate R & D as a systematic activity of their overall business activity. At the beginning, the activity of the industrial laboratory was chiefly development and some applied research. But, large-scale organized industrial R & D, involving fundamental research, began in the science-related industries early in the 20th century (19). From here, the example would later extend to other industries. In Barber's words, "...Older industries were much less quick to bring science into their activities" (Barber,1970,p.214) (20).

b) From the start, in-house R & D activity was an integral part of the process of capital accumulation of the science-based industries. In consequence, the shape and dynamism of this R & D activity was intimately bound up not only to the specific technical problems facing the particular industries but, indeed, to the very essence of the process of capital accumulation, namely, the profit making activity. In the context of the market, this meant that competition, or rather the constant attempt to negate it in the search for monopolistic positions, came to play a major role in shaping and stimulating specific technical challenges and hence, the specific content of industrial R & D. Birr (1979) has explained how this process took place in the US context.

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(19) In the telephone industry, for instance, the "Bell System's permanent commitment to research came in 1907 with the consolidation of its research activities in the Western Electric Company and AT & T, and was established institutionally in 1911 with the creation of its first research branch" (Hoddeson,1981,p.515). This was not a sudden development, however, since from the establishment of the Engineering Department in 1881, the Bell company had been organizing departments to deal with the technical problems imposed by the growing telephone industry. Thus, what took place in 1907 was in fact a major reorganization of the various existing facilities, bringing them together under a greater commitment to research [Fagen(1975), Coon(1939),Hoddeson(1981)].

(20) "On the whole those industries born in the laboratory or directly dependent upon new knowledge for their growth organized research activities earlier and more rapidly than the industries which had long been established. In fact in 1920 approximately two-thirds of all the research workers who were recorded in the first survey of the National Research Council were employed in the electrical, chemical, and rubber industries" (Barlett,1944,p.34).



"The late nineteenth century was a period of bitter competition, deflation, and business upheaval in America as industrial leaders desperately searched for security and stability. The search most obviously led to methods of lessening competition, including interfirm cooperation, price fixing, mergers and other activities which so aroused the ire of the antimonopolists. But in some cases the search for corporate security led towards science and technology...Such needs were most deeply felt in those industries characterized by rapidly changing technologies and particularly in those industries whose technologies were dependent on science. It was no accident that the modern industrial research laboratory first emerged in industries such as communications, electrical machinery and chemicals. The first two had never had a craft tradition in advance of scientific knowledge; indeed, electricity had never been of practical use before scientific understanding of the principles on which operated" (Birr,1979,p.197) (21).

However, the important part of the specific technical demands intrinsic to the development of the science-based industries should not be belittled in the face of the major role played by social factors. For, while it is true that technical progress has no dynamism of its own, it is equally true that competition, or more generally, the profit-driven process of capital accumulation, cannot explain completely the specific form and needs of the R & D system at any particular time. It seems clear that the latter also depends heavily upon both the current state of development of the technology and the scientific-technical requirements inherent to the technical goals associated to the overall business strategy of the firms (22). Hoddeson (1981), for instance, specifically gives technical factors an important role in explaining the incorporation of scientific research in the R & D activity of the Bell System during the early 20th century. She suggests the following three principles.

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(21) Both the American Bell Telephone Co. and Marconi in radio fought fiercely to control their respective markets. This situation was reflected in the technological and R & D policies of both companies. At Bell's, for instance, the establishment of the Engineering Department in 1881 was particularly the result of a strategy to control the market through an extension of the company's patent production. The Department was "to conduct research and experimentation and to evaluate outside inventions for relevance to the telephone" (Brocks,1981,p.103). For this reason Coon (1939) suggested that "...The Bell System is built on patents. Its objective is the perpetuation of its monopoly" (Coon,p.7). Another example within Bell was the company's decision to develop long-distance lines which was in practice an important aspect of the strategy "to develop industrial control" (Brocks,1981,p.104). On the other hand, in the field of radio, as Maclaurin (1949) described, "...Marconi's plans for marine wireless were large and ambitious. He hoped to control the basic patents in the art, and to equip ships of all nations with wireless apparatus. He hoped also to erect shore stations at key points around the world, through which all ships messages would be sent. In the pursuit of these objectives, Marconi was determined to obtain a monopolistic position" (Maclaurin,p.37).

(22) Our discussion in Chapter III has clearly emphasised this point by showing the enormous range of technical-scientific requirements intrinsic to an IMC.

"(1) nonscientific objectives lead the company to particular technological problems; (2) technological problems so profound or complex that the usual approaches to such problems fail, leading the company to seek deeper understanding of the underlying physical phenomena; (3) research that is successful in technological terms reinforces the company's commitment to scientific studies in the particular area" (Hoddeson,p.516) (23).

c) By pushing forward the frontiers of scientific-technical knowledge, industrial R & D activity brought about, more than ever before, the likelihood of two threatening developments for the market position of established firms.

(1) loss of technological control and competitiveness to other firms in the field, eventually leading to loss of market and fall in the rate of profit.

(2) complete or partial technological and market displacement as a result of radical innovations bringing about new and more competitive products and/or processes.

The effort to prevent both possibilities from materializing became a major factor in shaping the technological policy and, particularly, the R & D policy of established firms. At the beginning, the pioneering science-based concerns sought to protect their technological leadership by using the monopolistic protection provided by the patent system (24). Here they would try to develop, or

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(23) A particular instance described by Hoddeson (1981) relates to the influence on R & D of the Bell System's decision to realize Alexander Bell's dream of a universal system by constructing intercontinental lines. In her words, "...Out of Vail's [president of the Bell System at the time, 1908-1909 A.M.] largely nonscientific goal to create a universal telephone system grew his decision to build a transcontinental line, from which came the technological problem of developing a non-mechanical repeater, and this problem in turn contributed crucially to the start of Bell's formal commitment to in-house basic research. "Basic" industrial research was now recognized as intrinsically dual in nature, being fundamental from the point of view of the researchers while at the same time supported by the company for its possible applications" (Hoddeson,p.534-535).

(24) According to Sherwood (1967) a patent proposal may have been advanced by Hippodamus already in Ancient Greece, but "the earliest patent law on record was enacted in 1474 by the Republic of Venice" (Sherwood,p.488). In England, the patent system dates from the 16th century and a statute was passed by the Parliament in 1623. It was geared towards the promotion of new industries by granting monopolies to importers of inventions as well as to inventors themselves. In the US, the first Patent Law was enacted in 1790 and empowered Congress "to promote the Progress of Science and useful Arts, by securing for limited times for Authors and Inventors the exclusive right to their respective Writings and Discoveries" (Quoted by Sherwood,1967,pp.488-489). Since then patents have been considered to protect and reward the inventor, i.e., "to be either a reward to the inventor or a result of a bargain between him and society" (Bernal,1944,p.144). By 1860, this may have indeed been the case when Abraham Lincoln praised the virtues of the patent system for adding "the fuel interest to the fire of genius" (Quoted by Noble,1977,p.84). But with the

simply, acquire the rights to all those patents relevant to the technological control of the business. Indeed, as Noble (1977) has described for the case of GE and AT & T,

"[their A.M.]...individual policies...were carefully designed to gain and prolong monopolies over patents vital to their industry. Toward the end, they employed such methods as incomplete disclosure of information in patent applications, the use of trademarks, the outright suppression or delayed introduction of patented apparatus, the compulsory assignment of employee patents to the company, and the deliberate production of auxiliary patents" (Noble,p.93) (25).

In this way, the big corporations could monopolize the market and, at least for the monopolistic period of the patent, very little could take place which was technically out of their reach unless some major innovation were to alter the technical scene considerably. In practice, however, this policy could not offer long-term security to companies since not only patents lasted for a limited period of time (26) but, most importantly, the possibility of major competing technical changes was quite real and it could not be effectively prevented by a policy chiefly emphasizing the legal aspects of patents while overlooking their systematic production through organized R & D. In fact, without the latter, corporate capital realized that in time it might face loss of technological control or leadership of the industry or, simply, technological displacement as a result of technical development in other fields. Hence, the only effective way of covering against such possible threats was to carry out a systematic policy of industrial R & D seeking to keep abreast with most, if not all, aspects of technological progress relevant to the industry (27). This became particularly

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rise of the big corporations and the industrial laboratory seeking to control the process of technological change, the situation has changed altogether. In Noble's words, "...Within a half-century after Abraham Lincoln offered his glowing evaluation of it, the American patent system has undergone a dramatic change; rather than promoting invention through protection of the inventor, the patent system had come to protect and reward the monopolizer of inventors, the science-based industrial corporations" (ibid.,p.85).

(25) In the 1930s, for instance, a report of the National Resource Committee claimed that the Bell Telephone System had suppressed 3,400 unused patents in order to forestall competition (Sherwood,1967).

(26) An illuminating example on this score is what happened at the end of the Bell System's patent monopoly of the telephone in 1894. Prior to this date for 17 years Bell had enjoyed a total monopoly of the telephone market and the annual rate of return on investment had been approximately 46 percent (Brock,1981). After 1894, without the patent monopoly, the situation changed markedly. "By 1900 telephone competition was widespread. The independents controlled 38 percent of the phones installed in the United States...[and]... Return on investment for the system as a whole declined...to 8 percent during the years 1900-1906" (ibid.,p.117).

(27) Consider, for instance, how the invention of the vacuum tube by Lee de Forest and the development of radio became major technical challenges to the Bell System's standing in

true as the technical challenge emerging from the commercial strategy of the firms grew in complexity. For, as we have seen in the previous point, the more complex the technical challenge, the greater the need for scientific research and, ultimately, a well-organized R & D system. In fundamentals, this was the situation which the development of the large science-based corporations had reached in the US by the early 20th century, and which led them to organize the first industrial laboratories incorporating science as a systematic activity [Noble(1977),Hoddeson(1981),Birr(1979)].

d) The success of the science-based corporations and the growing R & D effort being demanded by the increasing complexity of the technical problems resulting from their market strategy, brought with it two important developments which were not only to expand the industrial R & D system beyond the quarters of the large corporations into smaller business concerns but also to bring the university within its sphere of influence. The first development was the spread to a wider spectrum of industrial concerns of the importance attached to R & D activities in relation to market success. The second development was the growing costs of such R & D activities as the range of scientific disciplines brought to bear into the technological process both widened and deepened. As we saw earlier, in-house R & D laboratories were expensive to keep and companies other than the large corporations could barely afford them. With increasing technical complexity and costs this problem became more critical since "even in those great enterprises which were able to support some fundamental as well as applied research (notably Du Pont, GE, and the Bell System), in-house industrial laboratories were not able to meet all their research needs" (Noble,1977,p.121). In addition, there had always been a crucial need that no industrial laboratory could satisfy, namely, to generate the scientifically

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the telephone industry [Reich(1977),Coon(1939),Brock(1981)]. Commercial and legal moves "protected AT & T from existing competitors using the existing technology, it did not protect the company against major technological change. Technological change could threaten either by allowing another company to enter existing types of telephone service or by creating a new product that would take business away from the telephone. Radio and the vacuum tube threatened both kinds of changes. Because the vacuum tube was crucial to a telephone amplifier for long-distance service, a company that controlled the vacuum tube could provide severe long-distance competition. Because radio could communicate without wires, it could lead to a new product to displace wire-based telephone systems" (Brock,1981,p.175). A policy of systematic R & D helped AT & T to contain both challenges. First, it enabled the company to swiftly spot the strategic importance of the vacuum tube and eventually to acquire its patent from de Forest. Second, it enabled AT & T to forestall any invasion of the telephone field by getting involved in the radio field first and thus negotiating from a position of strength the spheres of influence to be left to competing companies. As Reich (1977) put it, "...the use of patents rights could take both an

trained manpower to constantly reproduce and expand the R & D system (28). In these circumstances, there was a clear need for the galvanization of wider social resources to ensure the further development of the R & D system and satisfy the increasing needs of industry. In practice, this need crystallized not only in a closer interrelation between industry and the university but also in the emergence of a number of outside research institutions. In effect, as Dickson (1984) has noted in relation to universities, "...The industrial interests in science also meant drawing universities even more closely into the corporate sphere of influence, since they were soon recognized as offering the most likely source of ideas required for innovative products and processes" (Dickson,p.62) (29). As for the outside research organizations, they took various forms which have been well documented by various authors (30). The most important were university research facilities, trade associations laboratories, non-profit research institutes such as the Mellon Institute, commercial research laboratories such as the A.D. Little Laboratory, private foundations such as the Carnegie Institution, federal government research facilities in government bureaus such as the National Bureau of Standards and also, particularly after World War I, military departments research facilities. All these institutions, therefore, together with both the facilities of colleges and universities and the in-house R & D laboratories, greatly expanded the institutional web of human, financial and material resources at the service of industrial R & D and, ultimately, of course, at the service of corporate capital exercising the hegemonic control of such a process.

From the first pioneering efforts headed by the inventor-entrepreneurs, therefore, industrial R & D had come a long way towards an institutionalized system involving wider social interests than industry's. For the most part, however, before World War I the development and shaping of the US's R & D system had revolved around the industrial sphere dominated by corporate capital. The impact outside the industrial sphere has been limited and this had

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offensive and a defensive character, and the defense could be indirect" (Reich,p.209-210).

(28) As Purcell (1966) has commented, "...there were certain functions which were either clearly unprofitable or impossible for industry to provide for itself" (Purcell,p.232).

(29) The influence of industry on university science was also noted by Bernal (1969), "...university laboratories also grew, from the very fact that the new uses of science meant new jobs and attracted more and more students. Thus, despite all the protestations and disinterestedness, the academic science of the period was ultimately dependent on the success of science in industry" (Bernal,p.569).

(30) For instance, see Barber (1970), Barlett (1941), Noble (1977), Brand (1941), Miller



reflected itself in the small relative weight of other social interests in the social constituency shaping the development of the R & D system. With the advent of the First World War, however, all this began to change as the huge galvanizing force of war forced powerful social interests other than corporate capital into the process of shaping and controlling the development of science-based technology. The main result of the new situation was to be the crystallization, for the first time in an important scale, of what is today the most particular characteristic of the dominant social constituency of the US's R & D system. That is, the existence of a complex of social interests which has capital as only one of its constituents along with and in interrelation with the powerful interests of government, the military and science. As we shall see below, the historical unfolding of this new social constituency was to bring with it new problems and, indeed, a new dynamics of development for the US's R & D system as a whole. For, in the last analysis, the interrelation which will bind the diverse social constituents together will be inevitably one of simultaneous convergence and contradiction. Let us examine now the formation and impact of the World-War-I social constituency of the US's R & D system.

*World War I and the Widening of the Social Constituency of the US's R & D System.*

Up to the First World War, the process which we have examining above proceeded in a rather slow fashion. Thus, by 1920 the number of companies carrying out R & D activities was reported to be around 300. As Barlett (1941) pointed out, "...a small figure when compared with the number of companies for which research was a sound undertaking" (Barlett,p.34). Moreover, there was a great deal of concentration of industrial R & D activity in the science-based industries as two-thirds of all the research workers were employed in the electrical, chemical and rubber industries (ibid.).

With the outbreak of the war the strategic importance of science and technology became apparent (Schroeder-Gudehus,1977). The crucial role of the science-based technologies in military power and national defense was firmly demonstrated by, for instance, the widespread use of chemical weapons in the battlefield (31) and by the shortages, particularly of chemical products and

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(1966), Coben (1979).



equipments following the cut in exports from Germany. In the US, this situation led to a greater involvement of the government and the military into the sphere of the R & D system which so far had been developing largely under the unchallenged control of corporate capital (32). Although in the past government and the military had been involved in the development of science and technology (33), such activities were modest in scale and did not represent the manifestation of any systemic interrelation with science and industry. According to Lasby (1966), for instance, the early relationships between science and the military were superficial and marked by a continuous antagonism and tension. So much so that, by the turn of the century, "the separation of science from the services was nearly complete" (Lasby,1966,p.258). In addition, it was also the case that in the US the military utilization of science to improve or develop weapons was virtually nonexistent until World War I" (ibid.,p.252).

The advent of the War, however, was to provide the galvanizing force and context within which the first links of a systematic interrelation between science, industry, government and the military were forged. This was to be the actual beginning of the broadly-based complex of social interests which by controlling the basic resources of the R & D system has come to effectively shape the development of science and technology in the US. The main practical effects of the war period upon the development of the R & D system have been described by Pursell (1966).

"World War I left its mark on American science. Research, though not a complete stranger, was finally established as a strong partner of both industry and the military, and its position in the government generally was strengthened. Furthermore, the kind of cooperative assault on large problems which had been the developing technique of government bureaus for decades, now became a common experience for many American scientists. And finally, the war had left behind a whole string of new institutions, from the National Research Council [formed in 1916 A.M.] to the nearly aborted Naval Research Laboratory [finally set up in 1923 A.M.], which would have a vitalizing effect on government science in general" (Pursell,p.237) (34).

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(31) The First World War has been characterized as the "Chemists' War" [Lasby(1966), Rose and Rose(1977)].

(32) "From the standpoint of industrial research...the obvious connection between Germany's scientific establishment and its military prowess, combined with great shortages of commodities such as dyes and pharmaceuticals following the outbreak of the war in 1914, went far to convince many influential Americans of the necessity to give organized science strong support" (Lewis,1967,p.628).

(33) In this connection, see Pursell (1966), Lindsay (1973), Lasby (1966), Penick et al (1972), Mark (1982), Pavitt and Worboys (1977).

(34) Another important effect of World War I upon science was a severe blow on scientists' traditional values as they embarked in the cause of war. "The tradition of scientists'

The war, therefore, clearly expanded the social constituency of the US's R & D system beyond the realm of corporate capital interests. More crucially, during the wartime period itself, the very internal dominance of the social constituency was substantially altered. In particular, the relative weight of corporate capital underwent a marked decline as the galvanizing force of war propped up the relative position of military/government interests, who thus came to effectively shape the development of the US's R & D system during those years. The greatest effect of such internal alteration in the social constituency was immediately felt in the direction and content of the technological process as military goals swiftly displaced purely economic goals as the dominant preoccupation of the country's R & D pursuits. This situation was clearly depicted by Barlett (1941) when he wrote that, by the time of the armistice, "practically every scientist possessed of any capacities for research had been called upon to aid the country with his special knowledge" (Barlett,p.35). To the changes within the social constituency of the US's R & D system, therefore, there had followed changes in the very social purpose of such a system and, consequently, in the final product of its activities.

From the point of view of the nature of the R & D process, two important aspects were thus clearly highlighted. On the one hand, the profound social nature of the process of development of the R & D system and hence, the fallacy of any idea that technology possesses a "life" of its own. On the other hand, the contradictory nature of this process insofar as changes in its social constituency, by pressing into particular directions are bound to contradict its progress in others. During the war, for instance, as Lewis (1967) has described,

"The drain of scientific talent into projects of a military or semi-military nature...caused the temporary cessation of research in various areas of peacetime application and interfered with the progress of fundamental exploration in basic science" (Lewis,p.628) (35).

In other words, while the diverse social interests could certainly converge in their support to the R & D system on the basis of wartime military

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neutrality and internationalism was rudely shaken, if not totally destroyed by the outbreak of World War I. Scientists and technologists in all the combatant countries responded to nationalistic propaganda and their own patriotic promptings by enlisting their talents in the service of the nation-state" (Lakoff,1977,p.358).

(35) The impact of this situation for the case of AT & T's research, for instance, has been described as follows: "From 1917 to 1918 long-distance telephony research was discontinued. Efforts in the war years centered on the development of two-way radio telephone sets for dispatch purposes on subchasers and airplanes. In 1919 AT & T resumed its former program" (Maclaurin,1949,p.93).

concerns, such convergence was not free of contradictions insofar as the resulting militarization of purpose in the use of the basic resources of the R & D system tended to affect negatively the latter's progress into areas of mainly civilian application (36). After the war, however, such a trend was reverted as the waning of the galvanizing force of war was accompanied by a major decline in the relative weight achieved by the military interests on wartime R & D activities (37). As this took place, however, a new basis for the peace-time convergence of social interests came to the fore, namely, international economic competition.

In effect, the war had greatly improved the position of the US's industry in the world market (38). This meant that, in its aftermath, international economic competition developed into a major preoccupation and hence, a major new factor capable of galvanizing a social constituency behind the development

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(36) This is not to suggest that an antagonistic contradiction between the diverse social interests actually developed. After all, all of them shared a common interest in the expansion of the R & D system and, as we know, the main overriding concern of capital is not to produce necessarily for the civilian market but to ensure the reproduction of the profit-driven process of capital accumulation. In this respect, the military market may well offer important advantages in terms of profits and monopolistic protection, thus enticing industrial interests into heavy military involvement. On the other hand, government may well have strong interests in military power as part of its national and international politics, while the overriding concern of scientific interests seems to be much more with the the reproduction and expansion of research facilities than with any supposedly anti-militaristic ethical principle. Finally, it is also true that scientific and technological progress for military purposes does not exclude the attainment of civilian technological benefits, since many advances are of generic nature with application in both military and civilian fields.

(37) "Some useful work continued, especially within the Naval Research Laboratory, the Ordnance and Signal Corps, and the National Advisory Committee for Aeronautics, but the results were not such as to elicit enthusiasm" (Lasby,1966,p.263). See also Swain (1967).

(38) During the war, the US government confiscated all 4,500 German chemical patents and use them as a base for the creation of a strong US chemical industry. The rationale of such a policy was not simply that it would provide an immediate solution to the wartime shortage of chemicals but that it "would also serve to protect the new industry against German competition after the war" (Barlett,1941,p.36). Although not in such a dramatic fashion, the creation of a strong US radio industry was achieved by a similar government intervention in the face of major competition by the British and the German radio industry [Maclaurin(1949),Reich(1977),Freeman(1974)]. In the case of radio, spurred by commercial and strategic considerations, the US government and the Navy pushed forward the creation of a unified American company which would give the country a powerful and autonomous standing in the field of radio. With this end, GE was persuaded to buy a controlling interest in American Marconi -the subsidiary of the British company controlling the world market in the aftermath of the war- and in 1919, the Radio Corporation of America (RCA) was established. In addition, in 1920 a pooling of the radio patents in possession of all the companies with big interests in radio (i.e., GE, AT & T, and Westinghouse) was arranged. We may say, therefore, that in the cases of the chemical and the radio industries, a clear convergence of government, military and industrial interests gave these industries a powerful social constituency which deeply shaped its development in the national and international context.

of the US's R & D system (39). Such postwar social constituency, however, could not be the same as the wartime constituency with its dominance by military interests. Indeed, we have already said that the relative weight of military interests underwent a strong decline with the end of the war. Ultimately, the fact was that, with the absence of military pressures, the very historical basis for the convergence of the wartime social constituency of the US's R & D system had dramatically changed. As such, the wartime social constituency itself had become largely artificial and, ultimately, this expressed itself in the alteration of the different social interests' relative weight in the development of the US's R & D system.

In the new postwar conditions, therefore, the dominant social constituency of the US's R & D system reorganized itself on the basis of international economic competition. This meant that, on the whole, a new convergence of social interests took shape which brought together, particularly the interests of capital, science and government. In this respect, the arguments of prominent scientists of the wartime social constituency of the R & D system leave little doubt as to where the galvanizing pressures for the new postwar social constituency actually were laid.

"George Ellery Hale, the astrophysicist, Robert A. Millikan, the physicist, and other influential scientists used the argument that the success of research in industrial products depended on the acquisition of new knowledge attained through pure scientific research. American industry, they claimed, might be endangered by postwar competition unless aid were given to the basic science on which new products depended" (Coben,1979,p.232) (40).

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(39) A similar realization of the importance of R & D for industrial competitiveness also influenced the British, as it is shown by a report of the Department of Scientific and Industrial Research published in 1932. There it was argued that as a result of the war, "there was a general awakening to the fact that for success in times of peace as well as of war it was desirable that the resources of science should be utilized to the full. The perils of war furnished the precepts for peace, and it was realized that on the conclusion of the conflict a situation would arise in the world of industry which would call for increased effort if British industrial supremacy was to be maintained, and if the manufacturing product of the nation were to continue to hold their own in the world's markets" (Bernal,1944,pp.30-31).

(40) Robert Millikan and George Hale had led the efforts to revitalize the US National Academy of Science (NAS) taking advantage of the opportunity offered by World War I. When the National Research Council (NRC) was formed in 1916 as a subsidiary of the NAS, to centralize the scientific war effort, Millikan became chief executive officer and "the focal point of a large scientific enterprise" (Swain,1967,p.538). The NRC, with its numerous committees, subcommittees and specialized panels, "became the vehicle through which hundreds of individual scientists could participate in the wartime science program. The National Research Council solicited the co-operation of both university scientists and industrial specialists to carry out its mission. Moreover, it won the co-operation of the great



For all its worth, however, the pressures of international economic competition could not offer the same powerful galvanizing effect of wartime military pressures. This could be seen, for instance, in the reduction in size and influence of the NRC as a result of the decline in military and to a lesser extent government involvement which followed the end of the conflict (Swain,1967) (41). Thus, it was left primarily to industry, where the pressures of competition and search for monopolistic positions constituted an immediate concern, to retake its prewar role as the dominant social constituent of the US's R & D system. The context in which this took place, however, resembled little the situation of the prewar years as the impact of the conflict had clearly broadened the base and scope of development of R & D in the US (42). In particular, the awareness of the value of R & D was now wider than it had ever been before and, for the first time, a national research coordinating organization -the NRC which after the war, although reduced in scale, turned its attention to peace-time problems- was in existence which could provide an institutional set up not just for government support to research but for the coordination of the various institutional expressions of the R & D system (Noble,1977). In this context, according to Lindsay (1973), after "the mid-1920s the claim of basic research to be an integral part of the program of every industrial research laboratory was uncontested". At the same time, a sizeable increase in the number of industrial laboratories and personnel engaged in R & D activities took place. From 300 industrial research laboratories in 1920, the number went up to more than 1,000 in 1927, more than 1,600 in 1931, and 2,200 in 1940 [Coben(1979),Birr(1979),Barlett(1941)]. Correspondingly, the amount of personnel employed in industrial laboratories also increased markedly: from 9,300 in 1920 to 33,000 in 1931 and 70,000 in 1940 [Birr(1979),Barlett(1941)] (43). Finally, the number of large-scale research organizations also increased. "Only 15 companies had research staffs of more than

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foundations who showered their largesse on the NRC when federal funds proved inadequate" (ibid.).

(41) The postwar decline in the role of the government social constituent was greatly deepened by the impact of the Great depression of the 1930s. "The Great Depression of the 1930s had a disastrous impact on government-supported science activity. The downward spiral of appropriations for research forced virtually every scientific agency of the federal government to retrench" (Swain,1979,p.539).

(42) For Dupree (1957) the impact of the war has such a decisive effect that, in his view, "industrial research as a branch of the country's scientific establishment dates its rise to eminence almost entirely from the war period" (Dupree,p.323).

(43) It is interesting to note that of the total research personnel reported in 1940, slightly more than half (52.2%) were professionally trained, mainly as chemists and engineers. The remaining part was about equally divided between technical (23.4%) and non-technical (e.g.,

50 persons in 1921; in 1939, there were 120 such companies" (Barber,1970,p.214).

The quantitative increases, however, did not mean any substantial alteration of the fundamental tendencies which had characterized the development of the US's industrial R & D system from its beginnings. Thus, by 1940, three-fourths of all the professional people were trained as chemists and engineers clearly emphasizing the dominance of the science-based industries in the industrial R & D system [Cooper(1941),Barber(1970)]. On the other hand, although industrial research had spread to companies of all sizes, by 1940 still most of the effort was conducted by a "rather limited number of large corporations" (Cooper,1941,p.182). This fact highlighted as much as reflected the continuation of the hegemonic control of the human, financial and material resources of the industrial R & D system by the specific interests of large corporate capital. In other words, while capital in general became the dominant social force within the post-World War I social constituency of the US's R & D system, it was in fact large corporate capital, particularly of the science-based industries, which exercised the truly commanding role in the development of such a system. By and large, this situation was to remain in force until the outbreak of the Second World War when the resurgence of the huge galvanizing force of war would once again change the historical conditions, bringing back to life the wartime social constituency of power and consequently, initiating a new period in the historical development of the US's R & D system.

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administrative, maintenance) workers (24.4%) (Cooper,1941).