CHANGING CORPORATE STRATEGIES IN A PERIOD OF CRISIS: HIGH TECHNOLOGY MULTINATIONAL CORPORATIONS IN SCOTLAND

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ABSTRACT

CHANGING CORPORATE STRATEGIES IN A PERIOD OF CRISIS: HIGH TECHNOLOGY MULTINATIONAL CORPORATIONS IN SCOTLAND

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The dissertation proposes that the economics of the crisis of capital accumulation and the extraordinary pace of technological and market change have led to new corporate strategies and industry structures in the high tech electronics industry. The research, a survey of management in fourteen leading computer and semi-conductor multinationals, was designed to integrate and explore the usefulness of theories on industrial structure and labour markets.

The product life cycle model cannot solve the problems of diversified and increasingly competitive global markets and their evermore sophisticated demand for customised products. Similarly rigid barriers between differentiated and non-competing labour markets in dual labour market theory cannot account for new associations of labour and technologies or for the new importance of non-wage difference in global labour supplies.

The research demonstrated the necessity of linking both demand and supply conditions in explaining contemporary industrial structure. The data persuasively supports the view that the supply conditions in local labour markets not only are critical to the global distribution of capital, but more importantly shape those investments. Scotland provided the industry with an annual labour supply and appropriate skills and a training/education sector responsive to industry needs, offering unique ways for corporations to minimise the cost of reshaping and retaining their workforce. When combined with significant state support of capital investment, the region provided cost- and risk-minimising opportunities for using expensive advanced technologies and extending their effectiveness in rapidly changing markets.

Further, gender was a major factor in the emerging structure of work and the speed of industry adjustment. Rising male unemployment, shrinking employment vacancies for men, and the support of the region's women workers led to the industry's hiring men as the new production workforce, allowing new job design, recruitment criteria, employment expectations, and the worker commitment necessary for increasing the productivity of new investments.

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1.1 INTRODUCTION

The unprecedented growth in the 1960's and 1970's of the microelectronics industries captured world attention. The computer and semi-conductor industries were new industries producing products that seemed to have the potential for continuing market growth. These industries also held out the hope of improved employment opportunities in a world where traditional manufacturing industries no longer served as the primary creators of wealth and jobs. Leading firms in these young industries had grown fairly rapidly: employment at their home bases, most of them in California in the US, exploded during the early 1970s, and they expanded early in their development to overseas locations, where they also created a lot of jobs. These corporations attracted the attention of labour, and industry analysts and development economists (among others) because of their unusual form of internationalisation: their plants overseas were export platforms manufacturing one (or a few) part(s) of the completed product before sending them back to the US or a third market for final sale. Their employment overseas - particularly in the Far East - grew very rapidly.

The semi-conductor firms were `new' multinational corporations, and the computer firms, many of them long-established, were transformed by the capability and cheapness of the chip. These firms experienced unprecedented sales growth and, as a result, global expansion. These microelectronics multinationals gained significant global economic and political clout because of their record and potential for growth in both the First and Third Worlds. Global corporate expansion during this period was not to extract raw materials or to capture foreign markets, the conventional rationale for the internationalisation of production. The incentive in most cases[1] was to tap new labour supplies, the cheapness of which could not be matched in the home-base economy. This pattern challenged the adequacy of the dominant theory on multinationals which argued that firms expanded overseas to control product markets. This form of internationalisation of capital, introduced by the US semi-conductor industry as it expanded from California to the Far East, understandably captured a lot of research attention.

By the late 1970s and early 1980s, these same firms along with new competitors were establishing manufacturing facilities in Europe. There was little investigation into the structure and behavior of these subsidiaries, perhaps because they employed predominantly female labour like the plants in the Far East and the pattern in older electronics firms. They were assumed to be the same labour-intensive, low capital volume assembly plants already dotted around the world.[2]

By 1979 many market-leading computer and semi-conductor firms had established manufacturing facilities in Scotland. This concentration of high tech[3] was, however, little noticed outside the region. Regional officials called the development Silicon Glen. However, by the beginning of the 1980s, the number of high tech firms located in the area increased and established firms were expanding. Even at this point, the role of these subsidiaries within the global corporation went unquestioned. While the Scottish economy had as many differences as it may have had similarities to the economies in the Far East, there was no suggestion that these plants were any different from the predominant subsidiary form in the Far East or that they represented any alteration in the industry's international division of labour. The aim of the research on the region's high tech industry reported here was to investigate whether this assumption was justified.

1.2 RESEARCH INTEREST IN THE MICROELECTRONICS INDUSTRY

While the research reported here focused on the structure and behaviour of the multinational corporation as an economic unit, the character of the industry itself is fundamental, not incidental, to the analysis. Until the early 1980's, US firms propelled the industry and dominated the definition of its character. The US micros industry maintained phenomenal growth in employment, as well as sales and international markets, for a period of more than twenty years. The industry's economic compulsion to innovate produced many generations of products within its relatively short life.

Also the US microelectronics industry has a colourful history. It rapidly developed a reputation as a group of glamorous, fast-paced companies and managers: often beginning in California garages, their record of turning high profits within a few years captured the imagination of international audiences. The industry's entrepreneurs were always interesting, if not flamboyant.

The industry's vibrancy - seemingly continuous expansions of manufacturing capability to cope with surging demand and a fervor for technological innovation - contrasted starkly with so much of manufacturing as it existed at the time in most of the western capitalist economies. The US and UK, among others, were experiencing deindustrialisation in traditional industries and a shift to service industries. Further, many long-established manufacturing firms had transformed themselves into financial holding companies to take advantage of the incentives of international subcontracting or the substitution of acquisition for investment. As a result, well-paid, skilled manufacturing jobs were lost. The growing concern in industrialised countries about the economic implications of deindustrialisation and dependence on `hollow corporations' assigned great importance to the microelectronics industries as major manufacturers and potential new engines of job creation. The benefits of the industry's health and rapid growth reached far outside the home base economy. Many other countries including Third World countries gained investment and jobs as the industry spread across the world.

The industry's growth concentrated in particular regions of the US and the world. High tech firms have accumulated in large numbers in Silicon Valley (California) and in and around Boston (Massachusetts) in the US, and in Scotland and the M4 Corridor (`Silicon Gulch') in the UK, Singapore, Hong Kong and a number of other Far Eastern countries, as well as Japan. In many cases these areas became dynamic growth centres, fuelled by the support and intervention of the state. As a result, the health and welfare of many regions became dependent on the robustness of the industry and on the success of local operations. Public officials throughout the world, having watched other regions benefit from the industry's success, began competing to attract the industry's new investment as a way to mediate domestic unemployment problems. By the end of the 1970's and the early 1980's the industry's successes, record of growth and international scope had made this industry an important variable in economic development and policy-making worldwide.

The products of the microelectronics industries also have great economic importance. The integrated circuit[4] and the computer are technologies that have fundamentally changed methods and costs of production, the exchange and processing of information. These are products that have altered the ways work is done in every sector of industry - creating new opportunities for efficiency, reducing some labour inputs, lowering unit costs, and promoting new product possibilities. The productivity of the entire economy now to some extent depends on the output level, price, quality and capability of the product of these two industries. The market relationship of these firms, as intermediate and capital goods suppliers, with other industries has become a pivotal economic nexus. Any disruption in production or distribution in the microelectronics industries will delay production and investment schedules elsewhere. As suppliers of critical technical inputs, the industries can alter income distribution amongst sectors of industry. Favouring large customers over small ones to deal with product shortages or channeling resources to new products and customers, which, in effect, ignores the needs of existing customers, can determine the market success or failure of dependent firms.

The importance of high tech electronics as a major employer has influenced the rest of industry in other ways. The industry's efforts to rewrite the management-labour relationship has influenced and may help transform the employment relation in and vitality of other sectors. This high profile, dramatic industry may be disproportionately attracting labour and financial resources - both public and private, denying access to other industries. Industry leaders recognising their political clout have in recent years actively pressured the state for supportive legislation and preferred treatment in the US, the UK and elsewhere. Protectionist trade laws and preferential labour market intervention by the state can alter (in some cases drastically) the conditions under which other industries must operate. The successes and failures of high tech can influence the competitive conditions for other sectors.

The computer and semi-conductor industries also employ large numbers of women workers across the globe: these sectors offer a valuable window for assessing women's position in the labour market in new and non-traditional sectors. While inheriting employment and structural patterns from its evolutionary predecessor, the electrical equipment industry, the microelectronics sector has been a major source of new jobs that quickly acquired a female gender-identification. These jobs were not `naturally' women's work, lifted directly from the household as food processing, textiles, garment-making and child care were. This is capital goods manufacturing which has historically employed men. However, electricals as `light' and `clean' work became acceptable work for women, in contrast to the oily, noisy and dirty work with huge machines that dominated traditional manufacturing. The gender-ascription was transferred as electronics grew to dominate the industry. This sector provides a good opportunity to examine the changes in the industry's reliance on women workers, the quality of these relatively 'new' jobs, the extent of ghettoisation and potentially the process of the gendering of jobs.

1.3 THE DEFINITION OF THE PROBLEM

My research interest was to explore if these corporations had maintained, without change, their past pattern of overseas investment in the face of radically new competitive conditions. The industry established global operations early in its history. By 1983/4, the time of this study, all of the world market-leaders were multinational corporations because of advantageous relative labour costs overseas. By the late 1970's and early 1980's, however, escalating competition and costs imposed phenomenal pressure on US multinationals to grow and to change.

In particular, customers demanded that major US firms produce better quality product, a challenge that severely threatened their sales and market base. While 'quality' has now become a buzzword in industries as diverse as autos and food processors, in the early 1980's the quality problem was a critical yet underestimated factor in transforming the industry. Also by this time Japanese semi-conductor and computer firms had significantly increased their shares of the US market. The Japanese challenge, which had already eroded the power of US auto and steel firms, shocked the industry. No one imagined that the strategy of continuous product innovation would ever fail to maintain US firms' control of US and world markets. (See Chapter 4.)

With these pressures, the static theory of the multinational corporation as a rigidly hierarchical global structure, (Vernon, 1966; Cohen et al., 1979) was problematic. It gave us only a simplistic model of the way capital extended across economies and created and exploited an international division of labour. Many, following Vernon's seminal work (1966), had divided the world into two - the US or other advanced industrial economy (eg Japan or Germany) and the low-wage economies. All overseas manufacturing operations were essentially clone plants to exploit low-wage labour.

The significant economic changes in the industry by the 1980's brought complexities and uncertainties that suggested that this model is too simple. The aim of this research is to examine how changing competition has influenced corporate strategies and the industry's international division of labour. Was the multinational corporate structure established in the 1960's and 1970's suitable to handle changing competitive conditions? Long-established examples of multinational corporations defined overseas production as relatively unskilled work for low-wage labour. Could the low relative costs of overseas manufacturing with cheap labour, in this case women's labour, continue to provide competitive advantages in spite of dramatic market changes?

If this were no longer the case, what were the new, compelling features of competition and how did management alter the global distribution of responsibilities, technologies and employment as a result? The central research questions of this study, then, are as follows:

- how did US microelectronics multinationals adapt to the new competitive conditions provoked by rapidly changing technologies and markets and by the Japanese challenge, and

- how did new strategies alter the role of overseas subsidiaries?

To answer these questions the research focused on the industry's development in Scotland during the five years, 1979 through 1984. The region had been the location of a number of US semi-conductor and computer multinationals prior to the study period: this suggests these subsidiaries had contributed to the international division of labour that had been successful for US firms in the past. Furthermore, industry investment in Scotland grew significantly between 1979 and 1984, indicating that the region offered economies important to new global strategies.

The study concentrates on identifying changes in US multinationals' operations in Scotland. As both an indicator and consequence of change, the impact of new corporate strategies on women's employment and work in the region was an important secondary focus. However, during the course of the study it became clear that industry changes were affecting the work of and relationships amongst all workers and occupations. That meant opening up this last question to examine the impact on the structure of work. These were the questions at the centre of this research.

CHAPTER 2: PRODUCT LIFE CYCLE THEORY AND THE THEORY OF SEGMENTED LABOUR MARKETS: A Survey of Relevant Literature

2.1 INTRODUCTION

The multinational corporation and segmented labour markets are two areas of prodigious theoretical and empirical work. This chapter explores the conventionally separate bodies of literature on the multinational enterprise and segmented labour markets: the aim is to examine the explanatory power of the theory of these in analysing the global structure of the high tech electronics industry.

The chapter is divided into two sections. The first half considers the literature on the development of the multinational corporation as the internationalisation of productive capital. The multinational corporation has many forms: the discussion here focuses on it as the institutional attempt to organise production globally to improve capital accumulation. As such, it is a business organisation whose market strategies and competitive successes and failures can affect job opportunities and employment patterns in many global locations simultaneously. There is a wide and rich literature on the multinational corporation. Theoretical work has concentrated on the macroeconomic issues of the role of the global corporation in trade, capital flows, economic growth, and uneven development and the micro concerns of how this company form succeeds in overcoming market imperfections and inefficiencies. Also, the theoretical debates have explored the political economic activity and implications of corporations so large and powerful that they threaten the political and economic sovereignty of nation-states (Warren, 1975; Murray, 1975).

The discussion here, however, telescopes in on the development of theory to explain the reasons that corporations invest in production overseas and the resulting division of labour within the global firm. Raymond Vernon framed the theoretical discussion of the product life-cycle (PLC) theory (1966). This section examines his work closely and discusses how it must be modified to take into account the pressures on multinational corporations in `information' markets and from new technologies.

Vernon's work was an important contribution for its timing as well as its theoretical approach. His entry point was the explosive growth of world trade in the 1960's. His interest was to investigate the nature of US participation in trade and the seemingly counter-intuitive finding by Leontief (1953) that the US global corporation, a rapidly growing business form during the 1960's, contributed to this pattern of trade and focused his attention there. His analysis of the multinational corporation was particularly interesting in that he explored the relationship of the competitive nature of product markets and management decisions about the global allocation of technologies and the role of the nature of the product, its age in the market, and competitive conditions at home and abroad in investment and technology decisions, his work allowed both a specificity and a complexity that improved greatly on theories that depended upon calculable transaction costs to explain overseas investment.

Vernon's product-life-cycle theory deserves attention because it continues to have wide support both in industry and academia. In spite of the many changes in global industrial development and trade in the 1970's and 1980's, many still use the PLC theory as an explanation of US deindustrialisation and as a guide for empirical research on location and investment decisions (eg Heckman, 1984; Crawford, 1984). Consequently, it also remains the ideological framework for formulating policy for economic development and saving jobs.

For these reasons, the PLC model of the multinational corporation is an excellent starting point for analysing the global microelectronics industry. Vernon's consideration of the relevance of product market competition, technology choices and location, and the role of information and R&D focus on the most salient features of high tech electronics in the 1980's.

At the same time, the extraordinarily rapid pace of change of product and production technologies may test the applicability of a theory which is appropriate to a Fordist, mass-production economy. Most of the chapter's second section explores the contributions and limitations of Vernon's PLC theory. This section includes analysis of the work of those who offered a similar conceptualisation of the structure of the multinational derived from a Marxist perspective.

The second half of the chapter examines the literature on segmented labour markets. This body of literature developed out of the recognition of the increasing concentration of capital in large corporations and the power these complex institutions commanded in shaping labour markets. The dual labour market theory (DLM) is never defined or applied wider than one national economy, and, while applied in analyses of many other advanced capitalist economies, the theory arose from the experience of the growth of the US corporation. However, the DLM model of capital's structuring a class of jobs as secondary to require few skills and to employ economically inferior workers is consistent with Vernon's description of the overseas manufacturing investment of multinationals. This chapter considers the DLM theory first as an analysis of the organisation of work in the modern firm. As today's corporations are faced with compelling reasons to expand globally, the chapter then examines how well segmentation theory extends to the international organisation of capital and explains the relationship of a multinational firm to regional and global labour markets.

2.2 THE THEORY OF THE MULTINATIONAL CORPORATION (MNC)

The multinational corporation is the dominant organisational form of modern capitalism. This firm, operating across national borders, has come to dominate international trade and currency flows and to wield authority over the economic health and welfare of individual sovereign economies. As it became a more obvious actor in international economies in the 1960s and 1970s, an extensive and varied literature developed to analyse its global activities, the reasons for its development, and the implications.

2.2.1 Neoclassical Transactions Cost Theory

Orthodox microeconomic analyses of the global corporation contend that the multinational is an efficient agent in allocating factors of production and distributing commodities, given the distortions of the market at both the national and international levels (Caves, 1974; Kindleberger, 1969; quoted in Cohen et al, 1979). By concentrating on the economic pressure to overcome information problems, theoretical and empirical work attempted to identify and calculate transaction costs as the cost-minimising trigger for investment overseas. Foreign direct investment results as the way a firm minimises the transaction costs of selling abroad, eg losing control over exploitable intangible assets such as R&D through licenses, etc., or the expense of training foreign nationals. Understandably these firms with significant investment in exploitable information assets and with potentially large losses from uncertain turns in the market have the most to gain from investing abroad. The drive to maximise the return on technologies was found to be a potentially significant motivation for multinational expansion: firms with extensive R&D have tended to operate transnationally (Gruber et al, 1967). Managers committed resources to R&D based on the expectation of earning a return worldwide (Mansfield et al, 1969).

However, the literature ignores the potentially high costs and risks of managing a firm made up of interdependent yet globally dispersed parts. Low unit shipping costs, for example, cannot satisfactorily explain the willingness of more and more firms to undertake risky investments in foreign lands. Company size and economies of scale (by, for example, global centralisation of separate part-processes) seem more compelling economic justifications for overseas investments. Furthermore, theories arguing that calculable cost differences (between exporting and overseas production of between technology licensing and foreign direct investment) determine investment decisions are static in nature: they ignore that firms operate in and must respond to dynamic markets and global economic conditions.

Market power and strategy shape global investment patterns: calculations of relative costs may support or trigger reassessment of these decisions. An oligopolistic firm actively competing over unit costs or product differentiation would invite further competition by licensing its technology rather than controlling manufacture abroad. The transactions cost approach and, more generally, a static neoclassical framework fail to consider the dynamics of market power in corporate decision-making. Furthermore, as a static analysis, orthodox microeconomics cannot incorporate the economics of changing technologies and the introduction of new products, factors that have dominated microelectronics markets since the 1970's. Relative price signals cannot explain change in a dynamic economy with highly concentrated markets. Theory explaining multinational investment must centre on market strategies to survive or stifle competition.

2.2.2 The Product Life Cycle Hypothesis

Vernon viewed the multinational corporation as an organisation derived from and well-suited to economic change. The product-life-cycle hypothesis deserves careful examination because it periodises the changes in corporate organisation that respond to market changes. It looks at the dynamic adjustment processes that are outside the framework of the static transactions cost model.

Vernon's product life cycle theory, a hypothesis about the dynamic structural adjustment of an international firm, developed as a partial answer to a macroeconomic debate about shifting trade flows. In the 1950s and 1960s a theoretical debate over the reasons for international trade and trade shifts was at the centre of the international economics literature (as it is today).[1]

Vernon entered the debate partially to solve the so-called Leontief 'paradox' (1953, in Wells, 1971). The neoclassical theory of factor proportions, as an explanation for international trade, derived from a competitive model which, by relying solely on international price differentials, could not explain the tendency for US export industries to be more labour-intensive than import substitution industries.

Vernon (1966) argued that the assumptions of perfectly competitive conditions were too restrictive to interpret the post-World War II international economy. The theory, by relying on automatic responses to price differentials, ignored the development of institutions important to the flow of trade, such as common markets. Vernon also roundly criticised the neoclassical assumption that knowledge was free and instantaneously available. He argued that clinging to this assumption ignored the obvious differential abilities of entrepreneurs to know and respond to market opportunities and to turn ideas into commercial products. The patterns of innovation, manufacture and trade, while conditioned by differential factor allocations, could not be explained simply by calculating factor costs plus transportation costs.[2] Further, the resulting proprietarial knowledge and abilities effectively created product monopolies that were much more important than relative prices in stimulating trade in manufactured goods.

In spite of the macro entry point, Vernon focused on the role of the entrepreneur and the changing structure of the firm.[3] His model's focus on the actual global structure of the corporation and on the dynamics of the allocation of technology and labour makes it a singularly useful starting point for analysing global structure of firms in the highly international electronics industry.

Companies are at the centre of trade. Trade flows depended on management choices between exporting and investing in production overseas. His hypothesis focused first on the economics of this choice given monopoly control of intangible assets, then on the resulting structure of foreign direct investment as a product matured. His model reflected the importance of three factors which were underestimated or ignored in earlier work - the process and importance of product innovation and its timing, the role of ignorance and uncertainty, and the effects of scale economies. The economic role of information, particularly the monopoly control of information, was central to his analysis.[4]

The Model

Vernon argued that the ease of getting information about a market and thus proximity to that market were major factors in explaining the ability of some entrepreneurs to develop a new technology and turn it into a commercial product. He further argued that the shape and success of those innovations would depend on the relative factor scarcities of that economy: an economy with a relatively expensive labour supply would be more likely to generate ideas for labour-saving products. Entrepreneurs were more likely to commercialise this kind of product successfully in a relatively high income economy with the willingness and ability to purchase labour-saving devices.[5]

Vernon further suggested that the production of the new product would take place in the same economy (and possibly the same site) as product innovation and development. The producer, uncertain of market response to the new product, wants quick and easy communication with that market (customers, suppliers and potential competitors) to try to refine the product and production specifications appropriately, to sharpen production methods, to define the market, etc. In addition, management would be highly dependent on skilled production and professional labour to perform these tasks effectively. Maintaining and exploiting access to market information are key in successful commercialisation and in the location decision. The producer would be relatively protected from competition over price during this period because the price elasticity of a new technology product in a high income economy is low, and the producer has a monopoly by virtue of the innovation.

These were the economic concerns of the first or growth phase of a new product. The economics that drove management decisions on manufacture, marketing and trade would change as the product aged, suggesting a periodisation to frame the analysis. (The periodisation was further refined by his students Hirsch, 1965, and Wells, 1971.)

Standardisation and Scale Economies

The `maturing product' was a `stable', standardised product: all specifications were fixed to enable mass manufacturing. The experience of early growth had eliminated the uncertainties of product and production specification. Company success was now dependent on developing a mass market and on achieving economies of scale. During this phase, management might consider replacing exports with manufacturing capability overseas.

Fundamental to a decision for global expansion, however, was that the income level of the overseas economy must be high enough to support a large market for the product and, as a result, the subsidiary could capture scale economies (Vernon, 1971). Vernon suggested that firms would first invest in the higher income economies of Western Europe and that this would only happen once the price of the product had dropped sufficiently to create a mass market in an economy less wealthy than that of the

US. Firms would not commit resources abroad until the firm had sufficient experience and success with the production technology to minimise factor costs and to achieve reliable and certain results. Further, manufacturing was no longer dependent on a specially skilled labour force, due to a fixed production function: without high skill requirements, the firm was free to locate production anywhere there was an average labour supply.

Vernon argued that a simple transactions cost calculation, while consistent with his analysis, was inadequate to explain this decision. If continuing or expanding exports improved the scale economies of production at the home base plant, and/or if transportation costs were declining, the reliance in centralised production would grow stronger (Vernon, 1966; p.388). However, other considerations - such as import control policies - would more than likely dominate the corporate location decision. In fact, the most important trigger to investing overseas, according to Vernon, was a threat to the firm's monopoly power in those markets. Substituting overseas manufacturing for exports can pre-empt a threatened loss of market or market share in an oligopolistic market. This defensive rationale for internationalisation was particularly powerful for firms in research and development (R&D)-intensive industries; these sectors tended to be highly concentrated and oligopolistic (Gruber et al, 1967).

For an older, mature product, the dynamics of production would create wider opportunities for global expansion. Extensive production experience and scale economies would have further reduced product price. The lower price would create markets even in low income economies that were large enough to support a mass production facility. Production in a low wage economy would be attractive not only for increasing the returns on the corporation's technology by moving into a new market, but also as an opportunity to slash unit costs. Given the wider field of competitors for a mature product,[6] this relative unit cost advantage and potential profit margin increase might convince management, in Vernon's view, to manufacture in these new locations for a much wider market, even exporting back to the home base economy.

The drive to maintain market control in the maturing phase and to increase revenues and profit margins in the more competitive mature phase provokes management to invest overseas in Vernon's model, mediated by opportunities for achieving scale economies. He argued that neither nominal exchange-rates nor price-adjusted exchange rates affected the power of his hypothesis.

This model successfully explained much of the growth of multinational corporations in the post-war period, supported by Vernon's (1979) own and others' empirical research (Hirsch, 1965; Gruber et al, 1967; Wells, 1971; Forsyth, 1972; Horst, 1972; Magee, 1977; Caves, 1982). It also explained the tendency of US firms to become multinationals (and of such a large proportion of multinationals to be US-based firms) and of overseas investment to be concentrated in innovative industries (Caves, 1982).

The PLC theory offers a particularly useful starting point for analysing the international pattern of the high technology electronics industry. Vernon's emphasis on the economic role of information in establishing a technological monopoly and in directing the pattern and timing of overseas investment suggest that the PLC theory should describe the international organisation of this information- and R&D-intensive industry. Empirical research on parts of the microelectronics industry has provided support for his model (See for example, Scibberas, 1978; Lake, 1979; Heckman, 1984), particularly his emphasis on achieving scale economies as a necessary condition for overseas investment. A micro analysis like Vernon's, the research reported here on the high tech electronics industry in Scotland attempts to assess the extent to which Vernon's model of the global corporate allocations of technology, labour and product responsibilities predict the organisation of these multinational corporations.

2.2.3 Hymer's Analysis of the Global Division of Labour

Stephen Hymer's contribution to the analysis of the multinational corporation deserves consideration in this discussion. He wrote extensively on the economic motivation of overseas investment and the profile of the multinational corporation. He originally intervened in the debate, like Vernon, to argue against the explanatory power of macro trends, such as comparative advantage. His analysis (Hymer, 1976) centred on industry and firm characteristics: the motivation to expand transnationally was to protect or create monopoly control over foreign markets. The model of the firm in his later work (Cohen et al., 1979) looked very much like Vernon's product cycle; however, he examined more explicitly the impact of global corporations on labour.

As an organisation well-suited to economic control, the multinational corporation expanded globally to tap the differing economic advantages of the world's labour markets and, in the process, reinforced those differences. The geographical hierarchy of multinational operations, in his view, set up hierarchical and rigid divisions amongst workers around the world. His work, then, makes explicit -where Vernon was implicit - the connection between corporate technology decisions and global differences in labour markets and jobs. Hymer provides an international model of segmented labour markets. This is an important link and contribution to dual labour market theories, considered in the next section, which ignore the internationalisation of capital and labour.

Hymer's original research on the multinational demonstrated that a popular argument about diversifying one's portfolio of investments could not explain the pattern and growth of the multinational firm. He argued that management did not decide to establish manufacturing facilities overseas as a response to changes in the interest rate: foreign direct investment was not simply an alternative to other portfolio financial instruments whose return was diminished by a falling interest rate. The interest rate had little to do with overseas investment in productive capital.[7] As in Vernon's analysis, the possibilities for overseas investment in manufacturing originated with monopoly and differential advantages of firms in the world's markets. Overseas manufacturing provided firms with opportunities either to maintain control in important markets or to exploit more fully a market advantage, either eliminating competition abroad or expanding to appropriate greater returns on particular skills, knowledge or abilities (Hymer, 1976).

The multinational corporation expanded globally, in Hymer's view, to establish economic control - control over foreign product markets and labour. He argued that a spatial hierarchy and the resulting international division of labour best served that goal, fostering a growing centralisation of control by US capital and dramatic qualitative changes in the world economy (Cohen et al, 1979).

The corporation centralised planning and decision-making in the major capitals of the world (New York, London, Paris, Tokyo, etc.) which offered immediate access to the biggest capital markets and easy communications, including face-to-face contact, with media sources and the industry and political leaders who might influence corporate strategy. Management would locate R&D and related activities in other large cities in the home base economy ('regional subcapitals') where there were communities of scientific and technical personnel and other white collar professionals. This environment would facilitate information exchange and stimulate product development. While separate from headquarters, rapid and effective communication between these two levels was important to maintaining general understanding, employee confidence and loyalty and effective coordination.

The overseas subsidiary looked like that of Vernon's model. Hymer argued that stable, continuing production was the role of the subsidiary. Involving overseas workers in technological development might lead them to want to further develop some of their ideas and to try new methods of production rather than continuing to produce output in the old way, according to management prescription. It was in management's interest to cut the subsidiary off from idea development and involvement in decisions. Subsidiaries were restricted to standardised production processes staffed with low wage, relatively unskilled workers. These facilities were dispersed to low-wage economies around the world, the exact locations determined by labour and materials costs (Cohen et al, 1979).

The global organisation of the parts of the firm would mirror their places in the corporation's "pyramid of power" (Cohen et al, 1979). Further, this corporate organisation would imprint a global hierarchy of dependency.

> "A regime of multinationals corporations would tend to produce a hierarchical division of labour between geographical regions corresponding to the vertical division of labour within the firm... [C]onfin[ing] the rest of the world to lower levels of activity and income, that is, to the status of towns and villages in a New Imperial System. Income, status, authority, and consumption patterns would radiate out from these centers along a declining curve, and the existing pattern of inequality and dependency would be perpetuated...[T]he basic relationship between different countries would be one of superior and subordinate, head office and branch plant." (Cohen et al, 1979; pp.157-8)

Like Vernon, Hymer viewed controlling communications as a critical concern of corporate management. Management recognised the necessity for reliable and smooth communications both to and from the product development and marketing functions and would keep them nearby in the home economy. The marketing function features prominently in both Vernon's and Hymer's work. Vernon considered it critically important in the first product stage, when positioning the product in its biggest, most receptive market determined its success. The interplay of marketing with all corporate decisions kept product development and manufacturing in the home base economy. Hymer, in contrast, argued that the marketing function could not be confined to one stage but grew in importance and complexity, simultaneously integrating all the steps of capital accumulation - production, education and consumption - and, with the objective of control, thrust the corporation into global expansion. To capture and control overseas markets, firms had to understand and adapt to overseas cultural and social consumption factors. A sales office alone could not do that effectively: controlling an overseas market required a manufacturing facility which would allow the firm to use its technological expertise to satisfy local needs.

The Branch Plant

As might be expected, research outside the US frequently concentrated on the phenomenon of the `branch plant' itself and its impact on the host economy. Empirical work demonstrated that the subsidiaries of multinational corporations fit Vernon's and Hymer's prescriptions. They produced standardised products with relatively low skilled and inexpensive labour (Forsyth, 1972; Firn, 1975A; Massey, 1978; Moxon, 1979). The parent devolved little if any decision-making and for a number of reasons (eg creating low-pay jobs and having few links with the local economy) provided few benefits for the host region (Firn, 1975B; Hood and Young, 1983). These authors explicitly or implicitly endorsed the PLC formulation. The subsidiary was both `headless and heartless' because product development and growth was centralised in the home base economy. The branch plant was also potentially `footloose' because it was liable to move to a lower-wage location as the product matured.

Froebel et al (1980) focused on Vernon's mature product stage (though there was no acknowledgement). Their `world manufacturing platforms' were branch plants in the Third World that were responsible for highly routinised mass manufacturing processes for mature products and for exporting them around the world. That included supplying the home base economy. The economic rationale for this form of a multinational was, in contrast to Vernon,[8] solely exploiting the low labour costs. The locations that multinationals chose offered both the social, cultural and economic construction of an inexpensive (usually) female labour supply and state protection maintaining the employment contract and labour supply conditions.

2.2.4 Weaknesses of the PLC Theory

The PLC model has severe limitations in describing and analysing the high tech multinational corporation in the international economy of the 1980s. This section explores the theoretical limitations of the model. The discussion here centres on three points. The `business environment' disparities between the US and other industrial economies are no longer significant or instrumental in the timing of corporate global expansion. The world economy has become much more international, not least because of the major economic role of the multinational corporation. Vernon's entire analysis rides on the dominance of the standardised product in the world economy.

Vernon's analysis of multinationals grew out of a world with wide disparities of income amongst economies and, more specifically, between the US and the rest of the world. Some of the disparities between the US and parts of Western Europe and Japan had narrowed if not disappeared by the late 1970s. Also manufacturing multinational corporations were relatively new economic institutions in the early 1960s. By the late 1970s, individual multinational corporations had established extensive and complex international operations, and many major markets were becoming truly international.

Vernon (1979) acknowledged both of these points (see also, Vernon and Davidson, 1979). When taken together, the altered international business environment means that the unique conditions in the US market no longer explains the global structure of a US multinational (much less the world market dominance of US multinationals). Vernon conceded that, because of the convergence of per capita incomes amongst a number of industrialised countries, a corporation might not wait so long before manufacturing a new product overseas. His own and others' research found that the more international experience a corporation had (both in introducing new products and in producing overseas), the faster it was likely to transfer new products and production to those economies (Vernon and Davidson, 1979; Lake, 1979). The shortened time period before investing overseas was due both to the economic well-being of particularly First World markets and also to the likelihood that these corporations would be better informed about and experienced in foreign markets than the firms of the 1960s (Vernon, 1979; Vernon and Davidson, 1979).

Vernon, however, stopped short of the logical implications of the new assumptions. Firstly, there is no reason for <u>any</u> delay in manufacturing new products overseas. Why should corporations wait at all before manufacturing a product abroad if there are overseas markets that are economically receptive and, as has been suggested, if there is greater international homogeneity of demand? Indeed, given the rapidity of communications and the high degree of internationalisation in many sectors, a product in many markets is now effectively a global product from the day it is introduced. Management wanting to exploit the monopoly period of its new technology would surely strive for simultaneous new product manufacturing in all important global markets, unless there are other factors that explain multinational locational and timing decisions.[9]

Secondly, if similar demand conditions held across a number of economies, there was no longer an explanation of why a US firm must develop a product and manufacture it first at home. A firm (either a domestic company or a multinational subsidiary) in any of the sophisticated industrial economies would have access to the market information on which product and production technology development depends. Similarly these economies would have acquired, through the developments of their markets, the skilled production and professional personnel needed for product development: Vernon had considered the supply of skilled labour a critical factor in the pattern of global expansion.

To acknowledge these changes requires a reconsideration of the pattern, timing and economic strategies of the modern multinational corporation. The assumption of a standardised product was at the centre of the PLC analysis of the global reach of a firm and the eventual shape of the transnational corporation. This weakens the theory's explanatory power in a transformed market economy. Vernon's (1966) multinational was a corporation producing a standardised product horizontally in more than one country.

By 1979 his view had altered but without irreparably harming his theory. By the 1970's multinationals were commonly vertically disintegrated; the product had been broken down into mass produced component parts and production was widely dispersed around the globe. This structure enabled the firm to take advantage of international input and operating cost differentials and to integrate more countries into an international marketplace (Piore and Sabel, 1984). The driving force behind this global dispersion and `crosshauling' was achieving scale economies on a global level.

In recent years, however, the dominance of the standardised product has been severely challenged in international markets. The demise of GM and Ford's `world car' strategy, for example, derived from the failure of one car style and structure to satisfy a wide range of culturally-specific tastes and quality requirements (Sabel, 1987; Piore and Sabel, 1984, cites other major failures of global standardisation strategies, eg steel.). Standardisation is a particularly inappropriate strategy for capital goods markets where heterogenous uses demand heterogenous product (Rosenberg, 1982).

The development and growth of `information-intensive' products in the `information society' of the 1970's and 1980's have dramatically altered the viability of the standardised commodity in world markets. Vernon and Hymer, in spite of their interest in the economic role of information, did not anticipate how information processing would transform products and production methods nor how these changes would affect competitive conditions and the resulting corporate strategies for capturing markets and organising production and distribution. These changes severely undermine the applicability of the PLC theory.

Many information products (ie products that contain and process a lot of technological information about the specific end-use of the product) cannot be standardised either over time or across markets. In many high tech markets, the rapid technology advances and the economic benefits of adopting new technologies have forced potential customers to become much more sophisticated in their understanding of product developments and their own application needs. Markets can now keep pace with the newest technological improvements of the product through inexpensive and rapid communications opportunities and consequently demand continual product advances. While these pressures are particularly severe in high tech electronics and information technology markets, the necessity for firms to cater to many different markets and customers has been documented in a wide range of industries in the 1980s (Hirschhorn, 1984; Piore and Sabel, 1984).

Secondly, markets have demanded increasing customisation of products. In microelectronics in particular a product designed or adapted to a specific use will perform more economically: it is usually faster and more reliable. Marketing an information-processing commodity demands a high level of understanding of the product's end-use: the product must deal with if not incorporate the procedures and technologies of the customer's use. Increasingly, selling the product requires adapting it to that specific application.

The supply conditions and structure of the manufacturing firms must change to meet the demand for heterogenous, application-specific products. Neither Vernon's nor Hymer's rigid, hierarchical model can cope with the evolving supply conditions for a highly differentiated product and market. Firstly, the rapid pace of technological and market change challenges the concept of a fairly predictable, staged cycle of product life. Corporations could profit more from a technology monopoly by shortening the time gap between product introduction and exploiting world markets if the technology is likely to change quickly. Also, market demand for mature products seems likely to shrink rather than expand as Vernon predicted given the many newer, more capable (and cheaper) products that would already have appeared on the market by that time. The unpredictability of the market size for a mature product would seem to discourage a management strategy that delayed overseas production until the product matured.

Secondly, defining and creating a mass market is more difficult. With rapid product changes, potential customers are less likely to warehouse large amounts of components or equipment because of the threat of rapid obsolescence. This makes producing for inventory to achieve scale economies (Vernon, 1979) a very limited strategy.

The pace of change and the demand for customisation call for greater capital flexibility and a pattern of continuing feedback from the market (Piore and Sabel's flexible specialisation model, 1984; Hirschhorn's post-industrial model, 1984) beyond the scope of the branch plants in both Vernon's and Hymer's work. The organisation of production must prove capable of gathering changing information from volatile markets and must accommodate variations in demand and specific customers. The structure of the corporation must adjust to cope with these changes. A different relationship with the market is necessary to establish continuous feedback from customers to all the steps and stages of production - R&D, production design, testing - and administration and marketing. The responsive company structure that Vernon associated with the new product stage proves to be necessary throughout (and potentially to extend) the life of a technology wherever there is a major market.[10]

Interestingly, Hymer predicted the growing importance and complexities of a multinational's communications among its parts and with its markets (Cohen et al, 1979). However, he underestimated the limits of a rigid corporate structure to respond to these changes. Neither Vernon nor Hymer anticipated the competitive necessity for the multinational corporation to adapt to significantly different methods of competing in and controlling markets. In addition, increasing specialisation and customisation suggest the possibility of fragmented rather than concentrated world product markets. Corporate strategies to operate globally may no longer be the result of monopoly control. The rigidly hierarchical multinational corporate structure of Vernon's and Hymer's models seems ill-suited to respond to continually new information inputs and product demands and to win the heterogenous markets around the world.

2.3 DUAL LABOUR MARKET THEORY: CONTRIBUTION AND CRITICISM

Dual or segmented labour market theory provides an appropriate lens for viewing employment patterns and changes in the modern business organisation. This labour market model (in all its variations) derives specifically from the growth of and concentration of power in twentieth century US corporations, the same corporations that consequently became multinationals in the 1950's, 1960's, and 1970's. Because the institutionalisation of `good' jobs and `bad' jobs which the DLM theory describes generated the profits and the technological and managerial expertise that enabled corporations to expand globally, it would follow that the corporations would reproduce this employment pattern in their transnational structure. In fact empirical research throughout the 1970's and 1980's found the international employment structure that Hymer's model explicitly predicted. US multinationals expanded into lesser developed economies by creating low-skilled, low-pay jobs, shifting the exploitation of a `secondary' labour market from the US overseas (see, for example, NACLA, 1977; Froebel et al, 1980; Elson and Pearson, 1980; Grossman, 1979).

DLM theory provides an analysis for understanding the links between company and industrial growth and the structure of work in US monopoly capitalism. By incorporating Hymer's international perspective, the DLM theory offers a model for interpreting the historical economic role of overseas jobs and workers and a gauge for assessing current global employment patterns.

This theory developed out of the inadequacy of orthodox competitive models of the labour market to describe the actual operations of the unique market for labour and, in particular, to explain the existence and the persistence of discrimination. The postwar influx of women into the British labour market was marked by severe and continuing occupational segregation by gender. Sixty-three percent of all women workers work in jobs done by women; 80% of all male workers had all-male jobs (1980 Census; Martin and Roberts, 1984). This means that in spite of the growing participation and attachment of women to the labour force, the gender segregation of 1901 has remained intact throughout the twentieth century. Table 2.1 shows the historical pattern.

TABLE 2.1. OCCUPATIONAL SEGREGATION: 1901 -1980

	% of men working in jobs with 70% or more male workers	% of women working in jobs with 70% or more female workers
1901*	89%	71%
1921*	83	56
1951*	82	50
1961*	77	53
1971*	77	51
1980+	80	63

SOURCES: * Hakim (1978) from population census reports, 1901
through 1971.
+ Martin and Roberts (1984) from population census,
1980.

To explain this segregation, dual labour market economists claimed that institutions developed within labour markets to serve the interests of large corporations. Powerful corporations established barriers between jobs and workers to maintain market power, technological profits, etc. by controlling their labour supply. The resulting institutional barriers limited the firm's need to compete in external labour markets and blocked the (potential) effectiveness of wages and salaries in allocating workers to the economy's better jobs. The creation of `good' jobs and `bad' jobs were both the objective and the result. Different socio-economic groups of workers were associated with the job groupings, and formal and informal barriers blocked access for many people to the better jobs.

The DLM model is a good starting point for attempting to analyse the highly gender-segregated employment structure of the high tech electronics industry precisely because it begins where orthodox theory failed. Dual or segmented labour market theory recognised the theoretical importance of the growth, market power and economic requirements of the postwar industrial enterprise and the existence of persistent inequalities in the labour markets.

This section of the chapter introduces and assesses the work of major DLM economists, Doeringer and Piore, who worked both separately and jointly, and Gordon, Edwards and Reich (whose joint work will be abbreviated GER). The analysis of their work is preceded by an analytical summary of its theoretical context. The final part of the chapter reviews the contributions of feminist economists and sociologists who have criticised DLM theories for their incidental treatment of gender-exclusive labour markets.

2.3.1 Neoclassical Analyses of Gender Discrimination

The increasing participation of women in the US and UK labour markets throughout the 1950s, 1960s and 1970s has drawn a great deal of attention from academics and policy-analysts. That attention has been due at least in part to the tendency for women to be channelled into a relatively few occupations and their experience of low pay relative to male workers, a situation that persisted even as their participation grew to close to half of the labour force. This called for an explanation which economics orthodoxy could not provide. In a perfectly competitive labour market, individual productivity determines labour market outcomes. The market would not allow two workers of equal productivity to earn different wages. Profit-maximising firms paying more for their labour than their competitors would face a competitive disadvantage that would soon eliminate them from the market. And with perfect mobility, workers would move to jobs and companies with better pay. Within the model of perfect competition, any divergence between marginal productivity and pay could only be a short-term imperfection that the dynamics of competition would soon eliminate.

Gary Becker, a major contributor to the literature on discrimination, argued that gender-associated pay differences derived from individual choice or from different original endowments. Employers may have a preference for male workers: they can choose not to maximise profits by paying men more than women (of equal productivity), preferring to indulge a "taste for discrimination" (Becker, 1971). These employers would employ women, then, only if they were willing to work at a discount. Discriminating male workers also might cause pay differentials. Men who did not want to work with women might consent to work only if they were better paid. In both cases, discriminating employers refusing to minimise labour costs would lose profits. In a competitive economy, they could not sustain this behavior; competitors relying entirely on lower-paid women workers would in time force discriminating employers out of business. While attempting to explain women's experience in the labour market, this model clearly considered discrimination a temporary and aberrant phenomenon. Becker and his followers refused to recognise the persistence of discrimination.

Dropping the assumption of perfect competition led to a more convincing explanation. Madden (1973) argued that an employer could continue to employ women willing to work for less pay than men if there were no other firms competing to hire the women. Women's more limited mobility (due to domestic responsibilities and perhaps access to transport) could restrict them to jobs in one nearby firm. This firm could maintain pay and job discrimination even if the women were introduced into a male labour force. The women would have little choice in a monopsonistic labour market. This `power relations' model, as Bruegel (1982) labeled it, replaced individual choice with the effectiveness of (or absence of) market power: the market and its inequalities would remain stable unless new competitors entered the region willing to bid women workers away with better jobs and pay. Importantly, Madden rejected the orthodox dogma of the wage reflecting individual productivity. Her analysis revealed that distinctions between `male' and `female' work can save employers money.

The model of men and women working side by side at different pay rates for the same job is, however, not convincing over the long term. Employers could reduce total labour costs by substituting lower-paid but equally productive women for all their male workers. The entire labour force would in time be female. This does not accurately describe what has happened. The model does, however, allow major employers market power: employers have the power to distinguish between `male' and `female' work and to maintain that distinction by control over (for example) a geographical labour market. Firms reduce their wage bill by employing women and men in *different*, non-competing jobs and benefit as long as their power in the labour market remains unchallenged. The model also acknowledges that women's lack of market power v.a.v. men and their employers (eg less mobility, lower unionisation rates, etc.) makes them weaker agents in the labour market.

Industry and Occupational Segregation

Where women and men work - the industry, the type of firm and the type of job - turns out to be extremely important in explaining and maintaining discrimination. Workers with similar work experience and education earn different wages according to the industry and the size of the company (Bibb and Form, 1977; Lloyd and Niemi, 1979). Layard, Piachaud and Stewart (1978) found significant earnings differences amongst workers in different industries - holding skill, training and experience attributes constant - with the lowest paid industries having predominantly female work forces. Workers in small firms are paid less than people doing similar jobs in large firms (Bibb and Form, 1977; Blau, 1984A), and women are more likely than men to work in small firms. Further, studies by Treiman and Hartmann (1980) and Bielby and

Baran (1986) both located earnings differentials between men and women in their differing distributions across occupations, a relationship that grew stronger the finer the occupational definition. The latter study (like the UK report cited earlier by Martin and Roberts) found that the vast majority of a large sample of US workers were in occupations that were exclusively female or male. This segregation, rather than skill, size of firm, or education and training, was the major determinant of earnings opportunities. This has been supported in many other studies, even when productivity factors are controlled (See for example, Oppenheimer, 1968; Hakim, 1981; Stevenson, 1975). Blau (1984B) showed that men working in `female' jobs earned less than other men in similar but different occupations. Clearly job and pay inequalities were not different kinds of discrimination but different faces of the same problem.

Neoclassical economists Chiplin and Sloane (1976) attempted to analyse job discrimination. They claimed that the reason gender segregation lasted in a competitive labour market was that women chose their jobs. Women preferred, for example, jobs in small firms because these jobs could frequently be found close to home and small firms offered a more casual, family-like atmosphere than large firms. While the pay might be lower in a small firm, all individuals of equal potential reaped identical `net benefits'; so the system was stable. Chiplin and Sloane simply fell back into subjective rationalisation when the neoclassical tools failed (Bruegel, 1982).

Investing in Human Capital

Individual choice is also at the heart of human capital theory. In human capital theory, neoclassicals argue that labour market inequalities are not caused by discrimination, but result from workers (in specific, men and women) having differing productivities. The market cannot then fairly assign them the same jobs and wages. These productivity differences arise because men and women make different choices about investing in their own human capital - that is, the education and training that will qualify them for (well-paid) jobs. Women, expecting their domestic role to reduce the time and continuity of the labour force participation, want to maximise their earnings during their period(s) in paid employment. So they are less willing than men to forego wages for training (on and off the job). They choose jobs that do not require training (Mincer and Polacheck, 1974). They also seek employment where they will not be penalised for a break in their career or needing to work part-time (ie where wages/salaries do not vary with experience).[11]

The theory, which maintains a tenacious hold on the ideology of pay and employment analysis, places individual choice and expectations at the centre of labour market operations. It disregards the externally imposed barriers that frame that choice. Further, the sexual division of labour in the family is taken as given, and the result - women's constrained labour market choices - is portrayed as logical and fair. Yet Becker's theory (1957, 1973) follows a confusing circular path. Becker asserts that the decision to marry and to have children derives from women's expectation of occupational segregation in and lesser returns from paid employment. The 'utility' of two people can be maximised by allowing the man to realise his earnings potential in the labour force and by the woman accepting responsibility for unpaid work in the household. Occupational segregation reinforces the division of labour in the family and that sexual division of labour compels women to choose less well-paid, less permanent jobs than men (Amsden, 1980). Becker and, more generally, neoclassical theory fail to acknowledge sexism in the domestic sphere, so simply cannot explain the subordinate position of women either in the labour market or in the family.

In spite of its seductiveness, the ideology of individual choice at the root of neoclassical theory obscures the fact that an individual's opportunities, as well as preferences, are socially constructed. External social, economic and political factors shape behavior. Acknowledging the element of power implies that the options for some are more restricted than for others and compels an analysis explaining why. Bergmann (1974) and Madden (1973), building on much earlier work by Edgeworth and Fawcett, argued that barriers that could develop within imperfect competition severely limited women's employment choices. Their "crowding hypothesis" claimed that social conventions and outright bans excluded women from a large number of occupations, types of companies and industries. All women workers are crowded into a limited number of occupations. The resulting wages are lower than in other occupations (for both men and women) because of the oversupply of labour to those jobs. The broader range of men's occupations are protected from competition from women workers; an artificial barrier reduces the competition there, creating a higher wage than would be the case if all barriers were removed.

2.3.2 Labour Market Segmentation

The crowding and power relations models, while focusing on labour supply to explain discrimination in the market, recognised that barriers within industry could also be important in restricting employment opportunities for women. Theories of dual or segmented labour markets developed from the view that the potential barriers on the demand side had grown to dominate labour market operations because of the concentrated market power of large firms in capitalist industrial economies in the late 1960's and 1970's. Institutions within and between firms replaced the market forces in defining and allocating jobs. Barriers restricted access to job categories to certain groups of workers, blocking the mobility of capital and labour that is necessary to bring the wage and marginal productivity into line. The industrial structure and the nature of the firm determined the supply of good and bad jobs and which workers got them, not the supply of high and low quality labour or the numbers of people applying. Where neoclassical theories assumed that the economic system was neutral in the creation of low-paid employment, theories of segmentation targeted system structures as the *cause* of inequalities. In the neoclassical models,

> "women's low pay is explained by lower productivity (caused either by less human capital investment or innately lower productivity), by imperfect mobility or by discrimination which distorts the profit-maximisation process. It is argued that the economic system has no vested interest in such practices; indeed, efficiency would be improved by their elimination." (Humphries and Rubery, 1984, p.335)

In contrast, the segmentation theories contended that the demand for labour structured the labour market to discriminate.

Segmented labour market theory offered a stylised model of two institutionally and technologically disparate job segments, primary and secondary. The segmentation resulted from the growing economic importance of oligopolistic firms with extensive investment in physical capital. These large corporations depend heavily on employees who know how to make the equipment and the labour force work well: these company- and job-specific skills had become much more important to productivity and profitability in contemporary production than in earlier generations (Doeringer and Piore, 1971). The high fixed costs of extensive capital investments compelled employers to want to retain these employees. Firms offered these workers higher pay, better benefits and job ladders inside the firm to keep them in the company (Harrison and Sum, 1979).[12]

Piore (1975) further divided the primary sector to reflect the pattern he saw in large manufacturing firms and in class structure. The upper tier comprised managerial and professional jobs and the lower tier, well-paid blue collar skilled, craft work and a few white collar administrative jobs. The top jobs in the hierarchy offered the best pay, benefits and career ladders. Also these employees had more job control, and education, personal achievements and personalities rather than formal rules fixed their position in the hierarchy (Piore, 1975; Harrison and Sum, 1979).

The secondary labour market comprised more general, less skilled jobs, usually referring to less capital-intensive manual work. Because only a minimum (if any) training was needed in these jobs, there were few costs to the employer for high turnover in these jobs. Employers could save money by minimising pay and investment in working conditions for secondary jobs.

The disparate segments referred both to jobs and workers (Doeringer, 1975; Doeringer and Piore, 1971) distinguished by the differing behavioral expectations. The most important of these was employment stability (Piore, 1971). Secondary workers were not expected to have a long-term commitment to the job, so the jobs, in turn, offered little to solicit the worker's loyalty.

Firms structured work, hiring and employment practices in these segments in order to cost-minimise. Employers minimised costs by maintaining low turnover in the highly standardised, capital-intensive production areas through employee satisfaction and by filling lesser-skilled vacancies with the lowest-cost labour.[13,14]

A key feature in primary sector employment is the internal labour market. The employer designs a hierarchy of linked jobs and associated training opportunities within the primary sector to give an employee additional skills and/or to promote her/him. The internal labour market (ILM), then, is a system of job ladders and formal criteria within the firm determining pay, promotions and layoffs and cushioning the primary sector worker from the impact of the external labour market (Buchele, 1981). Management pays for this protected environment to retain long-serving employees as the least cost way of filling new vacancies that require company-specific knowledge. It will work as a cost-minimising strategy for workers with transferable skills in primary sector work areas and for employees who need only incremental enhancements of skill or knowledge to prepare them for the next job.

The conditions in the external labour market frame the extent to which employers rely on to which primary sector workers reap the benefits of an ILM. The external labour market determines the costs and benefits of the choice to train employees for job vacancies rather than recruit from outside. The most advantageous situation for the firm is one where the vacancy requires only an incremental addition to a worker's skills and knowledge, minimising the time and cost of training. The conditions in the external labour market can, however, convince employers to invest more heavily to train/upgrade and promote employees. The circumstances include when (1) the employee knows so much about the firm that losing him/her to competitors would be costly; (2) it is the only alternative because the needed skills do not yet exist in the labour market, and (3) labour shortages would make recruiting new workers very expensive (Doeringer, 1975).[15]

Management offers employment security and mobility only to primary sector workers. There are no ladders and few promotion options for workers within the secondary sector. The job gives them no saleable skills and no incentive to stay. There is no incentive to upgrade secondary workers into primary sector job vacancies because, with the very different production technologies in the two sectors, the training necessary would be long and expensive. Secondly employers hesitate from investing in secondary workers who are not expected to stay long at the firm. The ILM, then, progressively enhances the position of one group of workers, while continually reinforcing the negative characteristics of the secondary group. Primary sector employers and workers have vested interests in perpetuating the system. The barriers between the two sectors become insurmountable, making escape from the secondary sector all but impossible.[16]

2.3.3 Weaknesses in the DLM Model

Doeringer and Piore recast the analysis of labour market discrimination: the *firm* attaches pay, benefits, better or worse working conditions, and opportunities for advancement to *occupations*, not individuals. The factors that determine the mix of good and bad jobs - the product market position and size of the firm and the method of production - simultaneously set pay (or at least differentials) for the jobs, not the productivity or the educational qualifications of the individual (Blau and Jusenius, 1976). The theory abandoned the neoclassical concepts that labour is a commodity like any other and that individual behaviour propels the market.

> "[S]egmented theories are explicitly historical and focus on systematic forces which restrict the options available to (members) of the labor force. The primary unit of analysis is no longer the individual and his [sic] free choices, but rather groups or classes who face objectively different labor market situations which systematically condition their `tastes' and restrict their range of effective choices. The orthodox models (take) institutional parameters as given and then analyze the equilibrium which results from the choices of ...individuals within those parameters." (Carnoy and Rumberger, 1977; quoted in Harrison and Sum, 1979; p.695).

The theory, however, refuses to face one of the fundamental issues in analysing labour market inequalities: <u>why</u> do certain groups and not others end up trapped in secondary jobs? Doeringer and Piore offer only a convenient, functional explanation. Class cultures and subcultures produce young workers with the characteristics that channel them into secondary and upper and lower tier primary jobs (Piore, 1975). The social structure

> "produces the differentiated labour supply that the system demands...
>
> "`[T]he particular characteristics of the secondary workers are largely

> "accidents" which the economic system makes use of but does not create.'" (Piore, 1980, quoted in Humphries and Rubery, 1984; p.336)

This assumes that groups accrue social and political power outside and prior to any economic role and the social system will harmoniously continue to provide the needed quota of subordinate jobs for the maintenance of the economic system.

This happy "coincidence of wants" (Humphries and Rubery, 1984), oversimplifies and distorts the relationship between the demand and supply sides. Firstly, the model considers the secondary sector a homogenous group of workers all with roughly equivalent labour market qualities. The model views women both homogenous as a group of workers (Beechey, 1978) and interchangeable (in terms of behavioral characteristics and labour market power) with all other subordinate workers. That black, white and ethnic workers and men and women have differing experiences and advantages/ disadvantages in the labour market has been the source of a rich and growing descriptive and analytical literature (Wallace, 1980; Buchele, 1980; Malveaux, 1984). Further, Doeringer and Piore simply ignore that women workers face unique constraints and expectations in the labour market because of their domestic role. In addition, their gender-blindness orevents them from realising that all women are not identical in the workings of the labour market. Employers distinguish between white, black and ethnic women (Coyle, 1980; Phyzicklea, 1980; Siegel and Boross, 1980), young and older women (Goldstein, 1986), and `first' and `third' world women (Green, 1983; Pearson, 1983) when hiring, resulting in a diversity of work experiences.

Secondly, the fact that secondary workers do not display the characteristics that employers attribute to them shatters the explanatory power of the model. Doeringer and Piore claimed that the fundamental defining feature of subordinate jobs is management's expectation of and willingness to tolerate high turnover from some workers. However, research on women workers shows women to have a strong attachment to paid employment. An IFF study (1980) of women in the labour force, for example, found that, age for age, full-time women workers stayed as long as men with individual employers (though they may leave the labour market more often due to childbearing and domestic responsibilities). Women, particularly after childbearing, remain in their jobs for long periods while continuing to be concentrated in secondary jobs. Short tenure, then, cannot be used to define the secondary sector and cannot explain the relegation of women to the `bad' jobs and low pay in the subordinate sector. Conceding the possibility of statistical discrimination (that is, some individuals may be trapped in secondary jobs because employers mistakenly attribute to them the statistically valid and undesirable characteristics of the group; Piore, 1971) does not rescue the theory. Millions of single women without children in low-pay unstable jobs in the US and UK cannot all be a mistake of employer perception. Employers value these workers for secondary jobs precisely because they must keep their jobs to support their families and have few better alternatives. The DLM model fails to explain why particular groups of workers continue to be relegated to subordinate jobs.

2.3.4 A Marxist Analysis of Segmentation

Radical economists, most prominently Gordon, Edwards and Reich (GER), challenged the Doeringer and Piore's concept of a coincidental and harmonious match of supply-side characteristics with demand-side requirements. Their analysis of segmentation disputed the central tenets of Doeringer and Piore's model: to suggest that firms structured labour markets primarily to protect job- and firm-specific skills fundamentally misread the propulsion of the system. GER's model focused on the opposition of capital and labour. Capitalists developed highly compartmentalised and hierarchical job segments to increase their control over the production and accumulation processes. By segmenting labour markets, they could buy off, contain or quash the development of working class strength and minimise the cost of labour more effectively (Edwards, Reich and Gordon, 1975).

The increasing concentration of capital in the twentieth century made segmentation both possible and necessary, according to GER. Giant corporations wanted to protect and to exploit their market power. The labour movement, growing strong under monopoly capitalism, threatened capital's profitability and control. At the same time, product market control provided the stable demand to support investment planning and the resources to create a primary market, developing durable labour-management institutions to placate, incorporate and regulate the workers central to the company's operations. In GER's secondary labour market, capitalists use a divide-and-rule strategy to exploit social divisions and antagonisms amongst disadvantaged groups in the labour force. Playing these groups off against one another discourages unionisation and depresses wages.

While GER viewed the secondary labour market as a consolidation of common employment practices in the earlier, more competitive period of capitalism, ILMs created in the primary market were an innovative, more sophisticated form of control. As Doeringer and Piore had explained, more stable product demand and the large number of differentiated jobs in monopoly capitalism's corporations made the strategy of institutionalising rewards and control both possible and more important. The central concern was control - how to supervise the growing numbers of diverse workers, particularly white collar employees, in the large, complex, often geographically far-flung corporations of the postwar period. This, along with the problems of dealing with increasingly powerful skilled trade unions, threatened capitalists' control over operations and profitability. As corporations became more bureaucratic to cope with their growth, ILMs replaced the direct, personal contact of traditional supervision of workers. ILMs outlined the rules of behavior and career pathways for primary workers to get ahead. ILMs imposed the corporate hierarchy directly on the daily behavior of and expectations for primary workers (Edwards, 1975).

Class relations are the engine of the Marxist model, both the central opposition of capital and labour and the role of unequal class fractions. GER attributed capital's success in establishing segmented labour markets to the cooperation of unions, mainly those representing the relatively more powerful skilled workers. Union leaders agreed to adhere to employer work rules and internal hierarchies in exchange for high wages, relative employment security (Adler and Bowers, n.d.) and mechanisms that controlled the supply of skilled labour, impeding any infringement on their privileges.

A One-Sided Argument

This was GER's only acknowledgement of the interaction of the demand and supply sides in the segmentation of labour markets. Their model is a functionalist one[17] in which capital uses pre-existing social divisions in the working class to serve the interests of capital. The relationship of the groups is stable and exogenous to the development of segmentation. While the model explores how the demand-side structure keeps workers in their segments, it does not explain how they came to their positions of relative power/powerlessness or how the system responds to changes in those positions. GER document, for example, the relegation of women to secondary jobs in the growing post-war service sector (GER, 1982) and refer to the history of `new' subordinate jobs being created to employ women (in clerical work, for example, Davies, 1975). Yet they never ask why women. They ignore women's unpaid work in the household sphere and the resulting constraints on their participation in the labour market: being female was a disadvantage in the labour market without theoretical or operational distinction from being Chicano. Further, they neglect to consider the role that the relationship between women and male workers plays in shaping the demand for labour and the path of capital accumulation. Marxist feminists criticised this disregard for the gender dimension.

2.3.5 The Marxist Feminist Critique

Any analysis of women's participation in the labour force must start with a recognition of women's subordination in the family.[18] (See Elson and Pearson, 1981, for a thorough analysis.) Women tend to enter, leave and re-enter the labour force to fit around childbearing and other domestic responsibilities. They are often unable to hold full-time or full-year paid jobs because they have primary responsibility for these chores. This alleged lack of attachment has significant value for capital: female labour uniquely lends itself to part-time, flexible employment (Hurstfield, 1978; Beechey and Perkins, 1982; Hunt, 1975).[19] Part-time and adjustable working hours reduces the cost of the employment contract. Women's dual role makes them a unique reserve army of labour that can be quickly mobilised for paid employment or returned to the household according to the requirements of capital (Beechey, 1977; Bruegel, 1979; Humphries, 1976; Humphries and Rubery, 1984). However, that expendability does not always dominate their role in the labour market. The same qualities of women's labour have convinced some capitalists that using women as a core labour force offers useful cost-savings opportunities during recessions. Retaining women workers and expelling more expensive male labour may prove more cost-effective, as Bruegel (1979) found to be the case in some industries and occupations.

Most feminist accounts disagree with the GER assertion that women's subordinate status is exploited by capital alone. Working class men and their institutions have historically devalued women's abilities and experience. The concept of skill has itself been defined in traditional male craft terms that belittle or ignore women's capabilities (Phillips and Taylor, 1980; Cockburn, 1983). Male trade unionists - through actions on the shop floor, local and national collective bargaining and lobbying for state support - have acted to exclude women from access to primary jobs (Hartmann, 1976; Rubery, 1980; Kenrick, 1981). This has often been with the support of male capitalists and, in some cases, with the help of women (eg in the defense of household living standards, Humphries, 1977).

The 'Patriarchy First' Argument

Indeed, many believe that the patriarchal relationship dominates the role of capital in defining women's disadvantaged position in the labour market. Certainly patriarchy existed prior to the advent of capitalist production. The 'patriarchy first' position contends that capital had to adapt to the pre-determined sex-differentiated hierarchy: male power in the domestic and political sphere had to be protected within the work place. Cross-class male solidarity certainly offered significant material rewards: male managers and workers maintained both the benefits of women's domestic labour and privileged access to better jobs. The patriarchal relationship has, at times, prevailed even when quashing male power would have been in the interest of capital (eg when homogenising the work force would have been useful: Hartmann, 1979; Phillips and Taylor, 1980).

By asserting the autonomous and superior role of male domination, however, these arguments deny the interrelationship of the system of social reproduction - integral to the shape and pace of economic development - and that of capitalist production. The value of this literature, however, is that it clarifies that gender power relations have roots *independent* of and *prior* to capitalism that cannot be explained as simply functional to the requirements of capital. Also, acknowledging male interest in sustaining women's subordinate position both in market and non-market activities exposes the possibility of collusion and conflict within classes (Humphries and Rubery, 1984).

Where the DLM theorists subordinated the sphere of social reproduction to that of production, the `patriarchy first' arguments declare women's subordination in the domestic sphere autonomous and predominant. Both oversimplify and misrepresent labour market operations. The two domains have a dynamic relationship. US electronics firms, for example, expanded overseas - changing into transnational firms to tap the supplies of `green' female labour in Far Eastern countries. Why was the competition among secondary labour market groups at home insufficient to produce low wages for capital? Given that the companies expanded in low-wage and severely underemployed economies overseas, why did male managers not hire male workers to preserve the male breadwinner tradition which still has extraordinary ideological power in most cultures? Why did these companies relocate to other countries when constraints on the female labour supply (and in some case attempts to organise unions) pushed their secondary job wages up? Given the interchangeability of disadvantaged groups in the GER model, why did firms not hire local unemployed men? How would the DLM theory explain the substitution of men for women in the US computer industry and the simultaneous upgrading of jobs once the employer recognised that the industry might create a lot of those jobs, as in the case of the first computer technicians, the ENIAC girls? Why would employers in some industries restructure primary sector male work into deskilled jobs that were then given to women (in computer programming, Kraft, 1984; in telecommunications, Hacker, 1979). In these last two examples, the male employees had considerable expertise and control over the work process or the labour market (ie through unionisation). The patriarchy first argument cannot provide an explanation for these substitutions. The functionalist DLM analysis - in its gender-blindness - does not acknowledge much less explain that gender differences give capital economic choices amongst workers and work structures.

The Sphere of Social Reproduction

The demand-side determinism of the DLM theory is its gravest error. Capital neither defines nor operates impervious to the social context. Eliminating capital would in no way guarantee the elimination of gender divisions, the logical implication of the GER analysis.

> "In the feminist account,..[women's low pay and exclusion from certain jobs] does not simply operate at the level of individual decision-making: the process of mutual reinforcement of the domestic division of labour and the segregation of paid labour is more deeply, historically rooted in both the institutions of the trade union movement and of the state...[W]omen's unequal pay and limited job opportunities...cannot be fundamentally altered while the existing division of domestic labour between the household and the state, as well as between men and women, is taken as sacrosanct." (Bruegel, 1982)

In fact the sphere of social reproduction *alters* the structure of capitalist production. As suggested in the example of the Far East above,

> "the geography of gender relations [eg the availability of new supplies of inexperienced, 'green' female labour] has been an important element in British industry's attempts to reorganise geographically; to restructure itself out of crisis." (Massey, 1983)

The 'willingness' of women in economies with high un- or underemployment to work extremely long hours at very low pay rates knowing their capabilities will last only a few years (eg losing their eyesight due to the miniature tasks of the job; Grossman, 1979) gives capitalists the productivity to postpone investing in automating technologies (Froebel et al, 1980). While this may enhance short-term company profitability, the availability of this specific labour supply slows the industry pace of technological change and the shape of competition. Eventually, some firms, relying on manual labour rather than new capital investment, may lose market share and power to those investing in new technologies.

<u>The Assumption of Stability</u>

The quotation above points to another fundamental problem with the theories of dual and internal labour markets - their assumption of a stable economic state. Both Doeringer and Piore and GER suggest that the secondary labour market provides the flexibility necessary for capital to adjust to changing competitive conditions. Their models presume the continuance of the long period of relatively unfettered capitalist expansion in the 1960s and early 1970s and ignore the inherent unevenness of the capital accumulation process. External demand shocks or major changes in the conditions of profitability can jeopardise the market advantages and the resources of the large corporation and thus corporate ability to maintain the payroll and upkeep of a significant cadre of primary sector employees. The institutionalists (adherents of DLM theory) incorporated technological change into their model: it reinforced employers' reliance on company- and job-specific skills, so perpetuated the economics of the DLM.

However, corporate investment in new technologies are often precipitated by crisis (Massey and Meegan, 1982). Profitability crises largely determine the nature and timing of major investments in new technologies. Employers use new production technologies to break labour's control over the work process and the associated labour costs or to change the corporate cost structure. That gives management the opportunity to reorganise work and the allocation of people to jobs.

This may not only shift the balance of employment between the primary and secondary sectors. Major restructuring may also cause redundancies, including the abrupt termination of career ladders in the primary sector. In crisis employment stability amongst primary sectors workers - the economic rationale of the system of segmentation - can become a liability for capital. DLM theory was developed during the extended (and seemingly endless) expansion of the 1960s and early 1970s when perhaps crisis seemed avoidable. By the early 1980s crises abounded throughout manufacturing industries globally, and importantly they reflected resurgent international competition amongst fractions of capital. Capital-labour conflicts were key only in specific industry cases. The monopolistic market control by powerful US corporations which financed the labour market segmentation of Doeringer and Piore and GER was under severe siege by overseas producers. Rigid labour market structures could not withstand the advent of the crises of the 1980s. Neither can the DLM theory.

The challenges to monopoly control over markets came from many directions. Market demand for newer or customised products can threaten the viability of standardised product and production techniques (that Piore viewed as the basis of labour market differentiation). Wildly fluctuating demand, cyclical changes more severe than anticipated, and new or more effective competitors can all threaten the stability and the size of the mass market necessary to the profitability of these large manufacturing firms.

The potential for crisis has multiplied with the internationalisation of capital. Because the DLM theories are wholly domestic in their analyses, they overestimate the stability of the system. The internationalisation of capital has promoted international labour markets. The high degree of differentiation of labour internationally opens up a *world* of diversity that can shape the conditions for the purchase of labour power (Massey and Meegan, 1979). The prices, labour force characteristics and the conditions of the employment contract in one country now affects employment in others. Corporate strategies can take advantage of global opportunities for cost-minimising and minimising labour turnover (eg operating in countries where there is persistent unemployment or where the state protects the employment contract) more varied than the rigid and expensive rules of ILMs. That diversity is particularly important during crisis when capital consolidates, automates, restructures and potentially relocates production. All workers, not just secondary workers, are forced to compete over wages and employment conditions with workers around the world. Crisis eliminates the stability of internal labour markets and the employment protection for primary workers.

2.4 CONCLUDING POINTS

The criticisms raised in both sections are likely to be very important in analysing the growth and development of the high tech electronics industry. First, the industry is by definition both information- and technology-intensive. As a result, the industry's profits depend on company success in producing both rapidly changing and highly variable rather than standardised, mature products. That also suggests a company reliance on a bigger, thus more costly, group of primary workers than has historically been the case for mass manufacturing industries. Secondly, it is an industry that has been volatile since its beginnings and has been in flux throughout the 1980's. As a highly internationalised industry, in terms of markets and the organisation of production, the industry provides a particularly useful case study for examining whether or not the economic benefits resulting from the PLC and DLM models are appropriate and adequate for companies in the midst of significant technological and market change. The criticisms here suggest that the hierarchical and rigid structures of the two models and the dependence on - at least in the PLC international organisation of production - conventional scale economies will not be able to cope with the demands of fast-paced information industries. Furthermore, as the industry has been a major employer of women globally, investigating the recent developments in this industry offers the opportunity to assess whether gender does in fact affect the allocation of jobs and how those decisions can influence the structure and competitiveness of the entire industry.

Chapter 5 examines in detail the extent to which the PLC hypothesis explains the pattern of high tech electronics investment in Scotland in the early 1980's. The aim is to examine if multinational organisation has responded to the important new dimensions of competition discussed above - fast-changing product demand, product customisation and more intense international competition. Preceding that, Chapter 3 outlines the research methodology of this study, and that is followed by a chapter that reviews the history and changing dynamics of the industry. Chapter 6 then investigates multinational employment policies in the subsidiaries located in Scotland to determine if current economic pressures altered the segmentation of jobs and workers.

CHAPTER 3: RESEARCH METHODOLOGY

The research focus on corporate investment and employment strategies for coping with industry crisis required specific and up-to-date information that published data could not provide. Consequently, the research relies in the first instance on personal interviews with corporate managers, the only reliable and adequately informed sources. Further, the terrain of the study had to be restricted. While the research interest concerned the international shifts in roles and resources amongst subsidiaries and locations of multinational corporations, limited resources narrowed the geographical scope of the study. The field survey, thus the study, focused on Scotland, a major concentration of the industries' global investments.

The field survey included fourteen computer and semiconductor multinational corporations (ie SICs 366 and 367) operating in Scotland in 1983/4. Thirteen of the firms originated in the US, one in Japan. All but two of the firms ranked in the top twenty in world sales in their industries (1981 for the computer industry, 1984 for the semi-conductor industry). In fact four of the seven semiconductor firms and six of the computer firms were amongst the top ten firms. Using published or publicly available data, Appendix 1 lists the survey firms and outlines their history in Scotland.

3.1 DATA COLLECTION

The field survey also included seven multinational corporations with headquarters or advanced manufacturing and research facilities in California. Corporate executives and managers were interviewed to identify major international technological developments and global corporate strategies and to understand the economic forces behind the changing geographical dispersion of corporate investment. These firms included both headquarters for the survey firms and other corporations which were major actors in their industries. They also are listed in Appendix 1.

Because of the pace of change in these industries and the absence of reliable or illustrative data (See discussion below.), most of the analysis in this study relies on data from these corporate interviews. Corporate executives in these firms agreed to cooperate only on the conditions of a guarantee of confidentiality. To keep that promise, actual company names are omitted in the text.

Interviews were arranged with the managing directors of the Scotland subsidiaries and appropriate executives in the firms in California (eg Vice-President of International Operations or Technology Development). These were considered the people most able to speak with authority about the corporation's overall investment strategies, overseas operations in Scotland and the ways in which the firm had altered the organisation of technologies and employment in response to new competitive pressures. In a few cases executives in Scotland substituted their personnel or plant production managers. Management in all of the selected firms granted interviews. According to others involved in industry research in the US, Scotland and England, the 100% response rate was unprecedented.[1] Appendix 3 includes the field survey questionnaire. The field visit in all cases included a request for corporate data to document the following:

a. employment and output in the Scotland subsidiary (measured by sales or value added) from 1970 to 1984; and

b. the occupational distribution of employment for the subsidiary at the time of the survey, for five years earlier (1979) and for the end of the next five years (1989).

Unfortunately, managers were extremely reluctant to gather or divulge this information and, though a number of firms forwarded data, a complete data set could not be constructed. The data was either inappropriate (eg data at the corporate level rather than the subsidiary), incomplete or incomparable (eg measured in differing units).

Data from these firms were supplemented by interviews with a range of industry actors and experts who corroborated, explained and added to the stories of the managers. As a result, the field research included more than eighty separate supplemental interviews; some were in California, Boston, Massachusetts, and London, but most were in Scotland. The distribution of industry perspectives represented by these interviews is, as follows:

--- Managing directors of six small Scotland-based high tech firms, three in the computer industry and three in chip design;

--- Managing directors of three firms supplying the region's high tech industry;

--- Seven academics, most of them regional leaders in the education and training sector in Scotland and nine academic research professionals who have investigated the high tech industry in Britain and the US;

--- Twenty industry experts from both the public and private sectors in Scotland, England and the US;

--- A number of public sector officials, including three high ranking officers in the Scottish Development Agency, the region's development authority (two of them policy-makers for the development of high tech in the region); an economist as the Scottish Council (Development and Investment), the Director of Planning at Fife Regional Council, an elected representative on the Fife Regional Council; a representative of the Strathclyde Regional Council; the economists for two regional planning agencies and three professionals from the EITB in Glasgow and London;

--- Twelve trade unionists active in trying to organize in the Scottish and US high tech industries;

--- Sixteen industry workers, including production workers, engineers and administrators; and

--- Directors of three JobCentres in Scotland located in areas with a high concentration of high tech jobs.

All of the interviews in the UK and US were conducted in the autumn of 1983 and the spring, summer and autumn of 1984.

These interviews proved to be important supplements to the interviews of managers in the primary survey firms. A number of factors limited the reliability of the interview data from primary corporations. In an industry where control of information dominates competition, creating market and revenue advantages, executives were often vague, if not secretive. Confidentiality was assured, yet managing directors all avoided giving details in areas they considered sensitive. Also, the industry style is one of friendly, freewheeling bravado: distinguishing hopes or momentary opinions from strategic and operational decisions was at times very difficult. The supplemental interviews helped cross-check information and, as these interviewed were competitors, consultants or suppliers, added detail to the vague picture the multinational executives provided. The additional perspectives provided by these respondents offered evidence that helped distinguish important directions, if not trends, from minor or transitory activities. (The complete list of interviews is in Appendix 2 and the questionnaires are in Appendix 3.)

3.2 METHODOLOGICAL ISSUES

One of the primary purposes of the field survey was to determine whether or not the nature of the technology investments and, thus, technology-related responsibilities in the Scotland subsidiaries had changed from earlier investments in Scotland or other overseas locations. To do this, the survey asked managers for specific information about capital equipment purchased and installed during the study period (1979-1984). The survey gathered information on both the year of installation and descriptions of the functional capability of specific machines to identify those investments that were state-of-the-art technologies and those that were established technologies.

It was, however, impossible to realise this objective for three reasons. First, managing directors in some cases did not know the details of all their investments or the functional capabilities of all installed equipment. Their responses to these questions were, as a result, often ambiguous. This problem was compounded by the fact that many of them considered specific details on technological capabilities sensitive information. Furthermore, the fact that capital equipment for design, manufacturing and test was often custom-designed for the producer firms made distinguishing different generations of technologies by date and/or capability impossible. Consequently, the findings reported here rely on managers' responses about whether or not the specific technologies had been previously used within the corporation or within the industry. While this means conclusions about technology responsibilities at the Scotland subsidiary rely on managers' interpretations and assessments, these men were all experienced and knowledgeable electronics engineers. In addition, each had the responsibility of accepting from corporate headquarters and devolving responsibilities for technology assessment, investment and installation at their subsidiaries. Consequently, the findings reported here are in all probability quite robust.

The Frame of Reference - The Industry vs. The Firm

The focus of interest was from the beginning the industry. However, as an industry developed by individualistic entrepreneurs, there was likely to be considerable diversity amongst firms. It was not clear that industry-wide technological and market changes would cause an industry-level response rather than a series of individual firm adjustments. In addition, the industry, particularly the semi-conductor sector, had historically supported so-called niche strategies (ie market pockets for specialised products). So, the field survey concentrated on management policies in individual firms to capture this diversity.

The differences, however, were only ones of degree. The competitive pressures of the industry and the dynamics of industry development in Scotland were compelling: as major global market leaders, the firms were pushed in the same direction as the rest of the industry - competing through product differentiation and reducing unit production costs. A study of the entire high tech electronics industry, or even one dynamic region such as Silicon Valley in California, would have included a large number of small new competitors, starting with only a rented office and a telephone and a range of market strategies. Firms facing bankruptcy, merger and take-over would also have been included. Industry growth in Scotland had nourished some diversity: there were many domestic start-up firms, for example, a few spin-offs from the industry's largest firms. However, this was a very minor portion of the region's industry in terms of both employment and output. This study focused on the largest part of the regions' industry - the segment of well-established multinational corporations. There was considerable consistency in their strategies to set up or expand in Europe to compete for market share in a prime overseas market.

My research approach depends on "descriptive synthesis", as Amsden (1985) and others before her called it. Descriptive analysis captures the political economies of change while it happening. In cases of strategic, technological or institutional change, quantitative analysis is simply inadequate. Because it derives from historic patterns and existing relationships, it cannot capture change.

This research is essentially an in-depth case study of an industry segment, and the method proved to be particularly appropriate for this industry. At the time of the study, the industry was changing rapidly, both growing after a two-year downturn and shifting priorities to profit rapidly from that growth. While there had been a number of important descriptive studies, particularly of the semi-conductor industry (Borrus, 1983 and 1984; Ernst, 1983; Scibberas, 1977), they had not considered the international organisation of the industry an important variable in strategic market response or competitive capability. That made an in-depth examination of the industry in one region a useful contribution to understanding structural change.

The Inadequacy of Published Data

A descriptive approach was also necessary because the strategic changes taking place could not have been discovered from any published quantitative data. Neither annual reports nor government data could capture changing strategies of, for example, the global distribution of technological responsibilities or altered recruitment policies, each of which signaled a new role for the subsidiary. In addition, the time lag between data collection and publication was a more important problem in this fast-paced industry than is usually the case in industrial analysis. In 1984 no quantitative data were for the period 1980 through 1984: consequently, there was no way to capture the critical years of industrial change through published data.

Secondly, there was no reliable and consistent quantitative data available either at the national or regional level. At the national level, it was impossible to separate out activity in the computer and semi-conductor industries from that in older industries included in SIC's 366 and 367. At the three-digit level, each of these SIC's combines high tech firms with many older electrical and electronics firms producing older and very different products, using much less advanced technologies than in the sample firms. For example, SIC 367 includes radio and electronics components and capital goods which combines conventional transistors and passive devices such as resistors and capacitors with semiconductors. Manufacturing processes and industry structure in these slow-growth product sectors have in many cases changed little over the past five to ten years, years of phenomenal growth and change in integrated circuits. To use employment, occupational or investment-related data that combines these traditional products with information-intensive products would mask the discovery of any distinctiveness or new relationship in the newer industries. Published data at the national level was insufficiently disaggregated to be useful.[2]

Further, there were no consistent time series data for the industry's employment, occupational distribution, capacity utilisation, capital growth or wages/ salaries anywhere within the Scottish public sector. The regional development authority and planning departments relied on a highly imprecise and unreliable data set based on a postal survey. Known as SCOMER (Scottish Manufacturing Establishment Record), each year's data was based on a unique decision about the principle for inclusion of firms, so company and industry data were not comparable across years. The survey was only irregularly run. Responding was voluntary. The response rate was said to be rather low and often did not include the region's major employers, most of whom were the multinationals examined here. Large employers, continually negotiating with the public sector for money and favours, had vested interests to maintain secrecy, so had no incentive to respond. As a result, smaller and less technologically advanced firms were overrepresented in survey results though the large firms accounted for most of the industry's employment and investment. Further, the SEPD, the agency responsible for data collection, did not follow up questionnaires with interviews or any kind of cross-checks to determine the reliability of responses. The data was so unreliable that only by analysis of national Census data in 1983 was it discovered that employment in the region's electronics industry had <u>fallen</u> during a decade which was thought to have been one of growth. The industry actually lost as many as 10,000 jobs from 1970 to 1979, in spite of official boasts about the industry's growth in the region. The discrepancy was due to reliance on the SCOMER data (Young, 1983).

The only wage data disaggregated by region and industry was collected by the Scottish Development Agency (SDA). It included firms in the electronics and high tech sectors of the industry. At the time of this study, however, the agency had conducted only three half-yearly surveys (1982 and 1983) which, according the SDA's statistics department, were not strictly comparable because of data collection problems.

As a result, publicly-available regional data was wholly unsatisfactory for any analysis of industrial restructuring. The field survey was the only reliable way to learn how the industry was actually coping with change. The interviews were an opportunity both for learning the nature and logic of corporate decisions and for requesting quantitative data. While the firms fairly consistently provided current and historic employment levels, getting full and comparable data sets on past, current and future occupational distributions or output or value added figures proved impossible. The reasons varied from the absence of any data disaggregated to the subsidiary level (Ie the UK corporation was often the lowest level of analysis available.) and wide variability in company measurements of output to flat refusal to disclose competitively sensitive data.

3.3 CONCLUDING POINTS

At the time of the study the lack of knowledge about the actual activities of the survey multinationals and the economic role of Scotland's subsidiaries made the industry in Scotland a rich research focus. Given the rapid pace of change in technologies and market strategies, the survey interviews proved to be the only way to uncover contemporary economic pressures and responses. In spite of the limitations of the research method in providing reliable and comparable data, interview data describe industry changes surprisingly consistent across firms that would be difficult if not impossible to capture with quantitative data.

Chapters 5 and 6 report the findings of the field survey and assess whether or not they support the product life cycle and dual labour market theories. The final chapter considers the impact that the research method, the limitations of interview data and the timing of the study has in interpreting and generalising from these findings.

CHAPTER 4: THE US HIGH TECH ELECTRONICS INDUSTRY: ITS HISTORY OF DRAMATIC GROWTH, TECHNOLOGICAL CHANGE AND INTERNATIONALISATION

4.1 INTRODUCTION

The US microelectronics industry expanded globally early in its history. This chapter looks at the history of the industry and its global spread to explore the extent to which the product-life-cycle analysis explains the pattern of internationalisation. After a brief analysis of the economics of industry growth until the late 1970s, the chapter then outlines the changing economic conditions and mounting competitive tensions that led to a shift in corporate strategic priorities by the early 1980s.

To understand the role of Scotland within industry dynamics, the chapter reviews the history of high tech multinationals in the region. The economic role of the region shifted markedly in 1979/80: changes in Scotland in the early 1980s resulted directly from corporate efforts to resolve this crisis of accumulation. Chapter 5 will examine in detail the 'new' multinational subsidiaries in Scotland and compare their role within the corporation to that predicted by the the product-life-cycle hypothesis.

The integrated circuit[1] or chip as it is colloquially called, is a product that processes information, so has endless applications. It can work wherever information can be used to run or control operations, eg a switch to turn on household heating, a calculator a fuel level indicator, etc. The number of applications and their economic feasibility grows as the product becomes more powerful and the cost per function drops. The computer is an information processor used both on its own and in tandem with other industrial systems. It depends on the chip as its key component.[2,3]

This study focuses on the manufacture of the central processing unit or the brain of the computer. This product focus, however, is obscured by the complex interrelationship of hardware and software. To produce a finished product, a firm must design, manufacture and test the hardware and software operating system together.[4] In fact, software is a critical factor in the success of both computer and semi-conductor firms in defining and capturing markets. The chapter's discussion of software, however, is limited to its role in altering the costs and strategies in microelectronics multinationals.

The US semi-conductor and computer industries have different yet intimately intertwined economic histories and structures. Their interdependence derives from the relationship of their product technologies. This chapter discusses the development of the two sectors in parallel, tying them together where similar and exploring the dynamics of their relationship.

4.2 THE ECONOMIC DEVELOPMENT OF THE SEMICONDUCTOR AND COMPUTER INDUSTRIES THROUGH THE 1970s

4.2.1 The Product Market

The semi-conductor industry, a $13 billion market by 1979, gained attention because of its exceptionally high growth rates year after year. While the growth rate for the entire electronics industry (that is, consumer and capital goods) averaged 20% and 23% annually for the US and Europe, respectively, between 1963 and 1973, the sales of integrated circuits (ics) grew 541% and 600%, annual averages, in those markets over the same period calculated from data in Scibberas, 1977).[5] That phenomenal growth continued into the 1980s: from 1979 through 1981, the value of worldwide shipments of ics grew by an annual average of 31% (Cane, 1981A). The growth resulted from the rapid proliferation of new microelectronics applications for standardised memory chips throughout industry. By the mid 1980s there was concern about slowed growth. However, the slower growth rate still far exceeded that in traditional industries. World sales between 1981 and 1985 grew 21% (annual average: Sylvester, 1985A).[6]

The US computer industry, too, expanded rapidly in the 1970s due to, amongst other factors, a more generally perceived need for computing power and better developed and marketed applications. As Table 4.1 shows, the value of global shipments by US-based firms grew throughout the late 1970s, averaging 15% p.a., while US GNP averaged only 4.2% growth (1977 - 1979).

TABLE 4.1. THE INTERNATIONAL COMPUTER MARKET*

Shipments of US-Based Manufacturers

	No. of Systems Shipped	Percent Increase	$M Value Shipped	Percent Increase
1976	35,800		6,234	
1977	50,690	+42%	7,214	+16%
1978	88,000	+74	9,112	+26
1979	161,070	+83	10,627	+17
1980	221,980	+38	11,252	+ 6
1981	330,070	+49	12,296	+ 9
1982	497,190	+51	13,778	+12
1983E	707,450	+42	15,714	+14
1984FC	976,940	+38	18,244	+16
	Average Annual Increase	+ 52%		+15%

Source: International Data Corporation, Reprinted in *Financial Times*, April 11, 1983

* The data refers to totals of all general purpose (mainframe) computers, minis, small business computers, desktop computers and other systems (such as IBM's S/7) shipped by US-based manufacturers.

US computer and semi-conductor firms dominated world markets throughout the 1960's and much of the 1970's.[7] Tables 4.1, 4.2 and 4.3 show the overwhelming domination of both the computer and semi-conductor markets by US firms. While some European economies had major electronics producers that dominated their local markets (eg ICL in the UK in the early 1970's), indigenous firms came under severe attack by US multinationals in the 1970's. The US producers had, for the most part, superior technologies, product responses to fast-paced markets and price for performance indicators. US firms also dominated the

TABLE 4.2. SHARE OF SALES OF GENERAL PURPOSE COMPUTERS (Mainframes)

	UK Market Only* %			World Market Share** %	
	1964	1968	1972	1973	1978
IBM	40	23.4	38.4	65.8	64.2
Burroughs	0.9	6.4	3.9	6.6	7.6
Univac/ Sperry	2.5	8.8	3.7	7.1	7.1
NCR	7.6	10.7	2.9	3.8	3.9
Control Data	-	5.4	1.8	3.0	2.4
Honeywell	5.2	6.4	7.0	12.6	11.0
BUNCH Total	16.2	32.6	19.3	33.1	32.0
UK Cos.	42.5	41.9	30.5		
Others:					
IBM-PCMMs				- -	1.3
Other				1.1	2.5

* Source: Select Committee on Science and Technology, Subcommittee D, House of Commons, UK Computer Industry, HC 272; Volume II - Appendices, Appendix 2; 1969/1970. Also Appendices to Minutes of Evidence, Select Committee on Science and Technology, Subcommittee A; Appendix 14; October, 1973.

**Source: Financial Times, September 21, 1979; Reprinted in Locksley, Table 2.9, p25.

development and control of the minicomputer segment, the faster-growing segment in the 1970's. (Micros did not exist then.) In the semiconductor industry US-based firms dominated the technological innovations, as well as world sales from the industry's inception through most of the 1970s, as indicated in Table 4.3.

4.2.2 The Structure of the Two Microelectronics Industries

The US computer industry was an oligopoly. It maintained a fairly stable market structure throughout the 1960's and mid-1970's (See Table 4.2.), both in terms of market leadership and distribution of market shares. Markusen (1986) found the US industry modestly concentrated: four firms accounted for 51% of sales (1981; see Table 4.5). However, that concentration declined throughout the late 1970's. IBM dominated the market from

TABLE 4.3 RANKING OF TOP COMPUTER FIRMS BY WORLD SALES

	Sales Share of World Minicomputer Market* 1975 %	Ranking by Sales in All Computer Markets** 1981
DEC (US)	37.0	IBM (US)
Hewlett-Packard	17.4	DEC (US)
Control Data	8.4	Control Data (US)
Honeywell	4.6	Burroughs (US)
General Automation (US)	4.4	NCR (US)
Texas Instruments	4.1	Sperry (US)
		Hewlett-Packard
		Fujitsu (Japan)
		Honeywell (US)
		ICL (UK)
TOTAL	75.9%	

*Source: International Data Corporation, Reprinted in Scibberas, Senker and Swords-Isherwood, Study of the UK Minicomputer Industry; SPRU, September, 1978.

** Source: Financial Times, April 3, 1983.

1955; five corporations, known as the BUNCH - Burroughs, Univac (later Sperry), NCR, Control Data and Honeywell - followed in market share. However, IBM led the pack by far: it held 71% of total world sales (1977) and its total revenues were seven times those of its nearest competitor (1979). Each of the competitors held onto particular end-user markets as their revenue bases. Competition between them focused on adapting product to particular uses and on improving price/performance ratios.

TABLE 4.4 WORLD MARKET SHARES OF MAJOR SEMICONDUCTOR MERCHANT MULTINATIONALS
Percent Shares

	1972	1976	1978	1980	1984*
US Firms	37.9	43.5	38.7	41.9	44.1E
Japanese Firms	12.1	17.8	24.2	21.5	36.7E

Source: O'Connor, 1983; Table V.1, p130.

* Source: Global Electronics Information Newsletter, March, 1985. The data from the two sources are not strictly comparable. The figures for 1978 through 1980 derive from the industry's top 20 firms, while the data in the final column refers to the industry's top 50 firms. However, the figures correctly reflect the growth in the number of Japanese competitors and their rather sudden entrance in world markets. Before 1979/80 their market share primarily reflected their sales in the Japanese economy.

TABLE 4.5. CONCENTRATION RATIOS FOR US COMPUTER PRODUCERS

Bases on Percent Value of Shipments by Largest Firms

	1967	1972	1977
CR4	67%	51%	44%
CR8	83%	64%	56%

Source: Markusen, 1986; Data from Figure CP5 in draft manuscript, p9.

However, the development of the minicomputer outside the computer producer establishment signaled the entry in the mid-1970's of new competitors, altering the nature of competition. By 1981 one of those start-ups, Digital Equipment Corporation (DEC) had become the second largest computer producer in the world.

In addition, a number of new firms producing IBM-compatible machines entered the market in the early 1970's to exploit IBM's huge customer base. While their growth had little impact on total market concentration, they did challenge the market leaders' competitive strategies. IBM management could no longer depend on continuing sales to existing customers to support and expand its revenue base. The rest of the BUNCH faced a more difficult marketing job because customers suddenly had the choice of a much wider variety of product capabilities within the IBM operating system.

The semi-conductor industry was more volatile. While the concentration ratios looked relatively stable throughout the 1970's, the firms included in the CR4 and CR8 rankings changed every few years, as indicated in Tables 4.6 and 4.7. Three firms in the 1972 top eight world producers had fallen out of the ranking by 1980, and three new firms had gained significant market share (Table 4.7). Many of the industry's firms were growing very fast during this period, doubling their revenues every two years. However, two US firms remained market leaders by a wide margin - Texas Instruments (TI) and Motorola.

TABLE 4.6. <u>INDUSTRY CONCENTRATION IN SEMICONDUCTOR MARKET</u>

Based on World Market Revenues

	1972	1974	1976	1978	1980	1982
CR4	32%	36%	31%	30%	30%	25%
CR8	47%	52%	48%	49%	47%	39%

Source: O'Connor (1983).

While there was some industry consolidation during the 1970's, market power was actually more widely dispersed by 1982. The concentration ratios, particularly CR4, had dropped significantly and the revenues earned by the top ten world producers had declined as a proportion of the total world market (from 54% in 1980 to 44% in 1982). This reflected the growing competitive strength of new entrants, often smaller specialist firms. Also, end-user firms became a major source of competition in the industry. Those that were large buyers of chips began

TABLE 4.7. TOP SEMI-CONDUCTOR FIRMS
Ranked in Descending Order by Value of World Sales.

	Market Rank (% Market Share)			
	1972	1974	1980	1984
TEXAS INSTRUMENTS (US)	1 (11.8)	1 (11.4)	1 (11.2)	1 (7.2)
MOTOROLA (US)	2 (9.8)	2 (8.0)	2 (7.8)	2 (7.1)
PHILIPS (Neth)	3 (5.1)	6 (4.5)	9 (3.9)	8 (3.0)
FAIRCHILD (US)	4 (4.8)	4 (5.3)	8 (4.0)	-
TOSHIBA (Japan)	5 (4.2)	8 (4.0)	6 (4.6)	3 (6.0)
HITACHI (Japan)	6 (3.9)	7 (4.2)	5 (4.7)	4 (5.6)
ITT (US)	7 (2.8)	-	-	-
RCA -US \ SIEMENS / (Germany)	8 (2.3)	9 (3.2)	-	-
SGES-ATES (Italy)	9 (2.2)			
NATIONAL SEMICONDUCTOR (US)	10 (2.1)	5 (4.5)	3 (5.5)	6 (3.9)
NEC (Japan)	-	3 (6.0)	4 (5.4)	2 (7.1)
INTEL (US)	-	10 (2.6)	7 (4.1)	7 (3.6)
SIEMENS	-	-	10 (3.0)	-
IBM** (US)	-	-		5 (4.7)
SIGNETICS (US)	-	-	-	8 (3.0)
AMD (US)	-	-	-	9 (2.9)
GENERAL INSTRUMENT (US)			14	16

SOURCES: O'Connor, (1983); Tables V.1 and V.2; p130-1.

* _Global Electronics Information Newsletter_, (1985).

** NOTE: Captive producer not included in earlier calculations.

TOTAL MARKET SHARE OF

	1972	1974	1980	1984
TOP 4 COS.	31.5 %	30.7%	29.9%	27.4%
TOP 10 COS.	49 %	53.8%	54.1%	51.1%

designing and manufacturing their own chips internally to protect their proprietorial information about the technology and to ensure a reliable supply. These captive producers, as they are called, reduced the growth of the commercial chip market.[8] In addition, the leadership changed and Japanese firms, such as NEC, gained market power.

The phenomenal growth in both industries resulted from and further propelled new product technologies, particularly, in the semi-conductor industry. There firms introduced new products every few years, each a technological improvement by several orders of magnitude. By 1980, engineers were doubling the memory capacity of a chip every year and its operating speed every three years (Vedin, 1980).[9] The increased capability and reduced price per function of new products opened up new applications and thus new markets. The pace of change in product characterisitics had to be matched by changing production technologies,[10] so the economic description of these industries must turn to the technologies of production.

4.2.3 Production Technologies

In both industries the technical requirements of each of the stages of production - product research and development (R&D), design, manufacture, final assembly and testing - differed sharply from one another in their proportionate dependence on capital, labour and other resources. When competitive pressures forced firms to make economies, strategies reflected the differing options in each stage of production. Because the operational and information links between stages were minimal, the processes could be geographically separated and dispersed, allowing firms to take advantage of opportunities for cost-cutting around the globe.

The Manufacture of an Integrated Circuit

The first stages, research and development, invent and perfect the basic technical operation of a new product. Once the basic technology has been determined, chips must be designed. A designer must map out the paths of each transistor and complete circuit and must double-check that they will perform the expected function on a chip. With the expanded complexity of LSI, the task has been likened to creating a functionally correct map of the sewer and electrical systems of Manhattan that will then be reduced onto a 1 square mm piece of silicon. The job requires an expert either in the electrical and communication properties being implanted on the chip or in the end-use application. With higher scales of integration, the task is aided by computers (computer-aided design, CAD) which specify, draw, and alter the design and simulate and check its functioning.

Fabrication of the silicon wafer refers to the 300 to 500 chemical and mechanical processes that transform a slice of pure silicon into a wafer containing hundreds of integrated circuits. This is the most complex manufacturing ever adapted for mass production (Saxenian, 1981). The slice of silicon is first chemically prepared, then oxidised to ready the surface for numerous deposits of chemical films. Then in photolithography a "mask" or pattern of each layer of circuits is projected onto the wafer in an optical, camera-like process. Chemical processes then etch those microscopic patterns into the silicon surface and treat the exposed pathways to create areas of electrical conductivity. Each series of processes to make one layer of circuits must be repeated for each of the dozens of circuit layers. Extreme precision in temperature and timing is essential to insure that each circuit is well formed and that the layers relate correctly to one another. Even one minute irregularity can ruin the whole wafer batch. The wafer is then put through a metalisation process, giving it a thin metallic coating. Fabrication ends with preliminary testing.

The next stages - assembly, packaging and final test - are called back-end activities. Once the wafer has been sawn into the individual die which will become chips, each good one is mounted into a package that looks a bit like an oblong centipede. Assembly requires extremely fine gold wires to be bonded under a microscope first to the minute outputs on the die then to the outlets, or pins, in the package. The package is then carefully sealed to protect the device from the outside world. While the specifications for each batch demand adjustments at each stage of fabrication, assembly and packaging are practically identical across products, differing primarily in the number of wires and pins. In final test, the finished chips are visually inspected for imperfections, then put through a sequence of electrical and atmospheric tests on electronic instruments to insure the chips will perform as required.

Each time the firm decides to introduce a product with more transistors and circuits, every procedure from design through final test becomes more difficult because it must be done more precisely. The size of each connection has been reduced yet must be constructed as perfectly as before. The production equipment must be better controlled and more sensitive. Frequently one machine cannot be stretched to produce more than one or two generations of product. New products often require new capital equipment.

Given that the costs of fabrication can better be amortised when the number of chips on one wafer has been increased, industry leaders pushed hard to reduce the size of each chip while increasing its density to lower unit cost. That drive to miniaturise has dominated the industry since its beginning and succeeded in creating the phenomenally rapid changes in product capability (Hodges, September, 1977). The industry's technologists doubled the number of elements squeezed onto one chip every year from 1959 through 1977 (Noyce, 1977 in Forester, 1981). This pace of change demanded continuing new investment in production technologies.

The Manufacture of a Computer

The steps in producing a computer more closely resemble a traditional assembly process. The design of the hardware, an extremely complex, information-intensive product, requires both computer tools (CAD) and people who understand intimately how the instrument communicates and how it will be used. The people developing the software - either the operating system or application package - must have access to the hardware specifications and frequently need to communicate and negotiate with hardware designers. This relationship became closer as product complexity increased. The product was assembled in many cases on a traditional conveyor belt assembly line. First the subassemblies (eg, the power supply and the keyboards) are put together. Also the individual circuit boards are `stuffed,' that is, loaded with chips and other electronic components, then the chips are soldered on. They must then be tested. All of the subassemblies are inserted into the computer cabinet and the boards are loaded into their drawers. Then all parts are wired together. The machine is thoroughly tested, checking the operation of all connections and components and simulating the machine's usage to insure the software and hardware perform the necessary functions.

4.3 THE ECONOMIC DYNAMICS OF THE US MICROELECTRONICS INDUSTRY

4.3.1 The Semi-conductor Industry

It was clear even in the early 1970's that the product cycle of the semi-conductor would create economic problems. The US industry focused almost exclusively on creating new, cleverer products to create new markets (Mowery and Rosenberg, 1983). The difficulty and complexity of designing new, more complex and smaller devices led to a long and expensive lead time before a product could be introduced. That product then typically had only three to six years on the market (Chang, 1971) before a product innovation would be introduced and it was considered technologically and economically obsolete. The monopoly period for an innovative firm to reap excess profits from a product it introduced was even shorter and highly uncertain. It was relatively easy to copy a new product technology once it was on the market: the innovative firm soon lost its position of technological leadership.[11]

With semi-conductor producers racing to miniaturise the circuits on a chip to reduce the cost per unit of information (bit), management needed a strategy that would generate sufficient funds to pay for new product development over the relatively brief market life of their products. The strategy for most firms was to concentrate resources on standardised volume devices - memory and logic chips (Borrus, 1983) and to aim to capture large market share as quickly as possible to gain experience and economies of scale to gain further reductions in unit cost. They used price cuts to create additional demand.[12]

The Learning Curve

The aim was to generate large revenues quickly to fund the development work for the next product generation. Revenues from continuing sales growth would provide return on the capital investment. More fundamentally, efforts to increase output volume were necessary to gain the technological expertise to improve the quality and speed of production. The learning curve strategy dominated the industry's development. This engineering concept proposes that moving quickly into mass production requires production staff to solve production problems early and quickly which leads to better output quality (yield - the number of good die on a wafer). This pushes unit cost down which, when passed onto the market, generates greater demand, supporting increased output and continuing engineering learning curve gains. The faster a firm moved down the learning curve, the greater its technological and economic advantage over competitors. Competitors, without having achieved the savings in unit cost, would be forced to meet the leader's low price to stay in the market; this resulted in reduced profit margins unless they achieved similar economies.

The concept became a competitive rule: each doubling of the cumulative units of devices produced led to a fixed percentage reduction in price. From 1964 to 1975 that price reduction averaged 27.6% (estimated in constant dollars by Benjamin Rosen; O'Connor, 1983; Figure IV.4). TI, the market leader, ruthlessly rode the learning curve to maintain a dynamic technological lead on the industry throughout the 1960's and into the 1970's. Management in competitor firms raced to match the progressively deeper price cuts in semi-conductor products that persisted into the 1980's.

The key to the viability of this strategy was continuing increases in product demand. While the Department of Defense created most of the demand and subsidised the industry early in its development (94% in 1963, O'Connor, 1983; Siegel, 1980; Mowery, 1982), the computer industry's demand for chips created explosive market growth in the 1970's which enabled US firms to dominate the world market (MacIntosh, 1979).[13] The two industries fostered each other's technological and market growth. Falling chip prices promoted increased demand in enduser markets and fostered the development and exploitation of new applications. All of the industry's competitors benefited to some extent from this rapid diffusion of the product technology and the wider customer base. As Table 4.8 shows, the US producers increased their delivered output of the 64K RAM by a factor of more than twenty as its price dropped. Many volume producers thrived on this rapid expansion of the market.

Table 4.8. CHRONOLOGY OF PRICE CHANGES FOR THE 64K DRAM MEMORY DEVICE

Shipments		Average US Selling Price	Cumulative By US Firms
1980,	Q3	$45	
	Q4	30	190,000
1981,	Q1	20	
	Q2	15	
	Q3	9	
	Q4	7	3,806,000
1982		5	

Source: O'Connor (1983), Table IV.11; p.113.

A number of manufacturers operated, instead, a 'niche' strategy to protect their prices and profits from this relentless pressure to reduce cost. These firms produced devices for specialised applications, so were less price-sensitive. Niche strategies could produce high profits. Intel, for example, pioneered highly advanced, very fast devices, particularly the microprocessor. The firm designed successive generations of product that were ahead of the industry. With this specialty and its technological lead, Intel could charge a premium for its clever devices. In this case, the niche strategy propelled the firm into industry leadership (seventh in world sales by 1980).

This strategy, however, could not completely or permanently protect a firm from market competition. The specialty market had to be sufficiently large and growing to generate a revenue base that would support the costly capital investment for production. The strategy was also not without large costs and risks. Success in niche markets still required producers to have first-hand experience of mass production methods to provide the technological know-how to keep production yield high. Also there was always the possibility that a new product would be introduced that would steal the niche or make it obsolete. Throughout the 1970's new devices were continually introduced which were faster, cheaper, more flexible and more innovative. A niche company could lose its market overnight. As a result, competitive pressure forced these firms, too, to offer more advanced products frequently: customers watching the functional capability of standard devices improving daily grew to expect similar improvements in specialised products. Also, these firms in most cases had to continue mass-producing memory chips to maintain manufacturing expertise.

The development of the microprocessor changed competition in the US semi-conductor industry. This product could be mass produced then programmed to fit individual customers' needs. The chip had a standardised structure, but could be programmed to fulfill a wide range of uses. Because they could be mass produced, these `computers on a chip' could be supplied at a cost low enough to create widespread demand. Most of the major producers, driven by the market to supply a complete range of chip products, began producing microprocessors and the necessary support devices.

Two important changes resulted. First, the microprocessor is no longer a component: it is a partial or complete system. Consequently the semi-conductor firms had to develop closer contact with potential customers to understand thoroughly the use of the microprocessor in order to design the chip and its software appropriately. Servicing the market was outside the expertise of mass producers, a gap which encouraged the entry of new, start-up firms.

Secondly, concern about technological exposure led more major computer firms to produce these chips internally, either by starting from scratch or by acquiring an independent firm. These firms wanted to avoid technological and price dependence on outside producers for a chip that was essentially the brain of their computer products (Borrus et al, 1983; Bierman, 1982; Keyhoe, 1982C; Ernst, 1983; O`Connor, 1983).[14] High R&D and capital costs, which had formerly limited competition in the industry, did not deter these large firms. Competition by captive producers further reduced the growth in the chip market and, by buying up independent producers, increased the concentration of the semi-conductor industry. This put significant new pressure on established semi-conductor companies. The captive producers had vast sums of money to devote to R&D, pressuring independents to generate greater revenues. Furthermore, captive producers, by designing and producing their own state of the art chips, denied the merchant firms access to the information and expertise they needed to develop advanced chips for new products. Some chip firms compensated for these losses by integrating forward to sell consumer and computer products.[15] These changes increased the competition, financial exposure and instability in the industry.

4.3.2 The Computer Industry

In the computer industry IBM served as the industry price and performance setter for the US and world markets. The rest of the BUNCH followed IBM's lead. They introduced their own models (architecture systems that were not compatible with IBM's) and attempted to undercut IBM's price while offering the same or better performance. The history of the computer industry had some of the excitement of a television melodrama: at times IBM lashed out with price or performance surprises when its market share was threatened. The pricing and new model procedures were, more usually, well contained within a stable industry framework.

Each firm depended critically on maintaining its customer base, which constrained any radical departure in competitive strategy. Each firm was simultaneously competing with other firms over new and improved products while trying to maintain customer satisfaction with older machines: that customer base provided a continuing revenue flow. Systems vendors expected their customers to buy replacement machines - this generated 60 to 70% of the producer's revenues (Duncan, 1981). To some extent the BUNCH producers targeted market segments, eg, Burroughs in accounting and business applications, to control their market base.

Dependence on the existing customer base restricted the parameters of industry competition. This was particularly true for the huge firm of IBM. Introducing a major breakthrough or a machine with a price/performance ratio far better than earlier models would in effect make earlier models redundant. This jeopardised the firm's replacement revenues and, because of the uncertainty suddenly created, potential revenues for the new product.[16] So cost-cutting was the most common market strategy in the computer industry for many years. IBM could exploit its huge economies of scale and the rest of the pack could attempt through improved design and marketing to find new customers to improve their market share and profit margins.

The introduction of the mini-computer shook up the industry's relatively stable competition. `Minis', developed by the DEC and Data General Corporation,[17] became the fastest growing sector of the market because these smaller and cheaper machines rivalled the performance of established mainframe products (DeJonquieres, 1980E). Also, the new firms targeted their new product at the office and data processing markets, the customer base of the established giants. The smaller machines could be distributed throughout a business - a faster, more efficient and cheaper use of information - by eliminating the need to queue projects through a centralised data processing department.[18] The mini's cheaper processing of information transformed computer usage and markets, stealing part of the replacement sales from established leaders. They soon introduced minis of their own. The new machines, made possible by remarkable improvements in the technological capability of chips,[19] dramatically improved the duality of computers while simultaneously reducing the cost per function of information processing. The resulting reduction in the price/performance ratio for computers (falling at a rate of 25% per annum for small mainframes throughout the 1970's and 1980's; Duncan, 1981)[20] put continual downward pressure on the selling price for all computer hardware. At the same time, competition forced most computer firms to supply a full range of computers, including minis, which escalated the pressure to increase R&D, already a relatively large expense for the industry.[21] The attempt by ic firms to sell computer systems was a further discouragement to established computer producers from initiating any major technological collaboration with ic firms.

Structural change in the two industries grew out of the new opportunities created by these technological innovations. The capability of one chip to contain an entire electronic system invited new competitors who could specialise in the design of and software support for specialised chips. The availability of programmable computers-on-a-chip and of memory devices that could store huge amounts of information transformed the concept of computers and both the demand and supply sides of the market. The mini-computer forced computer firms to offer a wider range of products and, consequently, to deepen their R&D commitment. Competition in the 1970's forced firms in both industries to provide a continuing flow of new products. The associated expense of product development for competitors sat uneasily next to cutthroat pricing, behavior more usually associated with mature products and industries.

An important element of competition in both industries was the phenomenal rate of technological and market change throughout the 1970's. The number of transistors (the fundamental connection or switch in a circuit) which could be crammed onto the surface of a chip had risen a thousandfold since 1970 (DeJonquieres and Keyhoe, 1984), which vastly increased the numbers of things a chip could do. The cost of a unit of solid state memory fell by the same order of magnitude over the same few years. Design engineers had doubled the number of circuits on a chip every year and a half for most of the 1960's and 1970's. An analogy dramatises the magnitude of this innovative pace:

> "...[I]f transport technology had progressed from stagecoach to Concorde as rapidly as electronics technology since the (development of the) transistor, Concorde would be able to carry half a million passengers at twenty million miles per hour...[And] a ticket for the Concorde flight would have to cost less than a penny if it were to compare with the rate at which microelectronics has gotten cheaper." (Rosenberg, 1982; p181)

This pace multiplied the risk of and pressure on the design phase for a new computer product. Computer designers had to thoroughly understand the operation of every new chip. Each new computer product had to be designed to use the newest devices extremely cleverly in order to maximise the potential sales life of the product, so it will continue to sell even after the next generation of ics was introduced. Simultaneously, managers have pressured their development departments to minimise if not reduce the development cycle to exploit new products commercially as quickly as possible. A similar race was going on in the leading ic companies. In both cases development costs were rising while the sales life shortened and the uncertainty of payback increased.

Each successive year of competition sharpened the pincer-like pressures of high and rising development costs and fast-falling prices. Management in both industries had problems in cost-containment and product planning. Reducing some costs was essential to maintaining competitive prices and profit margins. Management sought cost reduction opportunities that could be exploited quickly and easily and that would not jeopardise corporate technological progress. Both industries, in spite of their differences, targeted production labour, the cost considered the most amenable to reduction. Both industries had production processes that could be divided up, separated and dispersed geographically (Storper and Walker, 1983): that enabled management to minimise production costs in a unique way.

4.4 THE ECONOMICS OF GLOBAL PRODUCTION

Both the US semi-conductor and computer industries fanned out across the globe during the late 1960's and early 1970's for very similar reasons. Firms responded to downward pressure on prices by locating plants in the Far East to take advantage of dramatically lower labour costs for lesser skilled labour. Government policies in many of the Far Eastern countries encouraged this investment, helping firms expand rapidly to meet fast-growing product demand. The savings possible from locating manual manufacturing for standard products in the Far East were so great that once one firm did it, competition compelled all the other large and many small competitors to follow suit to maintain their profit margins.

In the early 1960's, management of US firms recognised the different economies of the separate stages of production. Fairchild Semiconductor, the `mother' of many of the ideas and most of Silicon Valley's ic firms, targeted the reduction of labour costs in the labour-intensive assembly and testing operations. At that time labour costs were 45% of the total cost of producing a semi-conductor (NACLA, 1977). There was then no alternative to the manual assembly of chips: no machine could reliably bond and wire the products' many sizes and shapes. While there were efforts to automate computer assembly (most notably IBM's), firms relied on manual methods because they were cheaper and more flexible. Because these manual activities could be separated from design and advanced manufacturing, managers realised that dispersing them to a low-wage economy would dramatically reduce costs. Fairchild relocated die-bonding, wire-bonding and packaging of chips from California to Hong Kong in 1962, then to South Korea in 1966.

US tariff policy also fostered 'off-shoring'. Items 806.30 and 807.00 imposed only a limited duty on the importation of (in the former case) certain metal articles that had been previously processed in the US and (in the latter) articles assembled from US-made components. The import duty, based only on the value added outside the US, was very low because of the exceptionally low wages in the Far East. The fact that standardised assembly and packaging could be separated and performed by relatively unskilled (what came to be called semi-skilled)[22] workers gave firms the opportunity to take advantage of these regulations. These activities did not require a large contingent of highly trained technical personnel, as fabrication would, and inexperienced assemblers and testers only needed a few weeks' training. Furthermore, global shipping was quick and inexpensive because completed wafers and components were small, light and fairly sturdy and could be shipped by air. Competition forced all of Fairchild's competitors to flock to the Far Eastern locations to match Fairchild's cost advantage. The growth of back-end activities was rapid and spectacular (Chang, 1971). By 1979, all of the top twelve ic producers, all US firms, had set up at least two and in many cases four, five or six assembly plants in the Far East.[23] Many Japanese and European firms followed suit. Offshore plants provided unbeatable "low tech" cost-savings in a market where price-slashing was a continuing competitive strategy.[24]

The computer industry, because of the nature of the product and its heavy dependence on government markets, traditionally had to be close to its customers to win large contracts. Computer systems, then, were usually customised, so designers, marketers and sales people had to know the requirements of potential buyers to present and sell these specialised, differentiated capital goods. In addition, with such a large proportion of a company's total turnover dependent on resale to existing customers, firms had to maintain contact with customers to insure they could design and sell appropriate upgraded equipment and peripherals to that customer base. Consequently, the computer industry early in its history expanded globally by investing in the major industrial, European community economies to qualify for military and other large government agency contracts. Once the Common Market was formed, industry leaders dispersed high value added manufacture (eg, for central processing units) inside EEC tariff walls.[25]

Improved price/performance ratios and the introduction of the mini in the 1970's made computers feasible for many data management uses, particularly for scientific and engineering design work, and greatly expanded potential markets. Locating high value added manufacture and design work inside the EEC continued to be important for computer firms. Design and development work located near major government buyers was mainly product modification: firms centralised research and most of product development in the home-base economy where secrets could be better awarded and where experienced technical personnel were concentrated. At the same time, assembly of the standardised sub-systems and peripherals was, as in the semi-conductor industry, dispersed to low wage economies,[26] often in the Far East. By the 1970's the EEC tariff persuaded a number of the US computer multinationals that they could reduce costs on a number of products by locating all manufacturing inside the Market. They did this by tapping a specific cheap labour force for labour-intensive low-skilled assembly - "married" (often rural) women (Massey and Megan, 1978). Burroughs, for example, claimed that its British operations (assembling the central processor and many peripherals) supplied products at 60% of US production costs (Hu, 1973). (See discussion in Chapter 6.)

Most of the semi-conductor and computer industries concentrated R&D and advanced manufacturing, as well as corporate planning and administration, in a California region called Silicon Valley. The computer industry, as an older industry, often had headquarters elsewhere in the US.[27] However, by the 1970's the dynamism of Silicon Valley demanded a presence (eg, R&D) in California.

4.4.1 <u>The Rise and Rise of Silicon Valley</u>

This section profiles the development of Silicon Valley.[28] The microelectronics industry began with William Shockley's success in building more than one transistor in a solid substrate, then miniaturising them in California in the 1950's. His employees at Bell Labs started the spin-off process: they got backing to start their own company, Fairchild Semiconductor, which in turn spawned almost fifty new firms over the fifteen years from 1957.[29]

These and other firms stayed in Santa Clara County, a valley of orchards, for a number of reasons. Since World War II grants had funded a ballooning `industry' of electronics R&D at Stanford University labs to design military components and equipment. Post-war weapons and missiles contracts from the Department of Defense also created a boom for the West Coast aerospace industry, of which Lockheed in Santa Clara County was a major actor. This generated demand for high tech electronics products, encouraging many large electrical/electronics firms to set up nearby in the 1940's and 1950's. Stanford University, specifically Fred Terman, was instrumental in this. The University donated land to start a high-tech industrial park. The university simultaneously expanded its exceptional science and techology programmes and labs during the period. By the 1950's the region had a rich and growing base of highly trained engineers, on-going advanced research activity and technology-intensive firms.

Silicon Valley became a magnet for idea people and became the most attractive place to cultivate, expand and capitalise on those ideas and the people who created them.

University-industry proximity provided a hothouse for technological competition and innovation. Dissatisfied engineers from the labs and firms frequently set up their own firms nearby. Barriers to entry were still low,[30] and the region offered start-up firms opportunities for technical exchange and for tapping the technical labour market. Industry suppliers and support services also flocked to the region.

The area also offered the cultural and educational 'quality-of-life' that attracted highly educated professionals - a significant, if over-rated feature of the Valley. By 1970, Silicon Valley had become the most concentrated centre of electronics enterprises in the US and the world (Keyhoe, 1982E). As the successes grew in number and riches, venture capital for new ideas flowed more plentifully into the region. Silicon Valley became the world leader in microelectronics exploitation and innovation.

Semi-conductor firms starting up in the Valley, often with just a few engineers, established both research and production facilities. Once the economies of shipping lower-skilled work to the Far East became apparent, management concentrated in California those activities that depended on technology-trained personnel in California - R&D, advanced manufacturing, and final testing. Seventy-nine percent of the R&D activity of Santa Clara-based firms was concentrated in the county, while management had dispersed ninety-seven percent of the assembly work offshore (Markusen, 1986). Advanced manufacturing, for example, chip fabrication, employed one highly skilled engineer for every two or three semi-skilled workers (Saxenian, 1981; Markusen, 1986).

A few features unique to the development of Silicon Valley guided corporate strategies in coping with the 1980's. The importance of technology personnel to company profitability, the continuing dependence on large numbers of relatively unskilled production workers, and the phenomenal pace of industry growth all shaped industry pressures and adjustments.

High tech companies in the Valley gained a world-wide reputation for cultivating their scientific and technical personnel - the source of the ideas that created new products markets and profits. In addition to lavish expenditures on gala parties[31] , gymnasia and leisure facilities, management built firms to enhance the informal communications amongst and active participation of these idea people (Howard, 1981), avoiding rigid bureaucracies and tiresome procedures. Ideas were at the centre of company, industry and regional success. The idea was to keep ideas and the people creating them contented and inside the firm.

Production, however, required lesser-skilled workers, too. Employment of operatives in the San Jose area[32] grew to 11,510 by 1974, doubling the 1966 level (Green, 1983; Table 12-6, p.311). While the industry's growth in the 1970's resulted in continuing increases in technical jobs, the industry also continued to rely on a significant number of relatively unskilled workers.[33] For example, about forty percent of a typical Silicon Valley chip producer's 1971 employment was professional, techical, managerial and marketing staff, while less than half (48%) was production workers (Saxenian, 1981).[34]

The microelectronics industry's explosive growth in Silicon Valley and competitive success bred serious problems that were associated with the industry's dependence on both highly skilled technical staff and production workers.[35] Regional employment grew by 156% from 1960 to 1975. Housing costs skyrocketed as a result.[36] Heavier usage clogged the county's roads: commutes of two to three hours between home and work within the county became commonplace, particularly for lower-pay workers who had to live further away from work. Schools were crowded. The beauty and the quality of life in the region, so important in attracting 4000 PhD's and other highly-paid professionals, deteriorated significantly. These developments, combined with increasing competition for labour at all levels, led to astronomic turnover rates. Managers of large high tech firms reported annual labour turnover of 25 to 40% (Interviews with Silicon Valley managers).

These problems translated into escalating pay for all industry employees (Saxenian, 1981; Keyhoe, 1982E). High turnover meant higher costs because of the operational slowdowns, unsolved technical problems, the expense of finding replacements, and a company's loss of technical information and possibly new products to the swelling field of competitors. To reduce turnover and counteract rising living costs, the industry continually increased wages and salaries - especially for electronics engineers and designers - throughout the 1970's (Saxenian, 1981; Keyhoe, 1982E). At the same time product market competition from the Japanese and the growing number of domestic producers forced cost-cutting. Rather than reduce the resources devoted to the idea people in the industry, management looked to production to find ways to save money.

4.4.2 The Far East: World Manufacturing Plants

Sending production to the Far East became an irresistible option because of the extremely low wages available there. 'New' supplies of labour in underdeveloped economies offered seemingly endless potential to slash both the direct and indirect costs of production in relatively simple labour-intensive assembly operations that were such a large portion of ic and computer production costs (Chang, 1971; NACLA, 1977; Lim, 1978; Scibberas, 1979; Hancock, 1980; Lineback, 1982; Borrus et al., 1983).[37] Average hourly wage costs in Hong Kong, for example, including supplementary compensation, were only 10% of those in the US in 1969/70 (Chang, 1971;

p. 27). Table 4.9 lists wage rates in a number of the Far Eastern economies that became important offshore locations for the microelectronics industry. Low wage rates translated into a 48% savings on the manufacturing costs of a chip in the early 1970's (1973: Parsons and Stowsky, 1986). While average pay for US production workers had risen to $4.52 an hour by the late 1970's (Saxenian, 1981), the wage differential with the Far East still offered significant savings. As a result, the number of microelectronics firms and industry employment in Hong Kong, Singapore, Taiwan, South Korea, and later the Philippines, Malaysia and Indonesia grew rapidly (Siegel and Grossman; 1978; Froebel et al., 1980). Fairchild had located 70% of its work force in Hong Kong, Taiwan and Singapore by the mid-1970's (Scibberas, 1979). Within three years of opening a plant in Malaysia, National Semiconductor employed more than 18,000 people in the Far East. By 1976 all of the major computer firms had offshore manufacturing sites in the Far East. As many as 300,000 women were employed in the offshore electronics industry in Southeast Asia in 1979 (Grossman, 1979).[38]

TABLE 4.9. WAGES IN THE FAR EAST

Average Hourly Wages Including Supplementary Compensation (US Dollars)

	1970*	1980**
Hong Kong	0.28	1.20
Singapore	0.29	1.25
South Korea	0.33	2.00
Taiwan		0.80
Malaysia		0.60
Philippines		0.50
Indonesia		0.35
US	2.92	8.06

Source: * Chang (1971) from USITC Commission Report; ** O'Connor (1983), Table VII.15; p.339.

The Far East offered multinationals other non-wage cost-minimising opportunities. Hiring and firing costs were minimal due to the continuing influx of rural women looking for work in these underemployed economies and due to the minimal training needed for the exported jobs. The industry relied predominantly on inexperienced female labour (Froebel et al., 1980; Siegel, 1981).[39] In fact, management in many firms targeted young unmarried women, age 16 to 25, when recruiting, using them to replace "older" women workers once exhaustion and eyestrain weakened their productivity (Siegel, 1981).[40] Employers found that (at least at the beginning) the supply of this young female labour force was highly elastic: whenever more workers were needed, they were easily found, and when demand slumped, they could be released to find employment elsewhere or return to their villages.[41] The gender and cultural characteristics of the labour supply in many of these countries made industry employment adjustments to cyclical change almost costless.

Benefits and other labour-related costs, which can double the wage bill, were also minimised in the Far East (Elson and Pearson, 1980). By hiring only young, unmarried women, employers avoided costs of maternity leave and family-related absenteeism (Siegel, 1980). In addition, a number of governments actively intervened to minimise foreign capital's labour problems. Governments outlawed strikes (Philippines: O'Connor, 1983) or unions (South Korea: Siegel, 1980), subsidised dormitories to keep workers near the plant,[42] and set up Free Trade Zones surrounded by fences, enabling the lock-in or lock-out of workers during labour troubles (Froebel et al., 1980). State intervention through protective legislation was rare: firms were able to require long work days and work weeks (typically 48 to 60 hours), demand overtime with little compensation and fire problem workers (ie, low productivity or union sympathisers) without concern about worker recourse to legal rights.

Industry analysts continue to argue that women's `nimble fingers' were the central factor in generating this offshore industry (See Froebel et al., 1980; Lim, 1979). These plants typically required a very low capital investment (NACLA, 1977): pictures depicting typical plants show banks and banks of women sitting at microscopes tending to microscopic assembly. The tasks of assembly were complex; technologies had not yet been developed to automate them reliably. The low labour costs made these low cost, low risk and highly flexible manual operations (Froebel et al., 1980) multinational management's choice for operating in a market well-known for its dramatic and unpredictable booms and busts.

The development of microelectronics multinationals in the Far East was a unique form of internationalisation. Traditional foreign direct investment typically led to setting up facilities to extract raw materials from resource-rich economies or to manufacture complete products that would replace exports from the home-base economy. The semiconductor and computer investments in the Far East were primarily part-process plants that shipped output back to the US or third markets. They were facilities that were tightly integrated into a multinational production and distribution schedule.

This global division of labour, dispersing labour-intensive manual operations to low-wage economies while keeping R&D and advanced manufacturing in the US, was tremendously successful.[43] For many generations of chips and years of computer production, it reduced costs of the still necessary manual labour activities (Borrus et al, 1983), maximised corporate flexibility, nourished unparalleled market growth and increased profits for US firms in the 1970's. In fact, these spatial cost-cutting strategies remained intact even though labour costs (particularly semi-skilled labour costs) were shrinking as a share of total costs.[44] Though capital requirements and costs grew rapidly toward the end of the 1970's, multinational management seemed more willing to use international wage and income differentials to cut production labour costs than to attack costs closer to home.[45] While this structural disintegration of production succeeded in the competitive and technological conditions of the time, this view of the global structure of the industry continues to dominate analyses of the industry in the much different competitive conditions of the 1980s.

4.4.3 US Microelectronics Firms in Europe

US corporate investment in Europe differed dramatically from multinational expansion into low-wage Third World countries because of Europe's higher standard of living and more sophisticated customers. US computer firms began investing in Europe shortly after World War II, particularly to win sales from government agencies, then the major buyers of computer systems.[46] US computer firms set up in Europe to qualify for the baldly nationalist preferential purchasing policies[47] and to meet the very specific technical requirements of many European countries. Germany, Britain and, to a lesser extent, France, were key locations because they were the largest and most technically sophisticated markets in Europe throughout the 1970's (USITC, 1979). In addition, a number of European countries actively supported the development of a national firm in the computer industry to provide public control over a strategic industry. Many US multinationals located manufacturing in Europe to maintain close contact both with these state-subsidised competitors (eg, ICL, LTd in the UK, CII-Bull in France and Olivetti in Italy) and their markets (House of Commons, 1973; Hu, 1973). In some cases, firms, most notably IBM, established software development centres in England to tap the ideas of the region's high tech engineers.

Major chip manufacturers also began locating in Europe in the late 1960's and early 1970's for the same reasons (Hood and Young, 1984; Scibberas, 1979; Hu, 1971); the aim was to supply both US and European computer firms in a region that did not have a large, well-established chip industry. While many firms first entered Europe as sales and marketing organisations, manufacturing capacity proved necessary to gain military, telecoms and other government contracts.[48] Also the 10% to 17% duty on imports imposed by the formation of the EEC in the late 1960s encouraged manufacturing inside the region for price-sensitive products.[49]

The production technologies were by all accounts relatively mature (USITC, 1979) and produced well established products developed and designed in the US, usually from the more sophisticated offerings of the corporate product line. US computer multinationals assembled the central processing unit and some peripherals within the EEC - monitors, keyboards, printers, etc. However, extremely labour-intensive work for computers and semi-conductors (for example, winding core memories for computers and assembling and packaging chips) was shipped to the Far East and reimported under the lesser duty (10%).

US multinational investment in Europe in the 1960's and 1970's, then, was very different in economic motivation and structure from that in the Far East. However, European subsidiaries for the most part produced mature US-designed products with long-established manufacturing technologies, thus fitting the `branch plant' model (Hood and Young, 1975; 1983).

4.5 THE CRISIS OF CAPITAL ACCUMULATION AND INDUSTRIAL CHANGE

Tensions within both industries built up during the 1970's and broke loose first in the semiconductor industry about 1980. The industry's past success in riding out serious economic storms - usually by waiting, closing down capacity or announcing redundancies - was no longer a viable response by the time of the 1981-2 recession. New factors and the increased severity of existing tensions aggravated the situation.

Companies in both industries were being ferociously squeezed on both the cost and price fronts. Due to the pace of technological change and the increasing complexity of product and production technologies, the two sectors faced rapidly rising capital and development costs and short and uncertain sales lives for their products. Firms also faced greater and greater competition from new products and new producers. This aggravated the downward pressure on prices and frustrated producers' potential to gain volume sales. These factors were squeezing profit margins even for leading firms.[50]

Industry analysts and academics recognised fundamental changes in the economics of the microelectronics industries:

> "Many companies are gradually becoming aware that a shift is taking place in the fundamental rules of the semiconductor game and are uncertain how to cope with it. Their anxiety is all the greater because they themselves invented the original rules." (DeJonquieres, 1980D)

> "The shape of the semiconductor industry is changing nearly as fast as the market is growing." (*Economist*, 1984)

> "..[T]he semiconductor industry is at a turning point in its development, a point at which its structure and competitive success in the industry will both be determined by a struggle *over changes in the economics and hence the strategies of production in the industry* [emphasis in original]." (Borrus, 1983; p.5)

> "There is also the concern that the [high tech electronics] industry may be entering more than just a patch of short-term difficulty and is confronted with fundamental structural problems." Investors had begun to shy away from electronics as a result, according to industry expert Guy DeJonquieres (1985).

> "The complexion of the global computer

> industry and the nature of competition has changed noticeably [in the 1980s] with the trend toward smaller-scale [product] systems." (O'Connor, 1985; p.316)

While many had romantically characterised these industries as technologically-driven (eg, Mowery, 1982), a technological innovation would not have solved the problems of the early 1980s. The situation clearly spotlighted the inseparability of the economic and the technological dynamics of these industries. This section outlines the causes of the international crisis. The text assesses the major economic shifts in detail - the increasing competition, both by Japanese firms and the proliferation of new products that brought in new competitors; the shift in market demand to more highly customised and better quality products; and the escalating development and production costs. The chapter then reviews the resulting shifts in management strategy and the importance of the European market in industry adjustment.

4.5.1 Growing Competition

The Japanese Challenge

Increased competition for US firms came from different directions. Japanese firms, previously focused on the Japanese market, became a major contender in world markets. New products introduced in both industries altered the size and nature of the competitive field.

Japanese producers significantly altered both the line-up in the competitive battle and the rules of the competition in both sectors by the early 1980's. The Japanese had largely been discounted by the US industry. They had sold low-end, often mature products in the US for years. While US producers leaped ahead to invest in the next product generation, US industry experts snobbishly accused Japanese firms of being unable to do more than mimic the technological innovations achieved by US market leaders. However, during the late 1970's Japanese products gained a reputation for quality and reliability achieved through their strategy of continually investing in the most advanced production methods.

In the late 1970's the Japanese took advantage of the ic boom in the US and the unit cost advantage provided by their highly automated production technologies (Borrus et al., 1983). They exported vast quantities of the then current generation of memories at prices that were lower than most US firms. In 1979 alone Japanese ic exports to the US swelled from $250 million to $365 million. By 1982 Japanese ic sales in the US were valued at $560 million (SIA, 1983). While US firms claimed that Japan was "dumping," US producers had to meet that lower price or lose sales and market share.[51]

A second event was important in the changing competitive climate. US end-user firms, led by an announcement by Hewlett-Packard in 1979, claimed that Japanese devices were superior in quality and reliability to those of US producers. Due to competitive pressures to eliminate defects, they claimed they would buy Japanese ics, ignoring the "Buy American" plea of the US electronics industry. Spokesmen explained that US chips were not satisfactorily tested and they had been receiving what had become an unacceptably high rate of defects per shipment.

Cheaper and better Japanese chips gained in the US and world markets as a result. By 1983 Japan produced 37% of the world's chips (Financial Times, 1984B) and controlled 70% of the world market in the newest chip - the 64K RAM (Thackray, 1983): "They [the Japanese] have irrevocably changed the [ic] memory business." (Keyhoe, 1982D).

In computers, Japanese producers were also gaining attention - if not so dramatically - by supplying technically competent, competitively-priced machines. They usually started by supplying low-end equipment to avoid head-on competition with IBM and the rest of the BUNCH and enhanced the product line over time. As mentioned above, they operated in the US market predominantly as Original Equipment Manufacturers (OEM: ie producing for US firms which would sell them under their own brand name); as a result, their presence in the US market was largely hidden. This dependence on Japanese products increased dramatically in the late 1970's because US management needed to have a wide product range to satisfy the market and wanted to avoid the high expense and risk of investing in the necessary production capacity. Japanese firms gained US and world market share covertly through OEM arrangements.

A Widened Product Market

At the same time, new products and existing products with enhanced commercial potential crowded the market further threatening growth potential and market share of US firms. In the computer industry the challenge of the mini and the microcomputer to the mainframe and the conventional organisation of computing capacity deepened. The technological capability and power of both the mini and the micro increased and market demand increasingly turned to equipment for decentralised data processing (Financial Times, 1980). Simultaneously, the introduction of and love-at-first-sight market response to the microcomputer shook the foundations of the industry. In semi-conductors, special order or so-called custom and semi-custom,[52] chips gained market share by satisfying new market demand for application-specific ics (ASICs) rather than standardised products.

The growth and consolidation of the mini market by the early 1980's represented the aggravation of an endemic problem in the computer industry. The industry's continuing to provide commodities with greater power at a lower price forced firms to seek ever larger markets. As Duncan (1981) lucidly explained,

> "Greater power for less price, called increased price/performance ratio, means that the turnover, let alone profit, generated by the same total

> power of the new system will be lower than the old one. To withstand the erosion of the existing customer base, vendors must offer a price/performance ratio generally in line with the industry, determined by the market leader in that sector - IBM in the case of mainframes, DEC in the case of minis and the three personal computer vendors in the case of micros [ie, Apple, Tandy and Compaq]. The price/performance curve is, however, dropping faster than the expansion in demand from existing customers in the vendor's portfolio - leaving a gap which has to be filled by higher volumes of production and sales, reinforcing the process of competition between the companies for a larger market share." (p.89)

The acceptance of the minicomputer, particularly as it became more powerful and more versatile, threatened the future growth of mainframe sales and the existing customer base of IBM and the BUNCH. However, the mini was also a new unexploited market that had a significantly higher growth potential than the mainframe business. All the established computer firms jumped into this market.[53]

The introduction of the micro sent another shock wave through the industry. This new machine, defined as a desktop system costing less than $8000 (Coffey, 1982), tapped an entirely new and very large market of upper income professionals wanting to continue work at home. They also offered business an even cheaper option than minis for tailored, distributed data processing (Cane,1983C), and this was the major growth segment for the early 1980's (Barclays Review, 1983).

The micro was essentially a good design for the assembly of standard components: producing them required little front-end investment. These low barriers to entry meant practically any one could produce them.[54] With their standardised inputs, they leant themselves to mass production.

This was a major change. The computer industry up to this point had been essentially a small batch production industry. Firms had in some cases achieved economies of scale mainly in peripheral manufacture and by constructing capabilities with fairly standardised building sub-assemblies that were tied together to fulfill a customer's requirements. Marketing had been the key to improving revenues and profits: firms sought new markets for their products and tailored systems carefully to those uses.

The micro, in effect, challenged all the established marketing and production strategies of the industry. The marketing and sales networks for micros were quite different from the extremely large and expensive machines in everything from targeting sales to the right personnel in a business to the primary selling features. Price in particular became much more important. Volume production techniques created the conditions for lively competition over price. This economic dynamic was not, however, restricted to the micro segment. Because of the rapid technological improvements in computer capability, micros threatened to encroach on the minicomputer market[55]: the capability of the small machines was approaching that of the larger one and was a less expensive, more flexible alternative. As Table 4.10 indicates, micros rapidly gained dominance in computer sales. This new competition threatened to pull the industry price/performance ratio down even further. As the analysts quoted below testify, the computer industry was in upheaval again.

> "The principle impact of micro-miniaturization has been the downscaling of systems with functionally equivalent performance characteristics. This has resulted in a steady improvement in the price/performance ratios of computer systems...The result [of chip advances] has been the appearance on the market of successive generations of computers, each of which consists of machines that are smaller, more powerful and versatile, and less expensive than their predecessors. State-of-the-art supermicros, for example, are not only more advanced than earlier micros, but also rival in performance minicomputers and

certain medium-scale mainframes."
(O'Connor, 1985; p.312)

"In 1981,...the momentum of expanding a customer base that provides future growth passed from the mini to the micro vendors." (Coffey, 1982).

TABLE 4.10. THE EMERGING DOMINANCE OF SMALL COMPUTER SYSTEMS

	1978	1981
Value of Large Computer Systems	65%	35%
Value of Small and Micro Systems	35%	61% (sic)
Total Sales	$33 Billion	$61 Billion

Source: Info Corp, published in Raymond Snoddy, (1983).

In the semi-conductor industry, the market for customised chips (ASICs) grew rapidly, stimulated by the explosion and diversity of micro-electronics applications. More successful computerisation of the design process shortened the design time and cost of ASICs, making them commercially feasible. Also, their marketability improved because one customised chip can replace many standardised chips, both improving end-product performance and reducing component and manufacturing costs.[56] Design and manufacturing technologies made it possible to mass produce ASICs.[57] This variable mass production enabled a producer to deliver a chip to a customer in as little as 16 weeks (1982: Williams, 1982A) in contrast to more than a year for a fully customised chip. In the fast-paced computer market, the faster turnaround time gave computer firms a new advantage in jumping in and capturing a market quickly. Experts expected that ASICs would capture as much as 40% of the world market by 1990, expanding from 10% in 1984 (Keyhoe, 1984B). The customised product brings with it a different production economics.

Established volume producers in the semi-conductor industry did not immediately jump into the small batch custom market. Management in these firms focused their strategies on coping with the relentless pace of technological competition and the growth of their traditional markets. A number of relatively small firms opened to fill the gap.[58] The economics of survival and success was different for the new competitors. Design costs dominated the costs of firms operating at low volume levels. Many of the firms opted to re-divide the stages of ic production and produced nothing but chip designs. They sub-contracted fabrication and assembly to established volume chip producers, many of whom had surplus capacity.[59] Other firms specialised in a different way: they developed software packages to enable customers to design their own chips, shifting design costs entirely to the customer.

The ASIC product and the new firms supplying them disrupted the competitive structure of the industry in two ways. First, the rather homogenous structure of firms and their strategies for competing were suddenly challenged by the new competitors with lower fixed costs and more flexible structures. Second, these new competitors seriously threatened the market base of the established volume producers. These were not just new products that would expand potential market demand: the ASIC was a technological alternative to a grouping of standardised chips, an option that many customers preferred. Volume producers saw their efforts to create and capture ever larger markets stymied by the new product. The simultaneous demand growth for micro-processors challenged the viability of a mass production strategy. Firms buying microprocessors needed to buy supporting chips and an array of programmable devices, and potentially ASICs, and they wanted to buy all their chips from the same supplier. Supplying only standardised memory chips was no longer a satisfactory strategy for maintaining a large and growing market share.

To offer customised chips, firms had to enhance their design capabilities and staffs to deal with customers and their technical requirements. To supply a wider product range required bigger and more diversified capital investment because many of the products required distinctly different production technologies. Volume producers also had to rethink market strategy: a big company either had to find enough large customers who would need many designs or to target particular end-user industries where an individual application-specific design could be sold to many customers (Borrus, 1983).[60]

As suggested throughout this discussion, these new products not only created new markets but also represented product convergence, a threat to the market base of all established semi-conductor and computer firms. With the right software and marketing, customised chips and mini and microcomputers could replace standard chips and large general purpose computers. While many of the new entrants (and some of the established firms, too) in both markets had from the beginning targeted product niches, the need for bigger sales and access to growth markets led many to leave their niches and attack other markets. This further increased the competition in both industries. Hewlett-Packard, for example, had established itself as a measuring instrument firm for the scientific, medical and engineering markets, but the cheapness of adding computing power turned their products into computers.[61] By 1984, its minis and mainframes had become major competitors to IBM in the data processing market (Interview with management at company headquarters, 1983). Similarly, other US niche producers targeted their products to the data processing and office automation markets by the early 1980's.[62] Niche strategies were often not sufficient revenue bases and management had turned to seize opportunities in larger markets.

In the chip industry, the captive producers cited above are a prime example of industry convergence. They were new competitors and their output was growing faster than that of the established merchant firms by the early 1980's.[63] Also the predictions of rapid growth of ASICs sales had convinced management in all the established volume ic firms to produce for this market; the division between the mass production and custom product markets was too limiting. The competitive field in the semi-conductor and computer industries were flooded with new competitors producing new products and new competition resulting from the declining segmentation of markets.

Service - A New Element in Market Demand

Increasingly sophisticated industrial buyers began looking beyond the product in choosing among the crowd of products and competitors in both industries. Customers in the 1980s wanted systems and wanted help in setting them up. End-users wanted to purchase products to computerise entire operations. Purchasing decisions were being directed toward equipment that allowed expansion and flexibility and toward companies that were expected to continue to support those systems.[64] The market looked to firms that could supply all the components of a system - from the least sophisticated to the most powerful technology link (DeJonquieres, 1980B).

Technical support, including applications engineering, and product servicing also became an important factor in competitive strategies and marketing. In these highly internationalised markets, that meant maintaining a far-flung servicing network to reach all existing and potential customers. Customers increasingly wanted both computers and chips to perform company-specific tasks. That meant computer and semi-conductor firms had to have sales and technical personnel products to suit those requirements and then to sort out any resulting technical problems.

The pressure to have this kind of distribution and support network favoured large multinationals over newer, small competitors because of the expense it represented.

IBM's well-known international marketing and distribution network was extremely important in the company's ability to fend off the smaller firms and dominate the micro market so quickly in the early 1980s.

However market demand for technical support and servicing forced most multinational managers to reassess global strategies, particularly in the semi-conductor industry. The world's leading producers of standard devices had to be able to approach the market as service companies by the early 1980's (Interviews with managers in California and Scotland, 1983 and 1984).[65]

4.5.2 Mounting Capital Costs

While both the number of competitors and the more sophisticated product demand were eroding the customer base of established producers, the costs of staying in competition were rising astronomically. Capital costs for production technologies and R&D and the costs of software development rose absolutely (Ernst, 1983; Markusen, 1986) and as shares of total costs with no end in sight. The ratio of high tech front-end investment to total turnover increased to 15% by the early 1980's from 10% in the 1970's - higher than in any other industrial sector (Williams, 1982B).

Capital investment grew for a number of reasons. More sophisticated, computerised production technologies were necessary to produce high quality, complex products with precision and to have the flexibility to produce a variety of products with different specifications.[66] Equipment costs rose with each product generation. A piece of optical lithography equipment for chip fabrication rose from $4000 in the early 1970's to $300,000 to $500,000 by 1983 (Interview with Silicon Valley executive). Managers argued that investment in this equipment had become a competitive necessity, particularly for US semi-conductor producers competing with the production quality of Japanese firms.

Also the R&D expense for increasingly technical products mounted dramatically in both industries. By the 1980's, "[a] central feature of high-technology industries ...[was] an apparently inexorable rise in the development costs of new products" (Rosenberg, 1982, p.284).

That is partly due to the greater complexity of products (Mowery, 1982,), thus the greater expense of the equipment and skills to design them. However, heightened competition over products also forced firms to introduce more products more often. For most companies the development period for each product was shortened and intensified. Competition had reduced one long-established computer firm's five- to six- year product development period in the 1970's to only 18 to 24 months by 1984. IBM took only 14 months to decide to produce a personal computer and to introduce it in the market in the early 1980's. Rushing R&D, however, increases costs: it means hiring additional product researchers and support staff, paying for expensive overtime hours and stretching other resources.

Furthermore, competition from the Japanese, particularly in semi-conductors, forced US firms into a burst of capital investment in the early 1980's, in spite of the costs. The Japanese had achieved their superior product quality by a strategic emphasis on production engineering, as they had done in a number of other industries. The Japanese producers invested heavily in equipment and personnel to improve their wafer yield and chip testing. Industry leader NEC, for example, invested a massive 10.2% of its 1982 sales in R&D, and most of that would have gone to process development (Garner, 1983B). Japanese firms also invested heavily in the most sophisticated production, handling and process control technologies (sometimes developing it in-house) to achieve high yields (Rose, 1982; Bruederle, 1984). That contrasted with the US producers' emphasis on introducing the next innovative product. US competitors spent on average about 5% of sales in 1982 on R&D, and most of that would have been devoted to work on new products. The focus of the Japanese industry on production engineering gave them both high quality output and lower unit costs.

> "From the very early days of their IC business, NEC has believed that cheap memory would make up for the deficiencies of software [a relative strength of the US computer market]. This led NEC to focus on the development of high density or cheap per bit [ie, unit of information] memory ICs. NEC also believed that higher reliability would result in lower overall costs. These views led to NEC's emphasis on mass production technology." (Interview with President of NEC Electronics Inc. in Corporate Times, April, 1985)

Also, in the case of Japanese firms, "[t]otal automation is the ultimate goal - an imperative for survival" (Gregory, 1984A).[67] To respond to Japanese success in US markets, US producers acknowledged that greater capital investment and attention to production economies were essential to compete in product quality and unit cost.[68] Similar pressures for improved quality and lower production costs were driving US computer firms to invest in more automated equipment. While the wage differentials between Far Eastern economies and the US had eroded slightly during the 1970's, wage costs and reducing labour costs were not the stimulus to this industry drive to automate. Higher quality performance driven by severe competition was the rationale for automation in the 1980's.

The costs for this capital investment had become exorbitant with the increasing complexity of production. The cost of capital equipment skyrocketed during the late 1970's and early 1980's: there was more than sixtyfold increase in the price tag on photolithography equipment over just two generations, as Table 4.11 shows. The estimated capital costs of a fabrication plant multiplied as the chip density and the precision necessary to produce them have increased. A plant for 16K RAM memories was $25 million; a plant equipped to produce 64K RAMs costs about

$100 million. A facility to fabricate the VLSI chips (for example, 256K RAMs) was expected to cost about $200 million (Thackray, 1983). As Business Week (1985) reported:

> "The price tag for a new chipmaking plant is climbing past the $100 million mark - 10 times the price a decade ago [1975]. The capital investment is becoming quite staggering."

TABLE 4.11. COST INCREASES FOR SUCCESSIVE GENERATIONS OF IC FABRICATION EQUIPMENT

Lithography Equipment*

	Line Width	Throughput Wafers/Hr.	Approx. Cost of Machine	Approx. Capital Requiremt. **
Contact Printing	10 microns	60	$15,000	$30,000
Projection Aligners	2 - 5	60	$240,000	$400,000
Direct-Step-on-Wafers (Wafer-steppers)	1 - 2	30	$480,000	$1.6 m
Electron Beam	0.5 - 1	6	$1.5 m	$25 m

Source: US Congress, Office of Technology Assessment (1983)
Reprinted in Ernst, 1985 (p336)

* These are successive generations of photolithography equipment that have been used to do essentially the same task with increasing precision. They expose the circuit patterns on the silicon wafer. The line widths listed above indicated their increased precision: the newer technologies have progressively reduced the line widths of each circuit path on a chip, measured by a millionth of a meter unit.

** The capital requirement estimates the expenditure on enough equipment to meet a production target of 1000 wafer starts per week.

The president of Texas Instruments claimed that an investment of between $25 and $35 billion would be necessary for the firm to maintain its market position over the ten years from 1980. That contrasts with the $4 billion spent over the previous decade (Financial Times, 1980).

The cost of entry into the microcomputer market - the segment of the computer industry with the lowest barriers to entry - similarly escalated during the early 1980's. At its inception, entering the micro market was "a comparatively cheap business to enter" (Newman, 1982; p46). By 1982/3 that had changed. Management of a UK-based micro firm, ACT Ltd. laid out the financial investment requirements for a start-up:

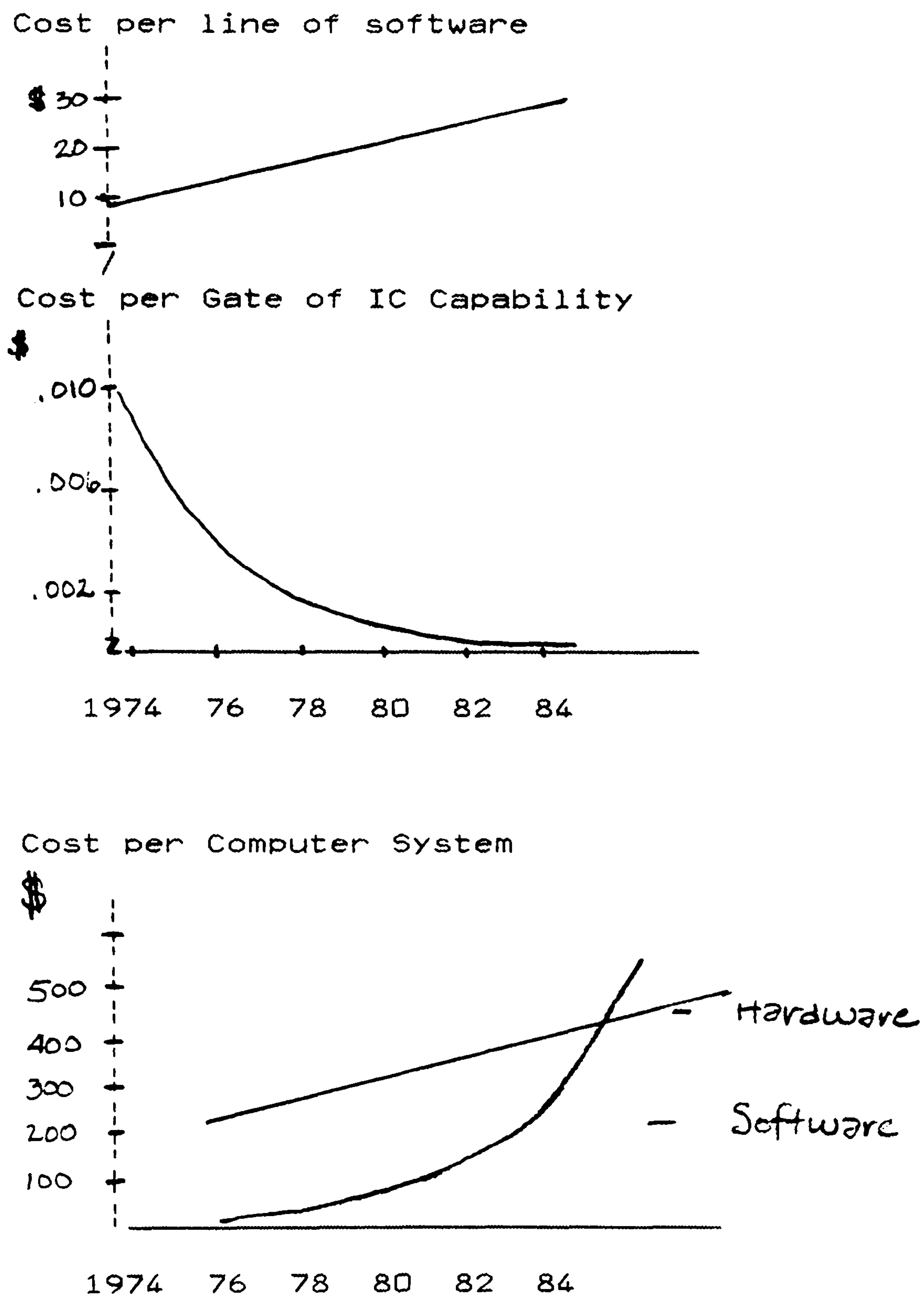
> "In the first place to be successful you have to be in the business in a big way - at least 3000 sales a month. Then you need £3 m for the company, £2 m for the increase in debtors, £2 m in factory costs, £2 m r and d costs, a £1 million software commitment and an introductory marketing effort of £1 million.
> "...You can guarantee that the cost of entry doubles every year. Two years ago, when we were developing Apricot, we needed £10 million, last year we would have needed £20 million, and if we were starting this year we would be looking at £40 million." (Danks, 1984).

He attributed the change to the growing domination and competitive muscle of the industry's market leaders, IBM and Apple Computer.

For the producers of bigger computers, a major cause of rising investment costs was the dramatic escalation of the unit cost of software. Software was a growing strategic concern in both the chip and computer industries. Software enabled a piece of hardware - chip or computer - to perform the functions that the customer demanded. Increasingly complex hardware depended on increasingly complex software. That software created more potential problems and expense for maintaining it. Industrial customers chose products at least in part by their software: they wanted to avoid buying systems that would burden the firm with great and unexpected costs for systems analysts and software engineers to adapt the system and keep it operating. The quality and appropriateness of the manufacturer's software was critical in attracting new buyers and retain existing customers.[69] Also producer firms could not design their complex products without the appropriate software. Developing the appropriate software to design and customise products became critical to making sales.[70]

The share of software development in system costs rose steadily through the 1970's and early 1980's (O'Connor, 1985; Ernst, 1983; Cane, 1981).[71,72] Figure 4.1 contrasts cost paths through the 1970's and early 1980's. Technological advances rapidly reduced the cost per function of integrated circuits, so hardware costs increased only modestly. Simultaneously, the unit cost of software relentlessly increased. The rising cost of the computer tools needed to produce software (O'Connor, 1985) and a worsening global shortage of software engineers (Ernst, 1983) accounted in large part for the rising costs. In addition, the artisan-like nature of the software production process had remained relatively intact.[73] That meant the turnaround time and the associated labour costs remained highly unpredictable and uncontrollable.

FIGURE 4.1. <u>SOFTWARE AND HARDWARE: COST COMPARISONS IN COMPUTER MANUFACTURING</u>



Source: Motorola Inc.
Reprinted in *Financial Times*,
November 3, 1980

In both the computer and semi-conductor industries, management's inability to reduce or contain the costs of the "software bottleneck" and unwillingness to scrimp on R&D or investment in particular new technologies put greater pressure on them to reduce costs in other parts of the production process.

4.5.3 The Double Bind of Uncertain Product Life and Falling Prices

The competitive pressure to maintain increasingly expensive R&D and capital investment mounted for both industries in an economic environment of rapidly falling prices and a relatively short and uncertain product life. The ability of firms to recover front-end investment costs and to reap sufficient revenues to pay for new product development was jeopardised by increasing difficulties in gaining a large market base. The shock during the late 1970's and early 1980's was the pace of change of all these factors. When US ic producers were pushing prices down through achieving learning curve economies, there was at least some measure of predictability. Japanese competition eliminated that. In the computer industry, the rapid proliferation of new products destroyed the protection niche strategies had provided from price pressures.

The Short Product Life of Microelectronics Products

A short product life was a feature of the dynamics of the US-dominated ic industry from its start. Many US firms had achieved their world leadership by their technological inventiveness and exploitation of the high (monopoly) profit period after the introduction of a new product. They then abandoned that product in two to three years to exploit a new one (USITC, 1979). The sudden increase in competition in the late 1970's threatened the firms' ability to earn enough to carry on development for the next product. The larger competitive field reduced the potential market base and the length of the product selling period.

The 64K RAM memory device was the turning point. It was an important product because it was the entry into

VLSI complexity: sales success and the associated production experience were critical to competing in the market for the next generation product. US producers faced competition from a Japanese product from the beginning. With their technology and unit cost advantages, they undercut the price of US firms. This was a surprise: in the past Japanese firms had successfully copied existing chip products and sold them in mature product markets. The Japanese firms won a significant share of the US market, and, when the ic market slumped in 1981/2, flooded the US market, further depressing the product price. By 1983/4 Japanese firms were mass producing the next product, the 256K RAM, for world markets. Their success in cutting into the US 64K memory market, along with the recession, had sharply reduced US firms' revenues: many US firms did not have capital capacity ready to compete in the 256K memory market. A number of US producers effectively surrendered that market to the Japanese by 1985 (New York Times, 1985). With the number of competitors and the basis of their competition changing rapidly, predicting the market life of the chip[74] became near impossible, as did which firms would profit from it.

Because the production technologies are so closely tied to changes in product technologies, particularly for semi-conductors, this fast pace of product introduction accelerated the pace of capital equipment obsolescence. In 1981, the average age of semi-conductor equipment was 4.4 years, a loss of half a year since 1975. (Ernst, 1983). Capital investment in fabricating a new product generation often means investing in new production facilities rather than just upgrading or replacing individual pieces of equipment. New generations require higher cleanliness standards and more precise equipment across most of the processing steps. As the market life of a product shortens or at least becomes more unpredictable, the financial risk of investing in new production capital becomes riskier and riskier with each successive product.

In the computer industry, competition - particularly in the micros and work-stations segment - similarly compressed the product life cycle. The rapid improvements in what ics could do and the fierce competition to introduce new products that would exploit those capabilities, squeezed the length and raised the uncertainties of the market life of any one product (Behr, 1985). The introduction of a new hardware product with an important technological enhancement or a better price, or even a successful software package for another firm's product can steal market share from an established product very quickly. Recognising this uncertainty, micro-computer managers set two-year targets for payback on their capital investment when launching new products (Behr, 1985).[75] The time pressure on computer capital goods, while less severe, was no less relentless. A leading edge instruments producer had to develop each new product from scratch (that is, from the new circuit technology up) around a new microprocessor introduced in 1983: that process would take about three years and would last only the few sales years of that one product generation. Formerly, a product technology was expected to last at least seven years and two or three product generations (Interview with company engineering manger, 1984).

In contrast to the industry convention for depreciating production capital over five years or more, a two-year product life can be a crippling pressure. The computer industry has more flexibility in its production technologies than the semi-conductor industry. Many firms maintained manual and semi-automatic procedures for many years to mediate the financial pressures. Labour-intensive techniques can adjust to many successive product generations. Also, the mini and mainframe have a marginally longer product life, so some protection from the relentless pace of product change. The market life of more expensive computer equipment may be three to four years (Duncan, 1981) and up to ten years with periodic additions to upgrade it (Interview with computer firm executive, 1984). Upgrading can be relatively inexpensive and easy: producers now leave room for inserting additional boards to add speed or new functions. In addition, business and the public sector, the market for expensive equipment, have slow, bureaucratic procedures for making capital investment decisions. They are unlikely to respond as rapidly as the consumer and small business markets to the introduction of each new product.[76] However, the rapid pace at which micro producers expanded the power and versatility of their products put them in direct competition with minis in the business market: this may have pushed mini manufacturers into a shorter product cycle.

Price Pressures

Unprecedented pressure on prices heightened the risks of introducing new products. Hardware prices fell in both industries due to continuing competition to improve the price/performance ratio and to create new and larger markets. Competition from Japanese producers drove prices down further.

Computer firms competed over price to create additional demand:[77] creating new applications would open up new markets as the growing number of competitors crowded the existing market bases. In the past, the price competition amongst market leaders had gradually pulled the industry price curve down (Duncan, 1981), but the price competition had not been severe, protected under IBM's relatively high price policy.

Pressures became severe in the early 1980's. This was largely because the increased power of machines all along the product range and the convergence of other technical equipment markets (eg, instrument and photocopier markets) broke down the barriers that had created protective segmented markets. In the micro segment management zealously reduced prices to make a dent on an increasingly crowded and confusing market.[78] And mini manufacturers diversified to produce a range of machines that could compete with the micros. This put direct pressure on the price of more expensive machines. The smaller machines could be connected to perform complex tasks extremely cheaply, creating a significant incentive for the market to substitute them for a mini with multiple terminals. Management of high-end machines had to resort at times to price-cutting to sell their machines in a market with lots of nearly equivalent cheaper machines.

In addition Japanese computer producers formally entered the world market in the late 1970's and early 1980's. The experience and scale economies they had gained from selling volume products to world markets under OEM arrangement gave them both quality and unit cost advantages over much of the computer industry. Their micro, mini and peripheral products sold under their own names - Toshiba, Fujitsu, Panasonic, NEC, Epson, etc. - undercut the prices on most US producers.

Rapidly falling prices more clearly defined the semi-conductor market. As explained above, learning curve strategies, as outlined above in the example of the 64K DRAM in Table 4.8, historically pushed prices of each successive generation of ic memories lower than the lowest unit price of its predecessor (O'Connor, 1983). The necessity to attract additional markets exacerbated this tendency in recent years.[79] The Japanese competition, undercutting US prices to use their surplus capacity (See discussion above), brought cuts that went far deeper than the price declines that learning-curve economics had given US producers. The industry sustained price cuts on average of 70% per bit (of information) every year from the late 1970's into the early 1980s (Thackray, 1983).[80]

For both industries the early eighties were years of a deepening vicious cycle of declining prices, additional and rising costs, and growing numbers of competitor firms and products. Gaining the greater volume sales that would have compensated for per unit losses was checked by the fast pace and extent of growth of the competition.

Inadequate revenues compelled ic firms to abandon expensive R&D ventures (eg bubble memories). Firms experienced cash flow difficulties and reduced profit margins. Some firms retrenched and some, particularly in the microcomputer sector, went out of business. Large multinational firms with their extensive corporate reserves were cushioned to some extent from the pressures.[81] Past strategies that rested simply on price-cutting or introducing a new product could no longer sustain a firm in the global high tech marketplace of the late 1970's and early 1980's.

4.6 CONCLUDING POINTS

By the early 1980's (particularly after the market downturn in 1980/1) management in US multinationals acknowledged that the changed competitive conditions and the mounting tensions for major industry competitors called for new corporate strategies. The existing organisation of production and corporate resources could no longer cope with the simultaneous and competing demands of improving product quality, customising product demand, continuing new product and process development, and finding flexible market strategies appropriate for capital-intensive production, all at a dizzying pace of change. In the past firms had traditionally adjusted the size of their work force or their capital utilisation to respond to shifts in market demand. The conditions of the late 1970's and early 1980's and the speed with which they could change made this strategy too costly. These conventional methods of adjusting (eg, major redundancies) "denied" firms opportunities to enter new markets and weakened future competitiveness.

The Role of Labour

While the analysis in this chapter has located the accelerating crisis in high tech industries in the competition between fractions of capital - US vs. Japanese corporations, multinationals vs. entrepreneurial start-up firms, labour has not been ignored. However, labour has not been an organised political force in these industries since their inception, except for a few long-established computer firms. There is little evidence to support an argument that labour has intervened to protect its interests in the organisation of production and competitive strategies in these sectors. Corporations in both industries have maintained non-union or anti-union policies internationally.[82] Active (at times insidious) corporate campaigns to suppress union organisation have worked along with the industry's shifting skill needs and structure to prevent the organisation of any formal labour opposition in all of the continents of industry operations. There have been valiant efforts to win representation and to improve working conditions, but they are isolated cases. Those unions that have been involved in the industry have proven relatively powerless to alter the course of events in this highly international and fast-paced industry.[83]

Changing labour qualities, costs and conditions of work prove critical to understanding the industry crisis and the forms of its resolution. However, these features have been shaped by demographic factors and by social/cultural and state policy responses to the explosive growth and economic importance of the industry, not by the active opposition of organised labour.

The Competitive Response: Multinational Competitive Strategies for the 1980's

One of the first efforts that managers in Silicon Valley mentioned was to locate new operations in other regions. Management felt compelled to do something to end the very costly technical labour turnover they experienced. Semi-conductor multinationals in particular were locating new fabrication plants in Colorade, Idaho, Texas, Washington, Oregon and other parts of California. They chose locations where they could find 'good people' or where the lifestyle and cost of living were sufficiently inviting that technical personnel would be willing to move.

Secondly, managers explained that the 1980's required them to target their products to markets much more closely. The strategy of the 1970's - producing relatively standardised innovative product and expecting the product itself and the marketing division to create a market for it - was no longer considered a viable approach to the large and increasingly sophisticated world marketplace. Producers targeted growth markets and large individual customers. Semi-conductor firms, for example, each targeted a few of the following end-user markets - telecoms, automotive, mini-computers, information managements systems, and robotics. Each had differing product requirements and cycles. All producers recognised the necessity to offer customised product. These priorities led to a number of changes in orientation to the market.

Custom-specific orientation meant designing products to solve particular technical and data problems that customers had. That required a much closer relationship with those markets and individual buyers. It required the producer to develop technical expertise in their industry targets and to devote time and personnel to working with the customer throughout the production cycle, even after the sale was completed. That meant a strong sales force trained in the technologies and an extensive field engineering work force to maintain contact with the market. In addition, it placed much greater importance on software development for products and for testing. Developing customised software was the prime method for turning a relatively standardised chip or a group of standardised computer modules into a product that would perform according to a customer's needs. The product then would have to be tested to perform those functions: that required tailored testing software. Management claimed that this direction was changing their firms from manufacturers into service companies.

Thirdly, the competition from the Japanese challenged US producers to concentrate resources on developing production economies. Every manager interviewed pointed to corporate efforts to economise on the use of capital and information. Top of their agenda was automation: in the semi-conductor industry, managers claimed they could not wait any longer for better perfected production technologies. Greater automation in this and in the computer industry was needed to achieve better quality and lower unit cost to compete with the proven record of Japanese producers. Japanese firms had won an important competitive battle by manufacturing 64K memories at 10 to 20% higher yield than US firms. Investing in more highly automated equipment would produce greater product uniformity and greater reliability. The custom orientation of the market made these even more critical objectives for a producer: when every single wafer or computer component is promised to a particular customer with a delivery date, succesful production scheduling demand high and predictable product quality (ie, low defect rates).

Another priority in using capital and information inputs more economically was to integrate separate stages of manufacturing. Managers emphasised the importance of computerised production equipment and software systems, designed to coordinate the different stages of production and to feed back information gained at one point to all other related steps - including design, ordering and inventory, manufacture, sales, and testing. Management's motivation for these expensive investments was

- to speed up product turnaround and to use up inventories more quickly, ("To get product out the door"),
- to improve the effectiveness of expensive production equipment through continuous production, and
- to turn information learned from the market more quickly into products and sales.

Consequently many firms had continuous, 24-hour, seven-day production weeks in many of their facilities. The aim was to use capital equipment as continuously as possible while the market for that product lasted. Developing economies of throughput, rather than of scale, took centre stage in strategic investment: the priority was to invest in capital that could flexibly manufacture a range of products smoothly and quickly. While these efforts were not without problems, management in the 1980's considered quality manufacturing targeted to market demand central.

These strategic shifts led to record investment in new, more automated and precise technologies (paired with expansion) in both industries in the years immediately after the 1981/2 slump (Financial Times, 1984B). They also stimulated management's reconsideration of the role of the individual subisidairy within the global corporation. For many of these corporations, these changes called for a more truly multinational firm. As one manager explained,

> "The first thing we're trying to do here is to be a multinational company. You can't conquer the world [market] from any one given spot."

As he went on to explain, that meant decentralising operations geographically around the world to serve the important markets more completely. He claimed that decentralisation and the resulting autonomy were critical to gaining customer confidence that a subsidiary could actually make a decision quickly and follow up on the design, delivery and support of a highly sophisticated product.

While there has been a debate about the extent to which these multinationals are automating and decentralising operations in the Far East and other global locations (See for example Russell, 1984; Ernst, 1985), this study cannot resolve that question. However, the next chapter reports the findings of the research survey among US (and one Japanese) high tech multinationals in Scotland to assess how these strategies have affected the operation of subsidiaries there. Are they still the `branch plants' that Vernon (1969), Forsyth (1972), and Hood and Young (1979) and so many others have claimed? Or have the demands of high tech markets and sophisticated technologies transformed them into a different sort of subsidiary?

CHAPTER 5: PRODUCT LIFE CYCLE THEORY AND MICROELECTRONICS MULTINATIONALS IN SCOTLAND, 1979 - 1984

5.1 INTRODUCTION

US multinational strategies to cope with the crisis of the 1980's reassessed the economic logic of the contribution of the subsidiary and its location. The necessity for firms to adjust swiftly to unpredictable market demands and to economise on the overwhelming capital costs of competing, forced management to question the value of `branch plant' subsidiaries. The US industry's overseas subsidiaries throughout the 1970's had generated huge cost savings by using cheap labour for manual assembly of mass-produced, standardised products. These production methods and the global dispersion of industry facilities could not deliver the economies necessary for the more complex and variable products of the 1980's. This chapter examines the US multinational reassessment of the role of subsidiaries in Scotland, and established a sizeable overseas concentration of microelectronics production by the end of the 1970's. Rather than disinvestment, US multinational management allocated to these subsidiaries the responsibility for capturing the European market, and as a result dramatically enhanced the technology investments in and autonomous of these plants.

The chapter has three sections. The first reviews the the history of foreign direct investment by micro-electronics multinationals in Scotland. The next section summarises survey findings on changes in the industry's investment in the region. That section includes an assessment of the reasons why Scotland serves as a focus of corporate, strategic response. The last section explores the implications for the theory of multinational corporations.

There was one Japanese multinational corporation in the survey. The strategic priorities and changes in this firm during the study period provide a useful contrast to the sample of US firms: this firm revealed some of the important features of the current and future threat to US markets and competitiveness. Inclusion of the findings from this provide a context for the developments in US multinational firms, which are reviewed in this and the next chapter.

5.2 THE HISTORY OF FOREIGN DIRECT INVESTMENT IN ELECTRONICS IN SCOTLAND

The electronics industry in Scotland developed in the midst of the ruin of the region's traditional industries - coalmining, shipbuilding, steel and heavy engineering, all now `sunset' sectors. The region had lost more than 200,000 jobs in the decade since 1975, and one-third of its manufacturing employment (Meredith, 1985A). In the midst of this industrial collapse, "One of the most powerful concentrations of electronics companies in Europe" (Financial Times, 1985) developed in Scotland. The industry grew to include three hundred or more firms,[1] employing about 42,500 people (Rosie, 1984), and represented an investment in new facilities of approximately £500 million (1984 prices) between 1978/79 and 1984 (SDA, 1983A; 1983B; Faux, 1984).

> "...[E]lectronics presently stands as Scotland's principle growth industry and a source of considerable hope for the future." (McDermott, 1979)

As such, regional economic policy had prioritised the growth and development of the industry.[2]

Though the area originally had a wide variety of electronics firms during the study period, `Silicon Glen' developed predominantly around `high tech' or micro-electronics (Johnstone, 1983). The region's producers supplied 79% of the UK's integrated circuit market and 21% of Europe's (Guardian, 1984) and represent the largest concentration of semi-conductor manufacturing outside the US and Japan. Firms in the region produced 100,000 personal (micro) computers in 1984 and were expected to fill fifty percent of UK demand for micros in 1985 and (forecast before the 1985 slump) to manufacture more than 1.75 million micro computers by 1988 (Interviews with SDA official and Andrew Hargrave, industry expert, April and August, 1984). In fact, Scotland had the highest per capita output in the world of both home computers (British Business, 1984) and integrated circuits - five per person per week in 1984, forecast to increase to 12 1/2 by 1986 (DeJonquieres, 1985C).

The corporate contributors to this growth were major actors in the world high tech market place: ten of the world's top 50 information technology corporations (Financial Times, 1981) have manufacturing facilities in Scotland, as do three of the top four market shareholders in the semi-conductor industry (O'Connor, 1983, p.131). Many of them were world leaders in sales and profits growth in their main product markets during the first half of the 1980's (Electronics Business, 1986). [See Appendix 1 for profiles of survey firms.]

Scotland had long been a site for multinational manufacturing investment. Foreign direct investment expanded during the 1970's (Forsyth, 1972; Firn, 1975): foreign-owned firms accounted for 16% of the region's manufacturing employment in 1979, in contrast to 89% in 1964. The portion of net manufacturing output produced by the foreign sector also increased, from 15.6% (1973) to 20.5% (1979) (Young, 1984, p.96). Foreign direct investment in Scotland was particularly concentrated in the more resilient industries of the 1970's - instrument, electrical/electronic and mechanical engineering (Hood and Young, 1980).

Multinational participation in the electronics industry has been more pronounced than in other industries in the region (McDermott, 1979). By 1978 22% of the industry's firms were US corporations, employing 41% of the industry's labor force (BAH, 1979). By 1983, US corporations, a small proportion of the industry's firms (13%) still controlled 41% of the industry's employment (SDA survey, reported in Firn and Roberts, 1984, Table 9.3).

US electronics firms began investing in Scotland around 1950 when the technology was actually electro-mechanical. By the 1960's major firms such as IBM, Burroughs, and Honeywell were manufacturing typewriters and accounting machines. Also Hughes had set up a plant producing diodes. A second wave of new US corporate start-ups invested in Scotland in the late 1960's to take advantage of the high and immediately realisable grant levels - 45% of capital investment - then available in the region (BAH, 1979; Dunning, 1973). Scotland served as their 'port of entry' to Europe - the overseas production site set up to get to know the relatively homogenous European market (Hood, Reeves, and Young, 1981; Hood and Young, 1980).

The production technologies and the organisational structure of these plants fit the models of Vernon's product life cycle. They were simply "foreign production centres" (McDermott, 1979), using mature technologies to convert and second-source US products for the UK and EEC markets (Scibberas, 1977; USITC, 1979; BAH, 1979). The plants had few sourcing linkages within the regional economy, manufacturing or importing most of the needed inputs (Forsyth, 1972; McDermott, 1979; House of Commons, 1980). Production operations were predominantly labor-intensive assembly and test. The US firms tended to employ proportionately more women than do indigenous firms (Forsyth, 1972; Scibberas, 1977), creating many 'semi-skilled' jobs for women (Firn, 1975A; House of Commons, 1973) in the midst of the high and rising male unemployment in the traditional industries.

As predicted in the product-life-cycle model, the role of these plants was import substitution using production techniques that had been extensively used by the corporation in the home base economy.

In keeping with Vernon's theory, there were layoffs and closures amongst the US multinationals in the region in the 1970's as mature product markets collapsed. 'Industrial menopause', as Hood and Young (1977) called it, caused many US multinationals to retrench local operations: the subsidiaries had not updated their product lines or production techniques, which either run their course or faced unbeatable competition from newly industrialised economies.

> "As a result Scotland...entered the latter half of the 1970s vying with the Mezzogiorno of Italy as the least competitive manufacturing region in the whole of Europe." (Hood and Young, 1977)

State policy targeted overseas electronics firms as early as the 1950's for regional developement. In 1954, the UK Ministry of Supply identified electronics as a strategically important source of growth for the Scottish economy (McDermott, 1976). The `growth centre' concept further underlined the official objective of developing the electronics industry to build a long-term self-sustaining growth (Firn, 1973). State preferential purchasing from firms producing in the UK further supported this effort. This policy required any electronics firms wanting access to government agencies, large technologically-sophisticated buyers, to establish an import-substitution facility in the UK.[3] (Scibberas, 1977).

Later, state policy directed firms to more capital-intensive investment (through the Industry Acts of 1966 and 1972) and to regions of high unemployment. Successive governments altered the levels of and balance between automatic and selective financial incentives and aid that benefitted Scotland, much of which was designated as an Assisted Area. The Government also subsidised construction of advance factories on industrial estates and in New Towns.

The regional electronics industry dominated by US multinationals did not generate unambiguous growth and benefits during the 1970's. Industry employment dipped severely in the mid-seventies (a fact only recently discovered due to the very poor employment statistics kept at the regional level), resulting from the change-over to truly electronic products and processes. By 1979 the region's industry was again growing: the five-year period of this study, 1979 - 1984, was one of significant growth, as Table 5.1 shows.

TABLE 5.1. EMPLOYMENT IN THE SCOTTISH ELECTRONICS INDUSTRY

1970	48,258
1975	38,700
1978	34,300
1981	37,628
1983	41,500
1984	42,500

Sources: SDA, 1979; McCrone, 1983; Young, 1983.

NB: These data, taken from different sources, are not strictly comparable; they offer only a rough indicator of employment change in the region.

Industry contraction in the 1970's persuaded the SDA to commission a study to determine future employment potential in the region's industry (BAH, 1979). At that time they found no evidence to indicate that the established multinationals had any plans for expanding operations in Scotland. In fact managers expressed hesitancy about the future of their plants, citing the importance of shorter product cycles, the rapid pace of technological change, exchange rate fluctuations, corporate consolidation in the home base economy and the primacy of reducing costs.

The Impact of Changed Market Conditions

Much of the academic literature presumed that any investment by the industry's multinationals would continue to follow the pattern of the recent past - transferring mature technologies to global subsidiaries whether for import substitution or for export platform production. This analysis of the use and organisation of the technologies within the production unit and within the corporation is entirely ahistorical. The rapid and drastic changes in technologies and markets pressured multinational management to fundamentally reconsider their investment strategies. Amongst other factors, management in US semi-conductor firms realised they had to respond to the Japanese producers' rapid domination of the US and world 64K integrated circuit markets (New York Times, 1985), and US computer firms had to compete with the vibrancy shown by the UK computer industry. US producers refocused their efforts to improve product quality to regain customers and to press forward with investment in more automated equipment (Interviews with managers in Silicon Valley).

These factors prompted management to reassess the shape and role of corporate global operations; these reassessments were then reflected in capitalisation projects globally. Scotland seems to have gained pride of place in corporate global realignments. From 1980 to 1984 multinational semi-conductor and computer firms invested £540.9 m pounds in 1984 prices (Rosie, 1984). That included three new start-ups and expansions in six already established firms. Four of those firms expanded twice during the study period. Further investment plans were announced subsequently - a major expansion by one of the start-ups, an established multinational corporation opening a new facility in a separate location within the region, and five additional firms planning to establish manufacturing plants in 1984-86.

5.3 SURVEY FINDINGS

Most of the fourteen survey multinationals[4] invested heavily in their Scotland subsidiaries during the study period. While many analysts assumed the investments were simply expansions of mature mass production capabilities, these investments were, in fact, transforming the plants into more highly automated, more integrated very modern facilities. The criteria considered important in assessing the industry's development included decisions about new investment, including the newness of the technologies, the integration of formerly discrete, dispersed production stages, and the allocation of new products and geographic market responsibilities. The discussion below outlines this transformation.

5.3.1 New Investments in the Subsidiary in Scotland

During the years 1979-1984 at least eight of the eleven established semi-conductor and computer firms invested significantly in their Scottish plants. Almost all of those investments were in new capital equipment and in expanded production capacity. Seven of those eight expanded more than once during the five years since 1978/9. In addition three new firms, one of them Japanese, started up in these sectors during the study period. In each case, the firms invested steadily throughout the period. The Japanese firm had begun a major second phase of capital expansion during the period.

Investment in all of the survey firms was directed to automating existing and new production processes. Every single semi-conductor and computer firm had recently invested in automated equipment to eliminate some of the manual operations in production. In some cases, management had announced more than one infusion of capital during the 1979 through 1984 period. These investments financed additions and new facilities, not simply capital replacement.

Many of the investments, particularly in the semi-conductor industry, doubled and tripled the size of the subsidiary in Scotland, as Table 5.2 indicates. National Semiconductor began a £100 million expansion (in 1984) which, when complete, would double its square footage and 1983 site employment. That followed an expansion in 1980 that had doubled employment. These expansions made the Greenock plant the corporation's largest site outside the US. Motorola, making the single largest investment in the region, increased plant size by 67% with an employment projection that was 163% over the 1978 level. General Instruments concentrated its corporate productive capacity in one particular chip technology in the Scotland plant with a staged succession of advanced fabrication wings. These investments doubled plant size by 1983 (SDA, 1983A), and tripled output capability.

TABLE 5.2. SEMI-CONDUCTOR INDUSTRY EXPANSIONS IN SCOTLAND

FIRM	FACILITY SIZE ('000 SQ. FT) CURRENT	PROJECTED	COST OF INVESTMENT (£m.)
Motorola	150	250	60
National Semiconductor	150	300	45
NEC	60	180	40
General Instrument	40	80	42.5
Hughes	60	92	1 (Est)
Burr-Brown	35	75	25

SOURCE: SDA, (1983A).

5.3.2 Investment in Automation

The semi-conductor firms had introduced automated equipment in every phase of chip production, but fabrication was a key target. All the survey firms had had fabrications before 1979, mostly for devises at the low end of the market. Chips were sent to the Far East for assembly and in many cases back to Scotland for final testing. The new equipment regulated and increased the speed of production and increased the precision of process control by eliminating handling.

Most firms automated the following steps in fabrication processing in the Scotland plant in the early 1980's:

--mask alignment and photolithography;[5]

--new equipment that amalgamated individual tasks, reducing the transfer of wafers between steps;[6] and

--automated transportation of wafers between processing work stations to further reduce human handling.

The investments in automated transport were still partial: most firms had installed equipment that loaded and unloaded wafers automatically at each processing step. Also they had invested in equipment that amalgamated processing stages further reducing transfer of wafers. Only one firm had installed robots to eliminate human handling. However, a number of managers in the region's largest plants indicated that they were participating in a global race to develop completely automated transfer of wafers and chips throughout production. One technical manager claimed he would install a completely automated transport system in the plant in Scotland by 1986.[7] All of the more automated techniques discussed above were introduced primarily to protect the investment in working capital - the unfinished chips.

In the computer industry, assembly was the primary target of automation. All of the plants had, in the past, used some sort of partly-automatic insertion equipment to put some chips onto printed circuit boards.[8] During the study period, three of the plants fully automated the insertion of at least 95% of the component chips, leaving only a few odd-shaped components (eg resistors) to be inserted manually. The programming difficulties for equipment dealing with various sized inputs had delayed this achievement in automation until 1983 and 1984.[9,10] Also, most firms had installed fully automatic flow solder machines,[11] fully automatic forming machines (to shape components to the required specifications) and automatic machines to drill holes for the components, all replacing machines that required operators to load, adjust, and uload the part-products.

While many of these investments in automation in both industries focused on reducing wastage of variable capital due to defects, managers were also keenly concerned with ensuring only high quality, products went out the door, that delivery to customers was fast and dependable and that capital equipment was used as efficiently as possible.[12]

Consequently, investing in more automated testing equipment was a high priority in both semi-conductor and computer firms. Managers in two of the four fully operative semi-conductor plants stressed that slowness in testing had become the biggest bottleneck at their plants. All of the survey firms had invested heavily at least since 1979 in automatic testing equipment. Newer automated test equipment (ATE) could test many more functions or parameters more precisely and faster. Those improvements were important given that, in the semi-conductor industry, a microprocessor in the mid 1980's might have required 500,000 individual tests. While test equipment was computerised and automated to some extent many years ago, managers claimed that they had stepped up the investment rate in recent years to have equipment that could test increasingly complex chips and computers. They were upgrading and replacing final test equipment in order to test the product more rigourously as it progressed through production. The semi-conductor market leaders in Scotland were replacing test equipment every two or three years, with each new piece of test equipment costing from $75,000 to $1m. The manager of only one firm admitted to using less than up-to-date test equipment. His firm produced a much less sophisticated chip for the consumer electronics market, allowing a less aggressive technology policy. Computer firms were able to modernise their test equipment without replacing it by adding new circuit boards and additional peripherals. These "kickers" enabled computer firms to respond incrementally to some of the technological changes in computer capability: firms could compete technologically with the same test equipment for five to ten years. In all cases, a firm's purchase of new ATE equipment was state-of-the-art technology.[13]

Speeding up throughput was a major reason for investing in other state-of-the-art technologies in both industries. Two semi-conductor firms had begun capital investment in 1984 to produce 6" wafers in the Scotland facility while the industry standard was still 4" and 5". This change required both an investment in state-of-the-art equipment in the preliminary steps of wafer fabrication (eg photolithography) and investment in more sensitive equipment in subsequent processes, because the larger wafer was more prone to breakage. The National Semiconductor facility was to be the first in the corporation to produce 6" wafers, and the subsidiary was given responsibility for selecting and installing the equipment.[14] The leap to a larger wafer meant producing potentially 1000 more chips than was possible on a 4" wafer, or a 100% increase in output per wafer. The Japanese firm's decision to invest in robots (to load chips onto boards and into furnaces) was in large part, to speed up turnaround time. While the corporation had used robots at other production sites, a manager claimed this was the corporation's most advanced installation to date.

While determining the modernity of equipment was not possible, publicly available information indicates that at least three of the semi-conductor firms and one computer firm had invested in equipment to produce the next generation of VLSI chips, which demanded state-of-the art technology The Japanese semi-conductor firm, following a strategy of incremental technology improvement, was building a facility in Scotland more advanced than its plant in Roseville, California, considered the most advanced facility in the world (Ernst, 1983). In the computer industry, IBM, a world leader in factory automation, had annouced that the plant in Scotland was its most adventurous effort in manufacturing automation to date. The survey evidence suggests that in many other cases investments in Scotland in the early 1980's were in state-of-the-art technologies. In other firms, managers indicated that production in Scotland had been significantly automated over the past few years, that there were extensive plans for further automation and that there was no longer an economic rationale for investing in anything but the newest technologies. Across the board, the Scottish subsidiaries with good market expectations were using every available opportunity to automate with the most advanced equipment available.

5.3.3 Integrating Production Processes

The subsidiaries in Scotland were also investing heavily in integrating the disparate steps of production. They were designing and implementing systems that co-ordinated processes, and they were investing in capital equipment that incorporated steps that had formerly been located elsewhere in their global networks. The objectives of both computer-integrated-manufacture (CIM) and fully integrated processing were to speed up turnaround for nearby customers and to apply as rapidly as possible every bit of market information that might improve both equipment performance and sales. Investing in continuous processing was considered important in exploiting their capital and information inputs to the fullest.

CIM, the automation of predominantly information-based tasks in production, had become a major point of competition among producers. Managers all emphasised their efforts to incorporate computers into production both to control individual pieces of equipment and to `tie' separate machines and processes together.

All survey firms in the study had installed computerised systems for monitoring material inputs and work-in-progress. Software systems like MRP (Management Resource Planning) monitored production supplies when once delivered on-site, ordered new supplies automatically and reduced paperwork on the shop floor. Some had purchased off-the-shelf systems. However, Hewlett-Packard and IBM developed systems for their own uses, then marketed them to industry. These systems replaced the informal or slow communications between the administrative offices and the shopfloor. They were designed to co-ordinate information so that inventory was not held unnecessarily long and that additional supplies would be on-site and available when needed. Management had been won over by `just-in-time' production scheduling: supplies arrive and are delivered to a work station only when it is ready. Particularly important in computer firms, these systems were often accompanied by automated warehousing, including robotic transport for supplies. This organisation can dramatically reduce the cost of inventories and uses more equipment more efficiently because it never stands to idle.[15,16] Computerised systems also allow the managing director or shopfloor supervisors to monitor the production status of any order at any time.

At least four (and probably more) firms had set up `islands of automation' coordinating the operation of a number of contiguous machines.[17] These were state-of-the-art first steps om the complete computer integration of the plant, the aim of most managers. Islands of automation are clusters of adjacent and different production operations where "dense arrangements of computer-controlled machinery is coordinated so that manual intervention is kept to a minimum" (Marsh, 1984). In one of the survey semi-conductor firms, for example, one manager had `married' a number of machines in the early, repetitious stages of fabrication so that the processing steps were automatically scheduled. This means one machine `talks' to the others to determine which is ready to receive a batch for processing and an automatic tracking system takes the batch to that work station. Flexibility is a primary aim of extensive computerisation. The entire cluster can be adjusted to manufacture together a changing range of product sizes, shapes and specifications. New products can be produced by reprogramming, rather than retooling.

Management in all the leading firms emphasised that they had committed staff and resources at the facility in Scotland to moving closer toward complete automation. Because of the extraordinary complexities and unexpected problems of such an undertaking, this will take time.

Management in one firm had a ten-year plan (beginning in 1979) to establish a completely automated computer production facility (`floating' an input to the first workstation at the right time, then on to the next, all the way through packing, labelling and shipping). Managers in three others explained that they first needed a little experience with the new equipment: they expected to attempt full automation within one year of the interview.

Managers explained that work on these systems was as advanced in Scotland as anywhere else in the industry. All of the firms employed (and some trained) manufacturing software engineers on-site for this work,[18] though in some cases experienced specialists were on contract from the parent corporation. In this, the Japanese firm's strategic emphasis on incremental technological development was widely accepted. By learning from the new system, technical personnel improve computer capabilities in the next installation. As the most recent investment for many of these firms, their efforts at computer integration and flexible manufacturing in Scotland were their corporation's most advanced.[19]

Managers in all the semi-conductor firms were more consistently committed to CIM investments in Scotland than in the computer industry. By contrast, only two of the seven survey computer firms were developing extensive CIM systems. Both firms produced fairly standardised, low-end products, which makes integration easier.

The point of CIM is essentially to capture and exploit market information as rapidly and efficiently as possible and to shorten throughput time. (See for example, Wilkins, 1984.) New information about customer specifications when programmed into flexible systems will, in principle, produce the needed customised product quickly. The economic drive to improve these information feedback systems was associated with management interest in bringing successive stages of production together.

Backward Integration

To link manufacturing stages by computer required bringing production stages together in Scotland that had formerly been dispersed around the world. In a number of cases, this consolidation of production was part of global corporate restructuring that brought `backend' activities, eg chip assembly, to Scotland. Incorporating these separated activities enabled firms to coordinate production more effectively with the demands of the market and to meet new economic pressures. Four of the seven semi-conductor firms in the study (as well as a new multinational entrant) built highly automated assembly and packaging facilities in Scotland between 1983 and 1984. In the computer industry IBM, a firm that had historically relied on a widely dispersed global network of standardised component production sites, had designed its new facility in Scotland to manufacture the entire personal computer.[20] However, the other established computer firms in the survey had always manufactured the entire computer system in Scotland because their products - predominantly mini-computers - are not standardised as is a micro-computer. However, these firm did not attempt to integrate manufacture of peripherals into the Scotland operations because there was no compelling reason to produce standard keyboards, printers, etc., on site. (In fact at least two firms had recently relocated peripheral production in Scotland to other parts of the world.)

Forward Integration

A number of the survey firms had added design and development activities[21] to their manufacturing operations in Scotland. These activities were formerly reserved for the home-base economy. Three of the region's semi-conductor firms and six of the seven computer firms had design and development staffs in Scotland. These personnel were variously involved in product modification to meet European or individual customer specifications and in both product and production technology development. None of them, however, was involved in fundamental scientific research. Centres for basic research (to the limited extent that the industry supported them) were still concentrated in home base economies. The size and economic importance of these staffs differed depending on their operational assignments. However, all except one were involved in true design and development, not just product modification for European standards. The design and development commitment of the region's high tech multinationals seem to have deepened during the study period.

In the semi-conductor industry three of the region's oldest firms had long had design staffs. In two cases the firms had significantly enlarged their design capability: the staff of one grew from 10 to 20 and the other from 24 to 64 over the five-year period of the study. In contrast one firm rationalised, closing its design and development facility in Scotland and centralising all design activity in the US.[22]

In two firms - a start-up and an established chip producer - the design personnel were not only custom-designing chips but also designing sub-systems - special order board-level high tech electronics products to solve specific technology problems. Already experienced in close collaboration with their customers in the telecoms and military markets, management had decided to seek the extra value added they could achieve by producing a finished product that incorporated their custom-designed circuits. This market orientation demands that design, fabrication and assembly be closed tied together, all near the customer: designs must be prototyped and communication between the stages of production is essential because of the inevitably frequent changes in specifications. While industry analysts had predicted that more complex chips would propel chip producers into systems work (Ernst, 1983), these were the only two cases within the survey firms located in Scotland.[23]

Four of the established computer firms with design/development staffs had majorly enhanced them during the study period. Management in some of these cases had significantly shifted resources away from manufacturing activity to engineering, focusing on developing better hardware and software designs for circuits and the central processing unit. This in some cases meant much tighter co-ordination of design, manufacturing and testing with company personnel taking on responsibilities for product prototyping, design modifications, developing testing protocols, etc. which had previously been done in other parts of the corporation.

During the study period, Honeywell Control Systems, for example, set up a Solid State Applications Centre. The mission of the Centre was to develop new computer control products from the chip through the systems levels for usage in industrial applications. Because of the complexity of the chip, the work included research in and design of the semi-conductor technology itself. This high technology unit was the only advanced engineering lab in Honeywell, located outside the US (SDA, 1980). Another corporation had from the beginning assigned its Scotland subsidiary the responsibility of developing basic product technologies into commercialisable products to be manufactured at the plant. Development and design responsibility at the facility had grown sharply: in 1976 only 43% of the plant's output was internally-developed product; by 1980 that had risen to 70% (Cressey, 1984) and by 1984, 100%. In a third firm, the size of the engineering design staff had remained approximately stable, adding a few young graduates yearly. However, the product development activity grew to dominate the operations of the plant. By 1984 the engineering division accounted for almost a third of site employment, compared with only 7% in 1979. In these three firms, engineers were developing ideas that would provide a stream of products for the plant to manufacture.

Design and development managers indicated that this had become essential in competing in high tech markets. Increasingly sophisticated customers demanded customised products: that required the region's firms to have design and development capability. In one firm, when two major customers asked for help, a computer repair centre and a very small R&D staff developed two new products for their specific needs. The firm then manufactured those products in-house for those customers and for wider distribution. In another computer firm, a team of staff engineers had redesigned product to make it manufacturable in a highly automated system. Staff engineers had also developed a new and highly automated production process for the facility in Scotland. This firm had no design or R&D centre in Scotland, but these personnel were clearly involved in developing what was to date the most automated production design in the entire industry. Another firm, a new start-up, had, at the time of the survey, only 6 technical people to modify their mass-produced product to meet European standards. However, within the first year managers acknowledged that they would soon expand that scope to include more fundamental design and development. Only one computer multinational maintained its original pattern of manufacturing entirely to designs transferred from the US.

All the survey firms claimed to have process development on-site. Because this work can arise out of the everyday operational tasks of any engineer, actual resource commitment for this purpose was unclear, though managers emphasised its value. The development work primarily focused on perfecting the operations and improving the productivity of their production systems ('massaging the system'). Because of the complexity of the operations, however, managers mentioned a number of cases where staff developed entirely new procedures and software to solve unanticapitaed problems or to fill technical needs as yet unmet by the parent.

5.3.4 Product Responsibilities

The product-life-cycle theory, even in its updated form, predicts that overseas branch plants would manufacture established, if not mature, products developed in the home base economy. The economic rationale for overseas manufacturing remains export substitution to improve multinational competitive position vis-a-vis domestic producers. The product orientation of the firms in Silicon Glen indicated a very different role for these plants in world markets and within the corporation. An increasing proportion of their products were customised, rather than standardised. More importantly, the plants were equipped to produce new products for growth markets. In fact, a number of the corporations had assigned the Scotland plant with product responsibility.

Products in Growth Markets

Every firm in the survey, with possibly one exception, produced new products. All of the semi-conductor firms produced devices currently dominating world markets, and a number had invested in production technologies to manufacture the next generation of chips on the horizon - 32-bit microprocessors, 256K DRAM memory chips, and EePROMs that are essential companion chips to new micro-processors. The capital investment in 3 of these 4 firms will allow precision down to a circuit line width of 1 micron (A micron is one millionth of a meter.) or less by 1986. At that point a two-micron width was considered state-of-the-art (Cane, 1984) and the world industry average in 1985 was more than 4 to 5 microns (New York Times, 1985). Managers in these firms commented that these technologies would also be able to produce a future generation of VLSI chips - the 1 megabit memory chip. Also all of the producers had targeted markets that would demand the most up-to-date product technologies - the military, aerospace, telecoms and computer markets. One of the producers, while manufacturing only to supply corporate needs, was an acclaimed world leader both in its mini-computer designs and in its design of chips specifically for use in sophisticated computers. None of the corporations had allocated mature products to the Scottish subsidiary. Even the Japanese firm, whose market strategy (not just for the subsidiary, but for the entire corporation) had previously been to enter a commodity market once the product was well-established, had jumped into the next generation product (the 256K memory) and was preparing to produce it simultaneously in Japan, the US, and Scotland.

The modernity of the computer products cannot be so easily gauged: software changes and adding a new memory board update a product without fundamental design changes.[24] Three of the firms manufactured products that were designed on-site, so the Vernon delay of product introduction overseas did not exist. The remaining four firms produced products designed and first manufactured in the US. The time lag between product introduction in the US and production overseas was minimal for all. Even the two volume producers - IBM and Wang - were manufacturing products that had only arrived in the US market the year before.

Customised Products

Almost all of the survey firms produced customised products - either solely or in addition to volume standardised commodities. All but one of the semi-conductor firms manufactured chips to customer specifications in 1984. Most of these firms had gained their market power as volume producers of standard chips.[25] Managers in all of the semi-conductor firms, following on industry forecasts, expected customised product to become a much larger portion of plant output over the next few years. The computer industry also was geared to customised production, but, because of the nature of the product, that had long been the case for most producers. Only one producer was solely oriented to mass production of low-end products, aimed at the office automation market. The others had, because of the expense and sophistication of their machines, always produce small-batch customised product. Industry managers expected that demand to continue; even one of the two volume producers anticipated that customised products would grow as a share of their output.[26]

Single Sourcing

Further, a significant proportion of the survey firms had been assigned world responsibility for some of their products - either as a second source for home base markets or global single sourcing. Five of the seven semi-conductor multinationals and two of the computer firms in Scotland had world product responsibilities. One of the semi-conductor firms and two of the computer firms were assigned single source responsibilities for the global corporation. While most of the other firms were assigned to supply the European, African, Middle East and to some extent the Far East markets, at least five of these firms were expected to be a second, if not a primary, source for the home base market - the US or Japan markets, the most sophisticated in the world. In one case the parent corporation was expected to buy as much as 75% of the output of the Scotland plant. This shows that output from the Scotland plants competed directly with the world's most advanced, highest quality products in some market segments. In industries where new, high quality product technologies can only be produced by new production technologies, world product responsibility requires investment in extremely modern, if not state-of-the-art equipment, corroborating the earlier finding.

The survey interviews further revealed that in many cases the product market assignments of the Scottish subsidiary had been upgraded during the 1979-1984 period. The share of customised business in their total output, the number of products they supplied for the world market, and the level of sophistication of their products had all been enhanced as part of recent global investment strategies. One computer multinational gave the Scotland subsidiary world market responsibility for its specialised business computers in order to eliminate duplication of extensive capital investment within the corporation. The Japanese multinational made a particularly interesting investment decision. Planning to build a chip fabrication facility in Europe, the firm decided to build it in Scotland, then upgraded its investment plan. Rather than manufacture the 64K DRAM, a product in a market that was peaking, the new plant would produce the upcoming generations of chips - 256K DRAMs and 1 megabit memories.

The multinationals, then, had allocated to the subsidiaries single source responsibility for the newest generation of products and the technological capability to produce the whole product - not part. This gave the Scotland plant access to the world market over the longest period of time possible, new scope for maximising sales. By restructuring the division of labour in the corporation, the corporation gave the subsidiary opportunities for scale economies while avoiding duplicate investments in expensive, fast depreciating capital stock.

5.3.5 Subsidiary Autonomy

The survey was not designed to explore the extent to which decision-making responsibilities such as financial planning had been devolved to the subsidiary management. Managers, however, frequently indicated that they had extensive independent responsibility (eg financial planning, technology assessment and investment) as long as they operated within specified corporate constraints. The nature and extent of those constraints, thus of the autonomy, varied with the individual corporation and its market position, and cannot be determined from the survey data. However, DEC was an example of a firm that had gone on record to claim that greater subsidiary autonomy in Europe was an operational objective for its UK facilities (Horsley, 1983). Furthermore, those corporations investing state-of-the-art technologies in Scotland had allocated responsibility for testing, selecting, and installing the new technology to subsidiary personnel. Exploring corporate limits on subsidiary autonomy and the changes in constraints over the business cycle would be an important topic for further research.

5.3.6 The Impact on Labour

The changes outlined above - the investment in new, at times state-of-the-art equipment, based on greater computer control and flexibility and the responsibility for increasingly sophisticated and highly customised products -

all required technically trained personnel. They were needed in greater numbers to oversee, modify and repair the operations of new production equipment, to design and test new and custom-ordered product and to deal with potential customers. This shift in the activities at the plant and the nature of new capital investment together reduced the need for lesser skilled workers per unit of output. While, as suggested by the product-life-cycle theory, semi-skilled production workers dominated the work force of survey firms at the beginning of the study period, 41% in 1979, they had declined to approximately one-third by 1984. Subsidiary managers predicted that employment of technically-trained personnel would continue to rise while that of less skilled production labour would fall over the next years.

The adoption of new technologies and the integration of design, development and testing activities at these plants radically altered the kind of work, the definition of jobs, and the qualifications for the new occupations, as well as the numbers of workers needed. All of these changes contributed to the industry's extensive and increasing dependence on highly skilled technical labour - by 1984, at least one quarter of the work force in survey firms. The next chapter will more fully address the impact on labour and the labour market.

5.4 ANALYSIS OF MANAGEMENT STRATEGY

5.4.1 The Drive to Economise on Capital and Information

All of the survey firms had invested extensively in more automated processes during the study period (1979 - 1984). Only the four firms with highly uncertain competitive positions and one with a highly specialised product had more conservative investment strategies. Management in the survey's market leading firms had invested in a wide range of automated equipment. For the market leaders it was a race to automate operations in Scotland constrained only by production deadlines. For weaker firms investment in new technologies in Scotland was moderated by corporate rationalisation plans that threatened to concentrate capital investment in other locations.

The rush to invest in new technologies was not the conventional rationale of a capitalist wanting to reduce his expenditure on labour or to eliminate his industrial relations problems. Here capital-saving was the objective. More automated processing was introduced to protect the increasingly expensive partly-processed product from contamination and breakage--thus to avoid defects, to reduce the time that expensive inventory and work-in-progress was held, and to use very expensive capital equipment intensively before it became obsolete. Economising on capital, not labour, was the competitive imperative (Elster, 1983; Ernst, 1983). Only those computer firms that had long delayed capital investment, maintaining manual production methods, were introducing automation in part to reduce labour costs.

The economics of automation were more compelling in the semi-conductor industry than in computer production because of differences in the production processes. In the semi-conductor industry, yield is a critical determinant of both unit cost and profit. The most effective way to improve production yield, or the number of good chips per wafer, was to use more precise production equipment. Because the yield depends so heavily on successful, predictable chemical processing, a major concern was to eliminate the impurities that the wafers would be exposed to in processing. That meant both purifying the air (to meet conditions as stringent as those for an operating theatre) and reducing the numbers of times wafers and production inputs were exposed to air and handling during the more than 200 processing steps. People's dandruff or the particles a smoker exhales can contaminate a whole batch of wafers, as can any imprecise or irregular movement when putting wafers into a chemical process. Table 5.3 shows the range of ordinary activities that can contaminate the product. Errors that would seem slight in other environments can ruin wafers: with the higher value added in recent generations of chips (due to the front-end research and design investment), contamination represented a major cost threat. Eliminating potential contamination and irregularities improved yield.

Even a slight drop in yield radically alters the unit cost, can eradicate unit profitability in sharply contested markets, and can shift the cost advantage of producing in one location over others.[27] Japanese firms, realising this, had invested in advanced automated equipment earlier than most US firms. Corporate managers, facing unprecedented cost and price competition from Japanese firms (New York Times, 1985) had insisted that improved production yield was critical to survival under the new conditions of cost competition. Investing in automated procedures was a way to protect their wafers and minimise input costs. In the early 1980's, US firms automated production systems to replace human intervention to increase yield (Financial Times, 1984C). The aim was to preserve capital, not to reduce labor costs.

Survey interviews and trade press articles emphasised the importance of removing people in production to protecting capital.

> "The only problem with humans," as one managing director said, "is dandruff."

> "In the latest very large scale integrated circuits (VLSICs),..the contamination which is introduced when an operator, even one clad in surgical type gown and gloves, picks up a wafer is enough to disrupt the entire operation of the circuits...[H]andling of the circuits is undesirable...."

> In addition, "[t]he point has been reached where human control of the processes is often not good enough. Human controllers are simply not as consistent as their computer counterparts." (Keyhoe, 1981A)

> "Wafer fabrication specialists have come to the conclusion that the human operator is the greatest contribution to potential contamination in semi-conductor clean rooms." (Semiconductor International, 1984)

> "It has been suggested that if all humans were removed from cleanrooms, yields would double... strictly due to the reduced contamination." (Singer, 1983)

> "Automation is...generally accepted as the route to higher production yields and greater device complexity." (Keyhoe, 1981B)

"In VLSI you have to separate people from the process to increase yields, and only automation will do that." (Electronics, 1983)

TABLE 5.3. CONTAMINATION CAUSED BY WORKER ACTIVITIES

The Increase in Contamination

	Times increase over ambient levels (particles, .2 to 50 per million)
Personnel movement	
Gathering 4 to 5 people together at one location	1.5 to 3
Normal walking	1.2 to 2
Sitting quietly	1 to 1.2
Laminar flow workstation with hands inside	1.01
Laminar flow workstation - no activity	None
Personnel protective clothing	
Brushing sleeve of uniform	1.5 to 3
Stamping on floor without shoe covering	10 to 50
Stamping on floor with shoe covering	1.5 to 3
Removing handkerchief from pocket	3 to 10
Personnel per se	
Normal breath	None
Breath of smoker up to 20 minutes after smoking	
Removing handkerchief from pocket	3 to 10
Personnel per se	
Normal breath	None
Breath of smoker up to 20 minutes after smoking	2 to 5
Sneezing	5 to 20
Rubbing skin on hands and face	1 to 2

SOURCE: Semiconductor International, 1984, p.19.

Greater speed, as well as improved precision was another way investment in new technologies helped reduce unit capital costs. The faster batches of wafers could be processed, the better management's chances of earning payback on the equipment before it became obsolete. Many managers stressed the competitive importance of investing in state-of-the-art equipment to speed up throughput, even though it often meant spending substantial time and money to get the new machines to work. They claimed that waiting for a well-tested machine or the next breakthrough in production technology would be a strategic mistake in the comeptition of the 1980's. The firm would lose the experience of working with a technology its competitors were using, putting the company at a short-term competitive disadvantage in terms of quality, unit cost and turnaround time. That rapidly translates into lost market share in this fast-paced industry. As one manager explained,

> "At the state-of-the-art end, the vendors are inevitably still debugging the machines. So producer, while developing its own product, has to debug the production system as well. There's no alternative. That's the price a company has to pay to stay in the front-end of the industry...If the company waits around for the two years it takes to iron out all of the problems with a machine, the company would be two years behind the industry. Though this process may be a bit slower, a company can't afford to wait. If a competitor working at the state-of-the-art end gets a 1 megabit RAM out six months ahead (of our company), they immediately capture that chunk of the marketplace the company needs.....So there's no way a company can avoid the changes. It's the marketplace that determines what individual companies do."
>
> – Manager of a VLSI facility in Scotland (Interview, 1984)

This manager made it clear that the `can't wait' technology competitiveness voiced by managers in Silicon Valley was just as central to the success of the subsidiary.[28]

It is also important to remember that the integrated circuit is a unique product with its production economics. Because the precision of production equipment determines how many microscopic circuits can be placed on a chip, a new, more densely packed chip demands a better machine than previous ones. Introducing new products usually demands new capital investment. There is rarely a choice in fabrication and now in assembly between a new machine and a manual method because most of these operations cannot be done manually. The production processes are predominantly chemical and the outcomes (ie the circuits and connections on the chips) are microscopic.

While competition stimulated increased automation in the computer industry, there was a wider range of technological options, thus investment strategies among the survey firms. These reflected the companies' competitive standing and product markets. The front-end costs of research and development, including software development, had skyrocketed and were increasingly unpredictable. Some managers called these costs - particularly the cost of software - uncontrollable. Given continuously falling hardware prices and price/performance ratios (Duncan, 1981), management had to attack costs somewhere: the target was the calculable costs of production (Ernst, 1983; Engstrom, 1984). Because many firms had maintained largely labour-intensive production methods, automated technologies to eliminate labour could significantly reduce a large share of production costs. However, the expense of these machines and the rise of information-related costs also pressed management to invest in new technologies as part of a range of capital-saving measures, especially in testing. Individual firms' investment over the period were more often than not more restricted in scope than those of the semi-conductor industry. This is due both to the differences in product and to the precarious competitive position of three of the firms.

However, the pressures to reduce and minimise production costs were felt by all competitors. Interviews suggested that this was equally true for producers of both volume/price-sensitive products and those at the technology/monopoly end of the range.

> "We are trying to move to a much higher degree of automation within our instruments because keeping production costs down is the way to kill the competition",

according to the engineering manager of a high-end instruments/computer firm. Management at Honeywell had publicly claimed that investment in automation was a high priority. Automation was most frequently introduced to eliminate wastage, to reduce work-in-progress and stored inventory, and to speed up production turnaround.

Testing was a prime target of computer industry investment. Increasingly complex computers required more and more varied testing. More highly automated (and sensitive) test equipment used at more frequent intervals during production helped both speed up production and reduce defects. As in the semi-conductor industry, the defect rate was a major concern to management. With the greater complexity of the computer, a defect that was not found until the product was complete cost £1000 to repair, while a problem caught earlier in production, eg at the board level, cost only £10. Firms could no longer afford the traditional manufacturing practice of an `allowable defect rate': they installed test equipment at many stages of production and altered the work organisation to strive for zero defects.[29] Even the two firms with the most unstable market positions[30] had been unable to avoid investing in new ATE in order to meet the technological demands of their government, military, and banking industry customers.

The two computer multinationals that had not invested significantly in CIM were the two long-established firms that had uncertain competitive futures. Their cost-minimising strategies depended on reducing production labour. They automated individual production tasks and they switched to buying in components and subassemblies rather than manufacturing them in-house. This eliminated costs in activities which had insufficient scale economies and reduced dramatically the size of their production labour forces.[31] In fact, these efforts allowed them to hire almost exclusively engineers and technicians, transforming large, long-established manufacturing plants into product engineering facilities. The plants had originally manufactured all components on-site, including cabinets, cables, printers and printheads, keyboards, power supplies, etc. The machine shop in one firm had even manufactured screws. They both streamlined down to assemble and test only the computer's central processing unit. In one case, the changes translated into a reduction in machine shop employment from a peak of 1000 in 1974 to 8 by 1984. However, the firms' emphasis on expelling labour and seeming neglect of product turnaround were out of step with the competition, reflecting waning demand for their products. Managers in both firms admitted that their corporations had surplus production capacity internationally and that corporate restructuring was on the cards, making extensive investment risky or impossible.

Economies of Throughput

That the semi-conductor firms were more consistently committed to investing in CIM than the computer industry resulted from the compelling economies of throughput possible in semi-conductor processing. Throughput refers to the effectiveness (yield), as well as speed, of processing and delivering small batches of finished chips. These economies with their focus on the quality of produced output rather than simply the quantity must be achieved by a smooth and flexible organisation of personnel and capital equipment in production and distribution. Equipment must not only provide speedier processing, traditionally the aim of automation, but also ease and speed of adjustment to a range of production inputs and outputs.

> "While manufacturing traditionally was geared to achieve factor savings by sacrificing product-line flexibility to economics of scale, the new generation of computer-based automation systems will allow firms to reconcile these conflicting objectives and thus open new paths to regain profitability. As a result of these developments, computerized automation systems are expected to transform the economics of many types of industrial manufacturing involving both mass and batch production." (Ernst, 1985)

The move to establish `systemation', as Perez (1985) calls it, was spawned by the new economics of micro-electronics manufacture.[32] Firms facing severe price competition had to reconsider the wasted expense of a global organisation that required frequent trans-shipment of materials, parts and sub-assemblies over thousands of miles (Ernst, 1985). Rising costs of the capital equipment and of the production inputs pressured management to synchronise production and distribution systems better. Systemation, or bringing together and coordinating formerly disparate steps in a continuous manufacturing process, when paired with flexible equipment, enables the complete manufacturing of a range of products fairly rapidly and on short notice.

> "The firm as a whole becomes a continuous flow system of activities, information, evaluations and decisions...[W]hereas the assembly line [of the past] was based on constant repetition of the same sequence of movements, information technology is based on a system of feedback loops for the optimization of the most diverse - and changing - activities...This potential ...could have a profound impact. It can transform production planning from a periodic hit-or-miss activity into a more reliable day-to-day adaptive system, coupled with flexible production facilities." (Perez, 1985)

Commissioning such a system, especially with the complexities of semi-conductor manufacturing, is extremely complicated, time-consuming, and risky. According to interviews, managers were willing to make these investments because of their capital-saving potential. According to one engineer who had designed an `island of automation' for one of the survey firms, state-of-the-art systems significantly reduced the time that work-in-progress sits around waiting for the next available machine. The savings are created by reducing the time unfinished product sits in the plant and by maximising the use of the production equipment.[33] For example, the manager of a semi-conductor fabrication plant adding an automated assembly facility explained that the firm wanted to be able to meet customers orders more quickly. The 1983 chip boom had created an acute bottleneck for the firm: sales were delayed because the firm had had to wait for their finished chips to return from the Far East. Integrating all the production activities in one plant would prevent a repetition of this delay and exploit the advantages of being near to customers. At the same time, local managers admitted their concern over how long and unpredictable the set-up time was for these complex systems.

Highly integrated systems both exploit and depend on the intangible input of information. Access to market information and knowing how to make the equipment produce what customers want are essential to keeping capital equipment busy and operating well. Maximising throughput depends critically on successful organisation of market and technological information and experience - called a `closed feedback loop' in the industry. The more frequently technical staff have to adjust the machinery for changing product specifications, the more knowledgeable and effective they become: that means less downtime and higher yield. There is a powerful dynamic between the economic use of information inputs and economising on capital.

The fact that so many of the survey firms served government and military markets made investment in integrated production even more compelling. Military customers, state telecoms firms, etc. want the assurance of quality, technical support and reliable supply that a self-sufficient production facility nearby can offer. As one engineer with international experience explained,

> "I think more people [firms] will begin to demand that the facilities [for assembly and test] are out here..a.[I]t's a comfort more than anything else that you're not doing it in the Far East... Quality is very important: it's becoming a big market now. I think it's a good business decision to have your facilities close. People can come into

your facilities and see what you've got, making sure you've got all the right controls. You can satisfy them on the quality issues."

The company decisions to incorporate design and development with manufacturing were to capture and exploit these information economies.[34] Allocating design and/or development capability to a Scotland plant enabled the subsidiary to establish a professional technical relationship with the market. That gives the subsidiary information and contacts that can create new products and possibly a new market: that would add to, extend and perhaps improve the usage of the production facility. That can enhance revenues prospects, productivity performance and, as outlined above, lower unit production costs.

Further, adding these capabilities to a manufacturing site enables the plant to generate new sales independent of decisions at corporate headquarters. This can be very important for the longevity of and continued investment in the subsidiary. In many of the firms, the subsidiaries competed with other plants in the corporation, as well as with the new potential locations, for each corporate investment project. The competition was based on productivity and unit cost performance, speed and success of starting up new operations, as well as relative input costs. Management and technical professionals in the subsidiaries had, for this reason, lobbied the corporation for increased design and development responsibilites. Because the cost of the capital equipment necessary for many aspects of high tech design and R&D is so high, locating these responsibilities in the Scotland plant indicated a corporate commitment and dependence that could not easily be abandoned at the first market downturn. That kind of commitment was an important step in retaining technical professionals (an important objective of high tech management, as will be discussed in the next chapter).

4.4.2 Supplying the World Market

Producer technology and investment decisions derived from the need to capture the European market (See discussion below). Supplying this market with advanced microelectronics products required modern production technologies. Given the enormous expense and relatively short period of return from advanced production equipment, management assignment of world market responsibility to the Scotland subsidiary was an effort to exploit that investment to the fullest. It minimised duplication of investments within the corporation and maximised for the subsidiary its potential market. In addition, US multinational management found that producing even the most sophisticated products in Scotland reduced costs over those in the US. They could realise this cost advantage even when supplying the US market. The discussion below and in Chapter 6 details the specific cost-minimising opportunities of producing in Scotland.

The competitive necessity to cope with fast-paced technological change, increasing competition, and the growing burden of capital costs compelled US management to reconsider the role of the plant in Scotland within the corporation. Economic priorities for rapid adjustment to market changes and more intensive use of new equipment had overwhelmed the conventional rationale for delaying the transfer of the most advanced (and usually knowledge-intensive) technologies to a subsidiary. The economics that had geographically divided up the industry, dispersing part-product and duplicate 'clone' plants across the globe, had become obsolete.

The aim of greater integration of all the stages of design and manufacturing was to establish a collaborative, non-hierarchical process that would facilitate the flow and rapid exploitation of information. Production engineering must respond to product design; design must accommodate the requirements of testing, and changes in test routines must be incorporated into design. This interdependence of processes necessitated moving away from the hierarchical structure imposed by the geographical separation of the stages of production. Restructuring the organisation of work to gain greater flexibility and responsiveness required placing formerly isolated activities next to one another and, because of its historic spatial organisation, a global restructuring of industry activity.

5.5 THE ROLE OF SCOTLAND IN THE INTERNATIONAL DIVISION OF LABOUR

This development of advanced, more autonomous manufacturing and design facilities marked a sharp break in the history of multinationals in Scotland. Did corporate management respond to market pressures by enhancing all their plants around the world? How do we attempt to understand the development in Scotland in the context of international product competition and the global competition for multinational investment? While the research in this study cannot answer the first question, this section will analyse why Scotland was the host economy for these developments.

Key management concerns in these two industries were how to respond rapidly to perpetually changing market conditions and how to manage the resulting financial and competitive risks of the large capital investments considered essential to stay competitive. The hectic pace of change was a critical feature:

> "Much of the industry remains subject to a repeated boom-and-bust sequence similar to the classic 'hog cycle'. But there is another twist. Production equipment grows obsolete at a relentless rate - its useful life can be

as short as five years - each new generation of chip-making machinery costs several times more than its predecessor." (Keyhoe and DeJonquieres, 1984)

These concerns are central to understanding the growth and nature of the industry's development in Scotland.

5.5.1 The Competitive Importance of Europe

By the late 1970s the industry had identified Europe as a critical market. Severe competition in both semi-conductor and computer markets and the heightened expense and risk of new investments had reshaped multinational corporation priorities in all investment decisions. Corporate location priorities were big, growing markets around the globe. The two industries were, at that time, bursting at the seams to expand their revenue base quickly. The European market was an attractive and fertile ground for electronics firms (Crisp, 1983A) because in population terms it was the largest individual market in the world, sales had shown rapid growth and this was expected to exceed that of the US (Meredith, 1983; David, 1984).

In addition Europe's domestic producers had barely scratched the surface of potential demand. "[I]ndigenous competition is weaker than in other markets" (Smigh, 1984): the market was wide open for large firms to gain market share quickly. Europe's highly industrialised economies had the high incomes and technological sophistication that high tech industry thrived on and the industrial markets the corporation had targeted. Europe had become the competitive battleground for US and Japanese high tech multinationals by the early 1980s (Borrus, 1983; Crisp, 1983A; Williams, 1983). The necessity for continuing communication with the market to win and retain customers and the competitive importance of being inside the EEC tariff wall meant the battle for market share could not be managed by exports: producers would have to manufacture within Europe. At least eight of the survey multinationals had established major manufacturing plants in both Germany and the UK to gain access to large industrial markets.

Britain was the first choice for many US electronics producers wanting a share of the European market (Financial Times, 1983A; 1984A). By 1984, the UK had become the largest overseas market outside of Canada for the US electronics industry (Large, 1984A). As an English language country and an economy with a large state and military market, a very strong computer market and new opportunities due to the deregulation of the telecoms industry, the UK offered many advantages as a manufacturing base.

To understand why high tech investment was concentrated in Scotland rather than other parts of the UK requires an examination of the political economy of the region. The next section examines the factors that influenced management decisions to invest in Scotland.[35]

5.5.2 Scotland's Well-Developed Infrastructure

Scotland had a number of features that made it attractive relative to the other UK regions vying for foreign investors. The region had a long history of US multinational investment (Forsyth, 1972; Firn, 1975; McDermott, 1977), though not all of it was harmonious (Hood and Young, 1981). Multinationals, mainly firms based in the US, dominated the region's electronics industry from the early 1970's (US firms employed 47% of the industry's 1973 employment; McDermott, 1976). The region also had an infrastructure that was conducive to the high tech industry. Scotland's `business climate', which was the result at least in part of explicit economic development policy, deserves closer examination.

Logistically, Scotland was very well connected to the rest of England and the Continent: the air, rail and road transport networks and telecommunications were well-established and reliable. Communications are essential for an international industry which depends on the continuous shipment of cargo, information and people around the world.

For the high tech industry, infrastructure means more than air and telephone connections. The infrastructure in Scotland offered many opportunities to soften the risks and minimise the costs of operating in the European market. The attractiveness of the region for foreign direct investment derived both from its growing base of electronics firms, including important defense contractors (eg Ferranti), and public policy initiatives and incentives that created a well-developed and growing private sector supply and subcontract network and mechanisms to ease the entrance of overseas investors.

By the end of the 1970s the region had a growing number of small firms that catered to the existing semiconductor and computer multinationals. There were plumbing and ventilation contractors experienced in building the industry's controlled-atmosphere facilities. The economy included suppliers of the industry's specialised gases and chemicals, well-known manufacturers of printed circuit boards, a quartz firm (to make the glass lenses for the photolithography steps in chip-making), integrated circuit mask (or pattern) makers and custom chip design houses.[36] During the study period many more supplier firms announced plans to open plants in the region, including a Japanese producer of silicon and a major US subsystem supplier to IBM. As the managing director of one of the start-up firms in the survey explained, a high tech firm could get all the subcontract services and production inputs to turn their design into a product within twenty miles of the plant. Officials at IBM also claimed that almost half of their outside sourcing came from suppliers in Scotland (1982). "The subcontracting opportunities [for multinationals] in Scotland are enormous," a company spokesman said (Eglin et al. 1983).

In an industry where swift market changes were the norm, a range of nearby suppliers was extremely important

(Oakey, 1983). The proximity of supply eliminated the timing problems and uncertainties of depending on overseas sources of supplies. A well-developed supply structure gives a firm a lot of flexibility: unexpected orders can be filled quickly and smoothly while the firm minimises its investment in employment and inventory. A reliable network of outsourcing and subcontracting firms also allows the multinational to focus its fixed capital investment: management can invest in only those activities that are tied to the technology of their product. As a manager in an instruments plant explained, the firm had to maintain an extremely high overhead to pay for the office environment of its design development- (and therefore engineer-) intensive facility. So, the firm outsources many inputs not related to its central technology: "It doesn't make sense to put our efforts into other (input manufacturing) areas which will push up the price of our instrument significantly." (Interview, 1984)

The growing number of large, market-leading high tech firms had begun to have a dynamic effect by the early 1980s. During the period of the study, managers had begun purchasing directly from other multinational producers operating in the region, particularly the chip manufacturers. Historically, most multinationals purchased major or technology-intensive inputs through a central corporate ordering agency and distribution system. This frequently meant receiving supplies of chips through intermediaries in the US, Japan and other parts of Europe. A number of managers mentioned that they had just recently begun dealing directly with the producer firms nearby. This simultaneously reduced the delivery time and offered them immediate engineering support and design adjustments. This relationship also works as a guarantee of supply, a serious concern during a market boom. This was the key reason one semi-conductor firm began manufacturing in Scotland: the firm moved into the region to capture IBM business (Interview with California manager, 1983), as did other major suppliers (eg SCI Systems).

The well-developed regional supply network operated like a just-in-time supply system outside the plant. It served as a buffer against changing market conditions. In addition, proximity and economic interdependence enabled firms to establish better communications and control over critical quality standards (O'Connor, 1985). This reliance on nearby supply companies mirrored that of high tech firms in Japan and had proven to be an important element in their success.

The infrastructure proved to be particularly important when starting up or expanding a facility. Once management decided on an investment, they wanted to bring those new technologies on stream rapidly. The rush was to earn return on the investment before the technology become obsolete. (Semi-conductor firms in particular had had the costly experience of investing in manufacturing facilities in the US which were never completed or delayed due to sudden market downturns.) The industry had found that the Scottish economy supported a rapid start-up phase. A manager in one semi-conductor firm claimed that a burned down fabrication plant in Scotland was completely rebuilt and operative within six months (1982): that experience favourably influenced corporate management to locate a new product facility at the site in Scotland at a later date. Another firm, with experience in the region, planned to build and begin operating first a modern assembly and test site, then a very modern fabrication facility all within 3 years. The local periphery of suppliers and subcontractors minimised the chance of long, unpredictable and costly delays in scheduling new investments.[37]

5.5.3 Public Sector Financial Incentives and Policy Support

The regional authority in Scotland, supported by the Government, had years earlier made a commitment to attracting the electronics industry to the area to create jobs (Scottish Development Department, 1963; 1970). That policy, modified and honed over the years, was supported both by the pro-active state industrial policy of the Labour Government of the 1970s and employment creation efforts of the Thatcher Government in the 1980s. Throughout this period, the regional authority was able to offer a handsome package of financial support and incentives to overseas firms: foreign direct investment by high tech electronics multinationals remained a major target because it brought not only employment but also expertise in the new technologies. The Thatcher Government was particularly active in attracting foreign multinationals during the study period (Committee on Scottish Affairs, 1980D; Fraser of Allander Institute, 1980).[38] This section briefly reviews the public support used to attract overseas investors and its importance for these multinationals at a time of financial crisis.

The primary financial incentives for overseas firms locating in Scotland originated from the Industry Act of 1972 which provided automatic grants on fixed capital available for firms in designated `development areas' of high unemployment. Also Section 7 of the same act established regional selective assistance (RSA), which were discretionary grants to firms. More recently, the Industry Development Act of 1982 designated a wide range of special projects - eg using new automated technologies - that could qualify a firm for public grants.

The Scottish Development Agency (SDA) had from the beginning been active in soliciting foreign investment to create and maintain regional employment and to further technological and economic development (Fraser of Allander, 1978). In 1979 the SDA sharpened its regional development strategy (Committee on Scottish Affairs, 1980A): the agency decided to consolidate its efforts more effectively to attract and support the local development of modern rather than mature technologies and industrial rather than consumer industries. In its aim to intensify the region's technological base and to increase employment

(Meredith, 1983), it targeted the growth industries of data processing, semi-conductors and office automation. The new initiative was supported by continuing central Government funds (both automatic and selective aid), particularly for new technology projects, and by organisational consolidation. At the same time that the international high technology stage was set for major technological and organizational changes, the policy framework and political climate in the UK and Scotland offered encouragement to those sectors by offering what the multinationals needed - money, incentives for capital-saving investment and the technical labour force to oversee the new equipment.

High tech multinationals gained a lot of financial assistance through the Regional Development Grants (RDGs) during this period. According to the annual reports of the SDA and reports in British Business, every multinational in the survey had received many grants between 1979 and 1984. (For example, IBM in Greenock received almost £9 million in RDGs plus a £650,000 RSA grant during the 1979-1984 period; almost £4.5 million was awarded to National Semiconductor, mostly RDGS, during the same five years.) Grants from Section 8, aid for projects that adopted technologies that the state had designated as important, were not as common. Only two firms, Hughes Microelectronics and General Instruments, were awarded grants during this period from this source.[39]

The total financial package (grants, incentives, loans, etc.) for the industry's foreign investors was often substantial.[40] The direct grants alone covered as much as 40% of the cost of a firm's fixed capital investment. However, comprehensive cost accounting of all public financial assistance to these firms is not possible: the actual size and mix of the components of any one firm's financial package were not made public. In addition, the legislatively mandated forms of incentives and aid were supplemented by lump sum payments given by the Government to firms it was particularly eager to attract. The size of these bribes was understandably undisclosed (Interview with Professor Simpson, Fraser of Allander Institute, 1984).

These firms' success in winning grants account at least partially for Scotland's disproportionately large share of these public sector funds. Scotland was the single largest regional recipient of both RDGs and RSA grants since the early 1970s (Economist, 1983; Moreton, 1985). During the 1979-1983 period, 54% of all national selective financial assistance (in value terms) offered to electronics firms in Great Britain went to predominantly multinational investors, and that share was expected to rise significantly in 1984 (Young, 1984).

There were other sources of public sector assistance for these firms. European Investment Bank loans offered funding for up to half of fixed capital costs at lower than commercial rates; national sources loaned funds at concessionary rates and in certain circumstances without interest (East Kilbride Development Corporation, n.d.). Also the Engineering Industry Training Board (EITB), for example, gave grants for training employees in the use of new technologies. Managers frequently took advantage of these grants (Haug, 1984). In addition, Scotland had maintained an industrial derating policy, while England and Wales had abolished this operational cost saving. This halved the rate bill for all industrial firms in the region (Interview with editor of Glasgow Herald, 1984).

The SDA's Role

Besides helping to negociate these financial packages for potential investors, the SDA structured and financed infrastructure development for the microelectronics industry. Rent-free or rent-subsidised factories were offered for the first five years of an investment, eliminating the delay of waiting to build a plant from scratch. The agency also assisted firms in recruiting, in contacting local sub-contractors and in finding low-interest loans. Agency policy was to minimise the problems and the costs of setting up a plant in Scotland.

With its mandate to encourage the growth of the industry in the region, the SDA actively supported the growth of the supply sector for high tech electronics. For example, the SDA financed a new firm, Semicomplex, to fill an important industry gap. This firm serviced and supported production equipment for the semi-conductor industry, ending the industry's critical and costly dependence on long-distance servicing from overseas firms.[41]

In addition, the SDA won Parliamentary approval in the early 1980s to set up Locate in Scotland (LIS) to reduce the bureaucratic problems for overseas investors. LIS served as the single agency promoting Scotland and negotiated financial assistance for multinationals. LIS reduced the confusion and sped up the bureaucratic processing: multinationals considering investing would no longer have to deal with many separate national and regional bodies. The LIS targeted industries and firms, particularly the semi-conductor industry, and supplemented its offerings to prospective, desirable firms with access to venture capital firms. Officials claimed the initiative was quite successful, winning £1 billion in foreign direct investment in its first three years of operation (Financial Times, 1985). Boasting the efficiency of the agency, LIS claimed that LIS claimed that it won the 1984 investment of a Japanese silicon producer, by completing all the necessary arrangements in one week.

State Regional Policy

Government regional policy provided further support for the industry's overseas investors. The New Town system, backed by local development corporations and funding to develop and improve infrastructure, offered potential investors an available and captive working class labour force, immediately available housing (Moreton, 1981; Meredith, 1981) and public officials tripping over themselves (due to high unemployment rates in these greenfield towns) to attract multinational investment. Because of their mission to create a town economy out of a village, the development corporations also aggressively built or remodeled facilities to have factories available for immediate occupation, a convenience "unmatched in most cities and ...towns" (Henderson, 1982). Scotland's five New Towns (Livingston, Irvine, Glenrothes, Cumbernauld and East Kilbride) were quite successful in attracting firms, many of them electronics multinationals, particularly during the 1983/4 period of industry growth (Van de Vliet, 1984; Jones, 1984).

The Importance of Equipment Subsidies

Managers were asked in interviews if public financing had influenced the nature, scale or rate of investment in new capital or new technologies (as was suggested by Hood and Young, 1984). While the survey responses did not provide a clear answer, many acknowledged that the state grants for fixed capital investment, the largest of the assistance programs (Haug,1984; Hood and Young, 1981) may have accelerated the pace and scale of already planned investment. This corroborates the expectations and findings of McDowall and Begg (1981), Thwaites, Edwards and Gibbs (1982) and Haug (1982, 1984).

Importantly, these fixed capital investment grants were paid out on the day the company opened the plant and, in some cases, earlier than that. This was extremely important to these cash-constrained firms. The automatic RDGs and RSA grants significantly reduced the actual front-end investment costs of a firm starting-up manufacturing. More commonly, public sector incentives were paid once production was under way - for example, tax rebates tied to output level or tax-exempt profits. One managing director emphasised the importance of this assistance to his start-up semi-conductor facility: he explained that the size of outright grants available in Scotland enabled him, in effect, to buy two expensive pieces of equipment for the cost of one. Because the biggest direct grants could only be applied to capital investments, firms gained the greatest financing by establishing highly-capital intensive facilities in Scotland.

One multinational's study compared the costs of locating semi-conductor manufacturing in six European countries and confirmed that state grants made a capital-intensive investment in Scotland extremely attractive. Only Ireland was cheaper in the calculation of identifiable costs (Confidential corporate location study for a VLSI chip facility, 1984). The potential savings of operating in Scotland were the largest for the most capital-intensive investment options.[42] While the findings cannot prove that public sector support shaped or accelerated technological change in Scotland's high tech subsidiaries, they do suggest that the grants helped mediate a crisis of cash-constrained firms wanting to invest in expensive new technologies.

5.5.4 The Education System and the Labour Supply

The region's universities and colleges provided important support for the high tech electronics industry. These public institutions offer education and training in electronics engineering and computer science, supplying the industry with a technically trained labour force every year. (This role will be examined in detail in Chapter 6.) In addition the highly-reputed science and technology faculties at these schools offered their facilities and staff to perform applied research for the industry.

Most of the region's technology institutions had organised industry liason departments and independent `teaching companies' to seek industry contracts for short-term process and product development or problem-solving research. Winning these contracts had become very important to the education sector. Many of the engineering schools were facing state funding cutbacks: the contracts provided financing to ensure that faculty could maintain their research staff and other resources. In some cases institution administrations had required technology faculty to attract private sector funding to maintain their research efforts. So the public sector's support for the high tech industry grew during the period of the study. These resources proved important, particularly to firms that were expanding rapidly with overworked or inexperienced staff. Industry managers could ask academic staffs to solve their unexpected problems.

The dynamics of the local labour market were an additional feature of the economic infrastructure that developed to support these industries. The combination of more than 300 electronics firms in the region, some of them modern multinational concerns, and a concentration of technology education institutions generated an experienced and highly educated technical labour pool. Firms had access to research faculty and staff and employees of other firms, as well as yearly batches of new graduates. The region's growing and increasingly varied demand for technical labour had created a local labour market that could attract and retain technical professionals. There was mobility not only within a firm but also among the many firms in the region, giving professionals a range of opportunities for developing their careers. This and other features of the labour market,[43] very important to the development of these multinationals in the region, will be examined in more detail in the next chapter.

One other aspect of the local labour market, however, is cogent to this discussion. By 1979, high tech multinationals had experience in operating in Scotland: management was impresssed by the high productivity high tech firms had achieved in Scotland. For example, the Greenock plant of IBM had 'beaten' the Japanese subsidiary in productivity performance by 15% and was at least equal in quality (Baggott, 1981). IBM in Scotland had achieved a doubling of output every five years for the last 15 while employment grew much more slowly. Other testimonials to the highly productive labour force include: "Overall productivity has risen 30 - 50% in three years'; `Overall productivity has increased substantially. This company operates `lean and mean' in everything except the injection of capital.' (Executives from a computer and a semi-conductor firm, respectively, quoted in SDA, n.d.B) A manager in one of the largest semi-conductor firms said yield had doubled at the plant over the past two years and that the plant performed better in terms of quality and low turnover than any of the corporation's other subsidiaries. A manager in another semiconductor firm, also now investing heavily in Scotland, similarly claimed that the plant's productivity quickly surpassed that of a corporate subsidiary in Ireland. While the productivity success in Scotland must be largely attributable to production capital (They were, after all, highly capital-intensive facilities even in the early 1980s.), managers also considered the region's hardworking, trainable and experienced production labour force a major contributor to performance success.

Because of the uncertainties in high tech electronics product markets, investing in expensive capital anywhere was risky (as the two years of market contraction after the survey proved). The entire package of state assistance for investments in Scotland reduced the risk of state-of-the-art investment as well as the outright cost. The managing director of a computer firm emphasised the importance of state aid for high tech firms. When asked why multinational firms were installing state-of-the-art manufacturing technologies in Scotland, he replied:

> "These industries are protecting themselves with Government money. They are sharing the commercial risks with the Government... That's why there is so much [investment] activity in Scotland. The companies are not taking the risk: the SDA is."

Corporate managers in California had stressed that financing capital investments was one of the semiconductor industry's two greatest problems in the early 1980s. With high tech/management worried about the cost pressures of investments they had decided they must make, the state grants in Scotland were the right kind of assistance at the right time. These grants gave them both upfront money and lower operating costs (eg lower interest payments) and surely must have influenced management decisions about investing, reinvesting and the quality and pace of that investment in Scotland.

5.5.5 Scotland as a Source of Both Technical Labour and Public Finance

The regional economy of Scotland offered these multinationals an unusual opportunity. In contrast to most of the world's regions competing for high tech multinationals investment, Scotland offered high tech multinationals public financial incentives and an established and growing technical labour market, both in the same region.[44] Many other regions across the globe advertised similar or better aid packages - usually to attract jobs to an underdeveloped area. But economically disadvantaged areas usually had no high tech activity. That meant the technical personnel had to be imported from an industrialised region, often far away. The higher costs of recruiting, relocating and retaining technical personnel in this situation made these investments both expensive and risky.

The availability of generous state incentives in the same region as a pool of appropriately trained labour and an industry-specific infrastructure made Scotland a prime investment site for these industries.[45] It set Scotland apart from most other potential and actual locations of high tech industry (outside the US and Japan). The Japanese semi-conductor firm decided to locate its VLSI fabrication facility in Scotland rather than elsewhere in Britain or Europe because of the combination of nearby support for VLSI work (the technology research universities in Edinburgh and supply industries), the public sector financial package and the availability of technology graduates, as well as the chance to economise by adding onto an established plant that was already highly productive (Interview with personnel manager, 1984).

> "`The [high tech] companies who have come to Scotland and got the most out of the move are not those who have come just for a cut-price factory and subsidised capital equipment - important though those elements may be. They are those who have come here and taken advantage of quality brains in developing R&D programmes, available in number and at an attractive cost....There are of course the financial incentives...There are other countries who may be able to offer slightly better terms to a would-be developer; there are countries who can provide lower cost labour. But what Scotland...can offer that cannot be matched anywhere in the world is an education [sic], trained labour force with a great track record as far as adaption to new techniques and disciplines is concerned." (Managing director of Burr-Brown quoted in Fife News, n.d).

One firm, for example, chose to greatly expand its semi-conductor production facility in Scotland rather than another plant in Ireland because the Irish economy had an insufficient supply of highly skilled technical people. Another multinational, in a corporate study comparing the costs of setting up a semi-conductor facility somewhere in Europe, recommended siting in Scotland: it offered both a high level of grant and highly trained personnel. The study explained that in the Republic of Ireland, the lowest cost option at first calculation, "the desirable support facilities [infrastructure] are lacking and local technical training is not so well advanced as in Scotland,..so local recruitment of key staff...would require commitment to a substantial training investment." (confidential corporate study, 1984).

An SDA survey further supported the importance of this combination. Their survey of overseas firms investing in Scotland found that the supply of technical labour and the level of labour productivity were the two most important factors in determining the location of a new plant. The third was the availability of financial assistance. (Interview with project planning manager for the SDA, 1984). When combined with the industry support available in the region, Scotland was a highly favoured location site.

> "Scotland now produces almost 50% by value of all semi-conductor devices made in Europe. It has acquired most of the support facilities enjoyed by companies operating in the USA, from university departments specialising in training staff at all levels (even possessing their own research and fabrication facilities) through service organizations, including the whole range of electron-beam mask-making and CAD houses to industrial gas and equipment support organisations." (Confidential corporate study of possible European locations, 1984)

This corporate comparative study also indicated why a number of the subsidiaries in Scotland had become global suppliers for the corporation. Reduced capital costs and wages and salaries lower than those in the US combined to produce lower production costs in Scotland than in the US, even for the most sophisticated chips. Labour costs, while not the biggest component in total cost, were still considerable. In Scotland they were 25% below those in the US. Total cost for an advanced assembly and test facility in Scotland reached only 77% that of one in the US. It was further assessed that a fabrication facility in Scotland would offer the same cost advantage. The corporation soon after began building a full fabrication plant.

Corporate management considered more than the short-term, calculable operating costs in decisions to upgrade the role of the subsidiary in Scotland. Tapping Scotland's technical labour supply - both graduates and experienced professionals - generated its own dynamic. Corporate managers, eager to move activity out of California because of the high turnover of technical personnel, faced severe international competition for technical personnel. They considered it important to create conditions in their other facilities that would attract good talent and would inhibit turnover. Devolving new products and design and development responsibilities to the Scotland subsidiary was at least partly to give professionals in the subsidiaries work they would continue to find interesting. In one semi-conductor firm, the production manager explained that the plant's technical professionals were pressuring corporate management to build a planned European design centre on-site. These professionals wanted opportunities to enhance their career ladders internally.

> "We don't like to be seen (by corporate management) only as hewers of wood and drawers of water."

Similarly, a manager in a start-up computer firm explained that the firm planned to expand its development work soon because of

> "the influence of the people we've hired here for manufacturing. [Our technical employees] have come from state-of-the-art manufacturing environments and have brought with them greater technology and process experience than our company has [formerly] had."

The technical professionals, only too aware of the boom-and-bust nature of the industry, were also concerned about job security. They wanted corporate management to demonstrate corporate commitment to the facility. Adding research and development resources was known to improve the technical synergism of a facility. (Ie personnel were able to improve production performance faster due to the interplay between R&D and manufacturing; Haug, Hood and Young, 1983.) Allocating product development resources would be seen as a corporate commitment to the growth and future of the plant in Scotland. Locally available grants and financial aid reduced the cost and risk of decentralising these expensive activities to Scotland.

The education and training facilities, state incentives to capital-intensive multinational investment and the developing infrastructure to serve the high tech industry made Scotland an exceptional location in the early 1980s. These resources made starting up and operating in Scotland smoother, less risky and less costly than in most other places in Europe. There were few locations anywhere else in the world - except perhaps Singapore - that offered the industry an experienced labour pool, resources to support flexibility and growth, and such a wide range of cost-reducing opportunities.

5.6 SUMMARY AND CONCLUDING POINTS

Findings Contrary to the PLC Hypothesis

This survey describes a cluster of predominantly US multinational subsidiaries in Scotland that are considerably different from what the product life cycle (PLC) theory of overseas multinational investment would predict. Capital investment in the subsidiaries in Scotland was more modern and sophisticated with respect to the parent's home base manufacturing plant than the theory suggests. The production technologies were in most cases as advanced as those in the home base facilities and, in many cases, particularly those where the parent had made a substantial new investment, the technologies were state-of-the-art with respect to both the individual corporation and the industry.

These technologies were necessary because the increasingly sophisticated international markets - particularly for capital goods - demanded up-to-date, high quality and customised products that in most cases can only be produced with modern equipment. As a result, the subsidiaries had responsibility for major new, growth products. Some of the survey firms were one of only two or three in the corporate network assigned to supply those products, and they were produced at a sufficiently high level of specification and quality to second source the home base economy (US and Japan). Many had global, single source responsibility for products.

The products were information-intensive: they either embodied or had to process appropriately the information needs of the customer. With the information requirements of past and potential customers changing and growing increasingly complex daily, the market was one of continual and fast-paced change. Throughout the study period, new demands for the performance of a technology and new ways to meet those demands - ie new, competing products - surfaced in the market. The products and the techniques that produced the products of the established multinationals had to be able to change in response to that competition.

While Vernon suggested that such a volatile period would surround the introduction of a new product, the uncertainty and change was, in his view, restricted to the first phase in the cycle. Change was not a continuing variable in the system. However, the findings reported here suggest that the volatility and the necessity for corporate adaptiveness was part of the nature of these information-intensive product markets. End-users buying expensive capital equipment would be unlikely to invest heavily in equipment that was not tailored to their complex and specific information requirements. The manufacturing facilities had to have a continuing flexibility in capital equipment and personnel to assess and respond quickly to meet these changing market needs and to make sales. The subsidiaries had to do more than manufacture: they also had to service their regional market. The facilities had to have the personnel to offer customers help in implementing the use of new equipment and guarantees of quick repair.

Market demands and competitive problems compelled investment in computerised systems that promised economies of throughput, rather than scale. That is, technologies and people had to be capable of producing small batches of variously-specified products quickly, effectively and at minimum unit cost in an industry where all the production inputs was rising. With its location in the European market and the regional capital grants and high techonology infrastructure, the subsidiary in Scotland became important in helping the corporation respond to the severe pressures to economise on time and on the use of capital and information.

Inadequacies of the Product Life Cycle Theory

Vernon's (1964) theory cannot explain this pattern of multinational overseas investment. While Vernon's work was clearly stimulated by his view of the importance of the internaional business organisation in the post-World War II world, he did not envisage the development of a truly international market. His reconsideration of the PLC theory in 1979 did concede that income disparities that had formerly set the US apart from the rest of the advanced industrial world had diminished. When paired with extensive experience overseas, he realised that multinationals might not wait as long as he supposed to invest in manufacturing overseas. However, he maintained a rigid concept of a geographically hierarchical staging of global investment.

A market that is so internationalised, however, weakens the economic rationale for this model. Information about new technologies is now diffused at least throughout the advanced capitalist world almost instantaneously - through information technology firms, many of which are multinationals, and through the trade press which operates globally. The failure of firms to supply newly capable capital equipment to industries throughout Western Europe and Japan once it is introduced in (for example) the US, would enable competitors to capture those overseas markets. That would be a costly mistake for firms striving to establish and capture the widest possible market base to support those new products. The competitiveness and speed of change in high tech markets had driven firms to establish their presence in and communications with potential markets to exchange information about the technologies and to respond quickly to produce to meet identified customer needs as soon as the product is manufacturable. Those pressures seem to have induced management to invest rapidly in major markets to exploit economies of information, rather than wait. Flexible manufacturing makes this feasible.

Product standardisation was a central assumption of the PLC theory. Producing customised technology-intensive capital and intermediate goods, however, alters the dynamics of overseas investment. The economic rationale for delaying direct overseas investment was, according to Vernon, to wait until there was a well-defined mass market overseas so that economies of scale for standardised products could be identified. Investment overseas would also be delayed until it was clear that the mass market in the home base economy was sufficiently big that losing exports as a result of an expansion overseas would not jeopardise domestic scale economies.

However, the part-process and/or clone manufacturing facilities that were conventionally the overseas outposts of multinationals are too rigid and limited in scope to serve markets demanding high technology customised product. The separation and geographical dispersion of production stages that achieved economies of scale for standardised products create diseconomies of time, of capital use and of skilled personnel that management found unacceptable in a regime of rapid change. Customers were no longer satisfied with standard products and were demanding customised commodities. They also expected their supplier to provide technical services as well as the hardware. Buyers wanted computers, for example, reconfigured to their needs or the software for a chip or computer developed for their specific application. With the anticipated growth and market dominance of customised product, relying on standardisation and associated rigid production organisation was no longer a viable competitive strategy.[46]

Computerised manufacturing equipment in principle[47] enables overseas investment without waiting for a critical market size. One installation of capital equipment can manufacture many product variations by adjusting the software program. Small batch production becomes economically feasible if the market is big enough to provide many customers. But the adequacy of the equipment, its operational reliability, the speed and sureness of resetting between orders - the economics of throughput - become the critical factors determining viability and competitiveness.

Given these competitive demands, the overseas subsidiary must have the advanced equipment capable of both more reliable performance and flexibility and the skilled personnel and autonomy to use the equipment fully and to serve a market where continual change is anticipated. The standardised manufacturing branch plants of Vernon, Hymer, and Froebel et al - the 'headless, heartless' overseas outposts of the corporation - would in most cases be a liability in these fast-paced and highly contested markets.

Implications for the Theory of the Multinational Corporation

These developments in the high tech electronics industry suggest that industry distinctions are sufficiently significant to discredit efforts to construct an all-industry ahistorical model of the global structure and economics of the multinational corporation. The pace of change in the industry had been phenomenal. The capabilities of the technologies and the expectations of the market have changed yearly, even in the older computer industry. Also the market power and position of individual competitors have shifted almost yearly, altering the economic necessities and strategies of the corporations. Vernon's static, ahistorical model assumes that firms invest overseas to protect and continue accruing the benefits of their undisputed oligopoly power. This ignores the potential of new technology developments to challenge that market power in any one regional market and around the globe.

Overseas investment cannot be explained solely (as seems implicit in Vernon) by management desire to increase monopoly profits (by increasing revenues) or to improve profit margins (by reducing transaction or unit labour costs). Corporate management has to generate sufficient revenues to support their rising threshold of R&D and operating costs to stay in the market. Increased specialisation, customisation and competition in each market segment has necessitated a presence in global markets to generate both the revenue and the information to continue to compete. With the Japanese (and other East Asian markets) still excluding US competitors and the US market under attack by the same foreign producers, US high tech multinationals must create and exploit all significant markets globally as soon as new products are introduced to create sufficient revenues for cash flow and continuing investment. The pace and dynamics of high tech electronics industries call for a reformulation of why and where corporations invest internationally.

There are, however, two ways that the timing of my research may have exaggerated the importance of the rapidity of change and of market pull in fundamentally criticising Vernon and Hymer's theories. First, the field survey was during a period of rapid growth: a deep recession followed soon after. Second, the potential for significant US Government intervention to protect the US microelectronics industry would significantly alter the economics of investment, growth and globalisation.

The period of my field survey was one of dramatic attempts by US firms to catch up in technological capability and market share after the recession. Scotland was a growth centre for the industry in part because, as explained above, it offered support for rapid start-ups and room to grow - in terms of space and available labour supplies. This period of dramatic expansion was quickly followed by two years of the most severe slump in industry history. The recession robbed firms of two of the only five to eight years of product saleability for amortising the expense of the new capital equipment.

The recession may have significantly altered corporate strategy as it undoubtedly altered R&D expenditure, relative market positions and competitiveness. Companies may have responded to their dramatically changed world by trying to slow down the breakneck pace of change. Firms may have decided that participating as market leaders in cutting edge product markets was too expensive and risky a strategy to sustain. Companies may have switched to market segments with lesser technological demands or markets where demand would not change very fast. For example, to compete for major telecoms and many military orders, firms have to guarantee to supply the product for anywhere from ten to thirty years. If this kind of change, maintaining production capacity over such a long period, were widespread amongst US market leaders, the pace of technological change would inevitably slow down. As a result, this would reduce the economic importance emphasised here of factors specifically supportive to the rapid exploitation of investments overseas.

Investigating actual corporate responses to the economic changes after 1984 is beyond the scope of this research. The likelihood of the scenario above is not known. However, even this kind of change does not alter the importance of the finding that mass production is no longer the inevitable and sole aim, much less the mature stage of, global production relations. The information content of products, thus the necessity of customising them to customer uses, demands flexible manufacturing techniques to allow variability for batch production (even if the batches are very large). Vernon's and Hymer's theories rely completely on standardised, mass production. Allowing for continuing product variability in all markets means relying on a larger proportion of technical personnel overseas than Vernon and Hymer anticipated and the absence of any economic rationale for a global hierarchy of production (except by major differences in market needs) and the rigid staging of overseas investments. The high tech industry still fundamentally challenges the adequacy of the PLC theory.

Second, the US microelectronics industry, led by merchant semi-conductor firms, has been actively lobbying for greater protection from the US Government. The seemingly unstoppable competitive challenge by Japan to US firms' survivability (Defense Science Board, 1987) combined with the damage of the recession to rally the industry to press the Administration and Congress to intervene and restrict imports, promote exporting opportunities and provide new ways to finance and organise R&D. Predicting the form and extent of intervention that will result from the strong protectionist mood in Washington in 1987 is impossible. As a result, it can only be said that most policies if enforced will influence the dynamics of the global microelectronics industry and in particular will likely alter the persuasive economic advantages and the timing of investing overseas. These potential structural changes do not, however, alter the continuing importance or character of major overseas markets and the necessity to serve them with advanced, flexible manufacturing and technical support capability. Government policies may alter the structure of these global markets but not their nature: state intervention in the US is unlikely to bring a return to markets for standardised high tech products and with a slower receptivity to technological advances. Only that would help restore the explanatory power of Vernon's and Hymer's theory of multinational investment.

Another issue this research raises is the heightened tension between centralised control and decentralisation within these multinationals. While control by headquarters remains central to competitiveness - to minimise production costs globally and to exploit market information rapidly throughout the corporation, devolving technological and administrative responsibilities to the subsidiary is essential to the corporate aim of finding, creating and exploiting markets quickly. Managers in survey interviews gave the impression that the 'rules' for centralised control and devolved responsibility were confused and in flux. How the conflict is resolved (if it is resolvable) at the level of the individual corporation and the industry is an important area for future research. The competitive advantages of flexible and knowledgeable responsiveness to market changes embodied in the models of flexible specialisation (Piore and Sabel, 1984) and decentralised continuous processing (Hirschhorn, 1984) may prove to be extremely powerful if the momentum of technological and market changes continues. It is significant that the people lobbying for the subsidiary's greater technological autonomy are the technical and managerial professionals with market and technological knowledge and skills that corporate management considered so critical to continuing competitive viability. Such a tendency would, however, significantly alter the mobility, the interests and the economic coherence of the 'multinational corporation' as an operational institution of capital accumulation.

CHAPTER 6: SEGMENTED LABOUR MARKET THEORY AND THE MICROELECTRONICS MULTINATIONALS IN SCOTLAND, 1979 - 1984

6.1 INTRODUCTION

This chapter examines the relationship of the survey's high tech multinationals to the Scottish labour market. Research findings on recruitment, employment and training practices of the survey's firms indicated corporate strategies that were not consistent with the DLM theory. Competitive pressures had driven management to reconsider how to organise work. New strategies did not, however, develop in a vaccuum. The specific conditions of the labour market in Scotland were very important in shaping those strategies and offered cost-minimising opportunities that proved competitively valuable in responding to global crisis.

The theme of the chapter is of a dynamic relationship between the region's industry and the local labour market, a possibility that the demand-side DLM theory excludes. While there is more to Scotland's high tech industry than the fourteen multinationals in the the survey, these firms clearly dominated the labour market. They employed a large and growing share of the electronics labour force. As Table 6.1 shows, that strength increased with the industry expansion of the 1979 - 1984 period.

A few large electronics firms - Ferranti Ltd. and Racal-Mesl Ltd. - and the printed circuit board manufacturers, Exactacircuits Ltd. and BEPI Circuits Ltd., were also part of the region's high tech sector. While their relationship to the local labour market was undoubtedly important, they were excluded from the survey because they were essentially British defense contractors and thus cushioned from competitive pressures. Most of the rest of the industry employment was in supplier firms (eg mask-making firms, computer cable and harness companies, etc). These were mostly quite small - 3 to 50 workers, according to survey data. The small supplier firms added

TABLE 6.1. EMPLOYMENT GROWTH IN SCOTLAND'S MICROELECTRONICS INDUSTRY, 1979 - 1984

High Tech Multinationals and the Wider Electronics Industry

		1979	1984	% Increase 1979-1984
TOTAL EMPLOYMENT				
a)	My sample	9855	11007	+12%
b)	Electronics industry*	37100	35500FC	- 4%
(a) as % of (b)		27%	31%	
ENGINEER AND TECHNICIAN EMPLOYMENT				
a)	My Sample	1816	2825	+56%
b)	Electronics industry**	4800	6550	+36%
(a) as % of (b)		38%	43%	

* Source: Employment data for the region's wider electronics industry derive from the MSC for Scotland (1983); 1984 employment figure is actually a forecast for 1985 employment.

** Source: MSC for Scotland (1983) using actual survey data for 1979 and predictions for 1984 based on annual recruitment rates (1983).

only a small number of new jobs. Consequently, employment change in the survey multinationals dominated industry activity. Furthermore, the survey multinationals had economic clout that exceeded their share in regional employment. These firms held the greatest promise for creating future jobs in the region (BAH, 1979). They also were global market and technology leaders. These firms, while few in number, clearly shaped the development of the region's labour market.

The first section of this chapter reports survey findings on company employment practices and the structure of work. The structure of work refers to how work is distributed amongst workers and, thus, is a relational concept - how workers relate to one another. The rest of the chapter analyses first the demand pressures, then the importance of regional supply-side conditions in framing multinational technology and employment strategy.

6.2 RESEARCH FINDINGS

Management Strategies to Gain Employment Flexibility and Stability

For DLM theorists, employers reap significant economic benefits by segmenting jobs and workers into non-competing, exclusive groups. The segmentation occurs both within firms and between an industry's big and small firms (the core/periphery divide). This hierarchical organisation of employment outlined in the DLM theory is entirely consistent with that of the PLC theory where the hierarchy is a global one: branch plants of a multi-plant corporation are often designed to rely on `secondary' employment, while primary jobs are concentrated in headquarters and home base advanced manufacturing plants.[1] This implies that overseas multinational subsidiaries would employ predominantly semi-skilled labour, along with only the small cadre of managers and skilled workers necessary to carry out standardised mass production for regional markets. Though there were a few exceptions in the computer industry, this had been the case in Scotland during the 1970s.

My research in the Scottish high tech electronics industry indicates that corporate management had, in contrast, been striving to find new sources of employment flexibility: the Scottish labour market offered them unique ways to cope with the concerns that had come to dominate management's agenda - rapid market and technological change. Managers had begun to believe that a more collaborative and less rigid organisation of work would create high productivity within the new dynamics (and constraints) of competition. To achieve this new work atmosphere, managers had sought to remove many of the barriers that had existed in the distribution of work across the work force and to alter their reliance on the external labour market by redefining recruitment procedures, required qualifications and target populations. As an example of that organisation, the Japanese firm had structured work to enhance and exploit the knowledge and experience of every worker. This was a structure of work far different from the tradition of the industry.

First, in line with the technology and product decentralisation reported in Chapter 5, the employment profile of high tech subsidiaries had changed markedly by 1984. Managers, professionals and technical employees had increased as a proportion of subsidiary employment: they were needed to carry out the more demand-responsive role of a subsidiary located in a highly contested market. During the industry's phenomenal expansion in 1983/4, primary jobs were the focus of company recruitment drives. In fact, in three long-established firms in the region - where employment had historically been dominated by semi-skilled employment, managers had not hired any production workers. They competed in the external labour market to hire engineers and technicians, and filled every vacancy for a semi-skilled worker with an engineer.[2] Table 6.2 shows that professional and technical labour had by 1984 become about one-third of the work force.

Because the figures below refer to total site employment, they mask the new and increased importance of technical labour in new company investment. Technical jobs clearly dominated the employment associated with the more technologically advanced expansions. Engineering and technician jobs comprised 60% of the employment in the new automated assembly of one semi-conductor firm. National Semiconductor, for example, announced that 50% of 1000 additional jobs would be for technical personnel (30% engineers, 20% technicians; Large, 1984). A planned subsidiary of International Microelectronics Products, custom chip producer, was expected to employ a large work

TABLE 6.2. OCCUPATIONAL DISTRIBUTION OF EMPLOYMENT IN SCOTLAND'S HIGH TECHNOLOGY MULTINATIONAL FIRMS

Percent of Total Site Employment in Scotland
Computer and Semi-conductor Firms

	% 1979*	% 1984**
Managerial^	5	5
Engineers+	11	17
Technicians	10	11
TOTALING	21	32
Semi-skilled Production Workers	40	36

* Includes 9 Firms
** Includes 12 firms

^ There was no consensus amongst firms on the definition of management. The problem arises because most of the industry's management are engineers who may continue in engineering and almost all but the most recently recruited engineers have some management responsibilities. To simplify, the survey asked for the numbers of top or senior managers. As a result, the numbers of people employed as managers, thus the numbers in primary jobs may have been underestimated if engineers serving as managers were not included in the data on engineer employment.

+ Includes software and computer professionals who may not, strictly speaking, be software engineers because of the confusion in the ocupational terminology. Because of that confusion, this likely underestimates this occupational employment: companies in some cases included these professionals in support staff employment and the data could not be disaggregated.

force in exactly the same proportions (Interview with SDA officials). The managing director of another semi-conductor firm claimed that the employment ratio of their new custom microelectronics systems unit was one technical person for every semi-skilled operator.

Managers in the survey, when asked to forecast their employment three to five years hence, predicted the proportion of engineers and technicians would continue growing, with increases in the annual recruitment of technical personnel and in many cases the continuing contraction of semi-skilled jobs. The director of a custom chip and microelectronics systems company predicted that 65% of his 1990 work force would be technical labour (with managers adding another 10%).[3]

This proportion of managers and technical labour in subsidiary employment in Scotland did not differ significantly from that in the home base economy. Table 6.3 shows that managerial and technical labour shares of

TABLE 6.3. OCCUPATIONAL DISTRIBUTION IN THE US COMPUTER AND SEMICONDUCTOR INDUSTRIES

- Massachusetts -

	Percent of Total Employment		
	Office, Computing & Accounting Machines SIC 357		Electronics Components & Accesories SIC 367
	1980*	1983**	1983**
Managers	9.9	12.5	10.1
Engineers	10.5	11.9	6.3
Technicians	8.4	9.2	7.0
TOTAL:	28.8	33.6	23.4

SOURCES: * Kuhn, 1982, pp. 93-4;
** DES, 1985, pp.188-9 and pp.206-8.

employment in the industry in Massachusetts ranged between 23 and 34%. Data from Massachusetts provides a useful comparison because the state has a high concentration of US high tech employment and of R&D and advanced manufacturing activity (while electronics employment in California is more diversified). The higher concentration of managerial jobs in the home base economy accounts for most of the difference between Scotland and the US.

Employment in these subsidiaries was no longer simply `secondary' jobs. Management needed more and more technology-trained workers to perform the tasks demanded by highly competitive global markets. As a result, management at headquarters could no longer expect to maintain continuous and tight control over the subsidiary or the growing number of college-educated and technologically-sophisticated employees. This work force could not be treated as peripheral or expendable labour, as the DLM theory would predict.

6.2.1 Removing Barriers Between Engineers and Technicians

Management in a number of companies had decided to establish (or more probably allowed) a more flexible work structure to accomplish the upgraded technology and market responsibilities of the subsidiary in Scotland. Worried about very short timetables for expansion and producing new products, managers reached across occupational barriers to deploy both engineers and technicians to get work done quickly. Interviews indicated that managers often considered highly trained technicians and engineers interchangeable. For example, managers frequently referred to both engineers and technicians as their `engineering talent' when allocating work and considered both bachelors degree and advanced technician course graduates in the same labour pool when recruiting (See Appendix 4 and discussion below for explanation of technology-related qualifications.) The complexity of tasks assigned to and the autonomy allowed an engineering employee depended on the individual's background and merits, product requirements, pressing schedules and the firm's difficulties in hiring engineers and technicians from the external labour market. Many managers reported either hiring higher grade technicians as engineers or gradually moving technician employees into engineering work.[4] Technicians with a qualification that included programming, for example, experienced a range of employment opportunities associated with the increasing importance of testing and the industry's heavy investment in ATE (Interviews with technical college faculty; Marshall and Brisbane regional labour market report, 1984).

Assessing the extent to which, for example, technicians had been given engineering responsibilities would require detailed research on the labour process in each firm, a task beyond the scope of this study. Attempts to estimate a shift of work to technicians by associating changing occupational distributions with changing plant activities proved impracticable: managers idiosyncratically and inconsistently interpreted technical qualifications and job titles, making occupational distributions reliable only for general interpretation. However, other labour market studies of the region confirmed the fact that many of the people employed as the industry's engineers did not have a university degree (SEPD, 1980; Hampson and MacLeod, 1983) and that there was considerable flexibility in the way that an employee with a given technology qualification was deployed within a firm.

Table 6.4 compares an employment forecast for technical labour for the whole electronics industry and the actual employment increase in the survey multinational corporations alone. The unanticipated growth of technician employment may have resulted from management's opportunistic use of technicians in the structure of work. Technician employment in the survey firms in 1984 was almost twice that predicted by the SEPD. While the data do not offer proof, the results may be interpreted as consistent with the substitution of technicians for engineers.[5] In addition, some managers may have substituted technicians for operators to implement new production technologies.

There were also reports that some firms in Scotland had hired engineers to fill technician jobs because of local surpluses. While this was not a widespread practice, it gave the employer a great deal of flexibility and expandability in assigning work to those recruits. Employment was not linked to a job description (except in the case of the few unionised firms). Management could shape jobs to match changing product demand conditions, the individual's experience and the labour market availability of technical workers.[6]

TABLE 6.4. ENGINEER AND TECHNICIAN EMPLOYMENT GROWTH IN SCOTLAND'S ELECTRONICS INDUSTRY

	High Tech Electronics Industry Only* (1)	Electronics Industry (2)
	1979-1984	Adjusted to reflect 1979-1984
	[ACTUAL]	[FORECAST]
Engineers	+ 56%	+ 52%
Technicians	+ 36%	+ 20%

SOURCE: (1) Survey data; (2) Scottish Economic Planning Department, Scottish Economic Bulletin, December, 1983.

* While the SEPD looked at employment prospects in the wider electronics industry, the small number of high tech electronics firms in my sample (12 by 1984) accounted for almost half - 43% - of the job growth in engineering jobs and 55% of that in electronics technicians in the region.

Also, many employers had created or were considering adding a new job title to maximise their flexibility in using qualified technicians. 'Lower-level technicians' were being trained to do the more routine technical and clerical tasks - delivering materials to machines, recording process flows, cleaning equipment, etc. - to free qualified technicians for more complex tasks. The training on the job lasted anywhere from 3 to 8 months.[7]

This development might appear to be an effort to deskill technicians. That was generally not the case: there was no evidence of management breaking apart the technician job to eliminate it or reduce the worker's autonomy. Managers were not trying to wrest control from these workers because of their technological and economic power in the firm, as suggested in Braverman's hypothesis (1974). The objective here was to utilise more fully (and profitably) the expertise of workers with formal technological qualifications. By removing the more mundane tasks, the technician's time was freed to repair more equipment and to concentrate on technological problem-solving, including taking on engineering tasks.[8] The reallocation of tasks amongst jobs or workers, then, was designed to enhance the opportunity for a qualified technician to use and improve more complex skills and knowledge, not to deskill the job.

Of course, this new structure helped reduce the firm's demand for qualified technicians (or at least the increase) and reliance on the external labour market. Managers could minimise their recruitment of more expensive and relatively scarce formally-trained technicians[9], and as a result, moderate the cost and time requirements for expanding and/or modernising. The new job, however, was not a major new source of employment: even the largest employers had only 20 engineering clerks.

6.2.2 Altering the Division of Labour between Technicians and Operators

Survey interviews also revealed changes in the work organisation between technicians and operatives in a number of the firms installing new production technologies. Managers had altered the division between tasks appropriate for an operator and a technician.

> "Basically the only thing [someone] has to do is to set up the machine every time you change the product. I think you'd find that operator [responsibilities] are beginning to change. They're somewhere between

the level of technician and operator", explained the designer of a new wafer fabrication facility. `Module technologists', as they were labelled in his new production area, were responsible for the calibration of the new equipment and for watching to insure that production proceeded smoothly and correctly. At least two other survey firms reported similarly upgrading the operator job and another had been pressured to make similar changes by the trade union.[10] Traditionally an operator's job had been limited to loading the machine and watching the process.[11]

Interestingly, those firms that had created the engineering clerk job had not upgraded operators' jobs. Adding the relatively unskilled clerical job to operators' jobs deskilled by the new technologies was an alternative to the bigger training commitment and higher expectation of upgrading (See discussion below).

Giving jobs new labels - engineering aid, module technologist, setter, etc. - was not a trivial change. New job titles give employers the opening to reject tradition and to target a different labour supply.[12] They make it easier to reorganise work without apparent link to pre-existing jobs and workers.[13]

All of these changes were accompanied by policies to foster individual achievement to divert employees from focusing on the expectations and limits of a job. In many cases formal barriers such as job grades had been eliminated.[14] Even where job grades had been maintained, managers no longer used them as automatic steps for promotion or pay increases. A worker's promotion and pay were determined solely by the supervisor and manager assessment of her/his performance. They would rate performance on assigned output and productivity targets, absenteeism, attitude, etc. The highly individual merit-based decision minimised the importance of time-served or seniority.

Without job descriptions or traditional barriers between jobs, managers could define both the content of the job and the pay to reflect individual merit and company needs. Managers had assumed control over the deployment of labour. The personnel manager at one of the computer start-up firms emphasised the importance of this change:

> "[An employee] walking into this office saying, `I don't have a job description and I want one,' would kill this place."

6.2.3 New Recruitment Strategies

Management concern to exploit this employment flexibility (or at least recognition of the new potential for flexibility) had altered recruitment strategies for much of the industry. Managers consistently emphasised newly important qualities when hiring new employees, and research indicates that managers were targeting non-traditional populations to fill the industry's jobs.

Personnel managers, college lecturers, and regional JobCentre managers underscored the qualities the industry valued - intelligence, `fit' and commitment to paid employment. The screening mechanisms, however, varied with the occupation.

Management had revised selection procedures to reflect the concern to hire intelligent workers at all occupational levels.[15] At the operator level most of the survey firms required the equivalent of three to five O levels. In one survey firm requiring a minimum of four O grades, a manager explained:

> "With the very high volumes we have the job requires a high level of awareness of what is going on, a very high degree of understanding the process. It is not just as assembly process. So they are responsible young people, they read their newspapers." (Wattie, 1984).[16]

This selectivity contrasts sharply with the 1970s when neither level of schooling nor achievement mattered, and employers did all they could, such as setting up part-time working patterns and mothers' shifts, to create and attract unskilled labour to support the industry's growth.

For technician and engineer jobs, college and university students were interviewed in the annual milk round and only those with top marks were hired into the multinationals.[17] Managers claimed to be unwilling to make concessions for an excellent academic record; they claimed to delay hiring if they could not recruit satisfactory `quality.'[18]

An applicant's suitability for work in the industry was a very important criterion when selecting new employees. Managers valued the qualities of being able to communicate and being sociable as much if not more than academic qualifications.[19] They looked for friendly, neat and articulate people when interviewing for operators. Weeding out haphazard, highstrung and uncommunicative workers had become more important as the new technologies demanded greater precision and watchfulness.[20] For technical jobs, managers were looking for people who could discuss clearly and easily the technical issues of the job, who took directions well and who could cope with the industry's high level of stress. In interview after interview, managers claimed to have hired as technicians young people who had no technology-specific qualifications yet who seemed to be `a good fit,' even though this required the firm's commitment to train the unskilled candidate for months if not years.

> "We're more concerned to find `the right person', to get someone of admirable qualities and to train him [sic],"

according to the managing director of one of the survey firms.

Employment stability, as well as flexibility, was of paramount importance in *all* occupations. Because of the high information and experience content of the job, the critical ingredient for high quality and high productivity performance was low turnover amongst both production and technical workers. Four firms had lifetime employment or no redundancy policies for all permanent employees. Also all the survey firms gave preference to applicants who were referred by family members who were already employees.[21] Having relatives nearby was thought to indicate an applicant's commitment to settling in the area. The firms also used the related employees and their work records to gauge the employability of the applicant. Once hired, relatives would help ensure that the new employee would be a disciplined and reliable worker.[22]

> "The more names [of relatives already employed here] you put down on the application form, the more likely you are to get hired,"

confirmed a personnel officer in one of the region's largest firms.

In recruiting technicians, geography figured more prominently than in earlier years. Managers in many of the firms had recently decided to restrict their search for technicians to nearby technical colleges. Scotland- and UK-wide recruitment had brought in young people who recognised their mobility and too frequently wanted to move back home after only a year or two of employment.[23] By restricting the recruitment area, companies aimed to hire people wanting to settle in the area. The locus for recruiting production workers had never been larger than the local community or a distance of five to fifteen miles.

There was also evidence that management had become much more thorough in investigating workers' backgrounds, particularly when recruiting production workers. The companies wanted proof that the applicant would be a stable, dependable worker. Recruiters tried to determine if applicants had a stable family and school history and if they were happily married. Women with children had to convince managers they had reliable child care to be considered, and women applicants were often asked if they were pregnant or had plans for children.[24] The routine medicals required for production workers before they started work usually included a urine test. This allowed employers to verify that the women weren't already pregnant.

Because low absenteeism was so important to production quality, management was looking for a long-term commitment from production workers. A number of the firms had a policy of hiring production workers first as temporaries. This practice was used to ensure managers that the worker was well-disciplined and productive before making the financial commitment of an employment contract. After six months or a year, some of the temps with good performance records would be offered permanent jobs.[25] This practice also served to discipline the rest of the workers by reminding them that there was competition for their jobs. This in effect applied harsher secondary labour market practices against the firm's secondary workers. This practice represented a new duality in labour market practice. While long a defining feature of the global division of labour between core and peripheral (eg Far Eastern) economies, the use of temporary workers was not common amongst employers in the UK.

As a result of all these policies, the regional industry reported extremely low turnover and remarkable productivity records. An SDA official claimed that total turnover in the semi-conductor industry was only 4% p.a., though the rate was higher for engineers and technicians (approximately 10 to 15% p.a., 1984). NEC claimed the firm had had no turnover and Motorola's per annum statistic in Scotland was the equivalent of *one month*'s staff loss in the US (SDA, 1983A). Managers in five survey firms boasted that the productivity record of the Scottish plant far exceeded other plants in the UK, Europe or even the US, attributing the success to low turnover.[26]

6.2.4 Changing Target Populations

Employers had begun looking for new populations to fill the industry's jobs. Having recognised these newly important labour qualities, managers selected new labour market segments as appropriate for industry work. Scotland's labour market made these shifts possible. There were two major strategic changes that were surprisingly consistent across the survey firms.

First, employers concentrated their hiring on young people without experience for all occupations rather than competing for experienced workers. For technical personnel, managers had adopted a policy they called `growing their own': they hired graduates directly from university or college and trained them in-house for the job. This training was very expensive. It took 18 to 24 months of on-the-job supervision supplemented by college and corporate short intensive courses to prepare an engineering graduate for a high tech job. Similarly, new technicians recruited from an academic course were usually trained for three to four weeks at the plant of the equipment suppliers, and often received further training once in the job. As mentioned earlier, managers were even willing to train unskilled recruits as technicians, requiring usually one month's intensive induction training off-site followed by three to four years of on-the-job training and day release for a course at a local college. Because of the industry's newness to the region, the local labour market did not have an adequate supply of technicians and engineers with (three to five years') experience with new technologies. In spite of the expense, managers viewed this "hiring lower on the skill chain", as a labour market expert called it, as cost-effective. It minimised the firm's wage bill, reliance on poaching[27] and costs associated with high turnover, such as escalating salaries.

Every multinational also had a policy of hiring young people for production jobs.[28] This was a major departure from the past: high tech production workers and `married women' with school-age children had been synonymous in the Scottish industry. Managers differed in opinions about how young. A few firms had hired school-leavers, but most preferred youth with some labour market experience so had a minimum age of 18, 19 or even 20 years old.

This was a relatively recent change at the time of the survey and was most marked in the start-up firms: one 1982 semi-conductor start-up had a 150-strong work force with an average of only twenty years of age (1984). For at least two of the firms, the strategy of hiring young people was not a global corporate strategy, but the result of a decision taken specifically in response to the labour market in Scotland.

Managers preferred young workers because they had no bad or out-of-date work practices to unlearn:

> "We're hoping to attract people
> who are new and bright and shiny."

Young people were also more likely than those with child care responsibilities to be able to change shifts, to travel abroad for conferences, consultations or training and to adjust to long working hours with ease. "This is a young person's industry", confirmed the head of a prominent technical college's electrical engineering department. He claimed that his staff counseled people over 25 years old against enrolling for training in electronics because of the strong industry's bias toward young people.[29,30]

Secondly, men were increasingly being hired into production jobs which had in the past been exclusively female work. All but one of the survey firms (1984) had at least a few men working as semi-skilled operators and assemblers, a practice unheard of a few years previously.[31] In six of the eleven survey firms providing gender-specific data, men were at least one quarter (and up to 86%) of the semiskilled workforce, as shown in Table 6.5.

TABLE 6.5. MALE WORKERS AS A SHARE OF THE PRODUCTION WORK FORCE

Survey Firms	Male Workers as Percentage of 1984 Production Employment
Computer Firms	
Company A	32
Company B	13
Company C	2
Company D	66
Company E	25
Company F	50
Semi-conductor Firms	
Company G	0
Company H	86
Company I	15
Company J	5
Company K	4
Company L	2
Company M	53

SOURCE: Field Survey, 1983/4

The shift to male workers was the most marked in the start-ups and in newly built portions of existing plants. For example, Companies F and M, a computer and a semi-conductor start-up firm, respectively, had hired men in half of their production jobs. Similarly, fifty percent of the production work force in Company I's most advanced chip fabrication wing was male: in older fabrication wings the work force was 100% female. Also, most of the assemblers in Company D's new highly automated microcomputer facility, a separate building added onto a long-established computer plant, were men.[32] The firms hired men to staff the new technologies.

In contrast, technical jobs had always been `male': men had overwhelmingly dominated engineering and technical jobs since the beginning of the industry. That was the case in Scotland as it was around the world. There was little change during the study period. Of the ten survey firms providing gender-disaggregated employment data, five had no woman engineers and four had no women technicians in 1984. Those firms employing women in technical jobs had very few. Ninety-seven percent of the industry's almost 1000 engineers were men and 91% of the approximately 900 technicians were male.

6.2.5 Eliminating Career Ladders

Grades, promotion paths and rules for progression had disappeared, even in the union shops. Managers had eliminated automatic grading increases and promotion steps by substituting a highly individualised relationship between a supervisor and her/his workers. To earn a pay increase or to advance, an individual had to be selected by a supervisor because of performance and attitude. Firms had reduced the number of layers in the occupational hierarchy: this eliminated many of the relatively few jobs, such as leadgirl and supervisory jobs, that were the traditional opportunities for production workers to escape their occupational ghetto. Supervising had in many cases been added onto the other responsibilities of technical staff. Technicians were assigned first line supervision of the workers on their machines, and the process or area engineer was the personnel manager for the group. In those few firms keeping the traditional supervisor jobs in production, recruitment for them was no longer exclusively from amongst production workers. People from other parts of the plant and often from the external labour market were hired. This eliminated job ladders in production. Formal job paths out of semi-skilled work had been reduced or eliminated or the jobs themselves were severed from their traditional internal labour markets.[33]

While management had in many cases trained workers for a variety of jobs, there was no association of promotion or pay with the addition of new tasks.[34] Workers were cross-trained to do a number of process tasks in chip fabrication, and in the computer industry workers learned both a variety of assembly tasks and clerical work in inventory or materials handling.[35] Training for each semi-skilled job was limited to learning the assigned manufacturing task, which usually required two weeks or less.[36] This so-called multi-skilling enabled management to train enough people to cover for absent workers and to adjust to demand shifts. It was not upgrading; it was only horizontal movement among parallel jobs.

> "[Cross-training] creates more interest for the operator and the operator sees herself getting a promotion with it",

as the managing director of one of the integrated circuit firms explained. The semi-skilled worker gains the _feeling_ of being promoted without any actual improvement in status or earnings.

In dealing with technicians and engineers, automatic progression through gradings or job titles was very rare. (Only two firms had unionised engineers.) Salary increases and job advancement were similarly based on the individual's performance and relationship with the supervisor.[37] While most engineers (and some technicians) were given management responsibilities, they referred in many cases to assignments for specific projects or part-projects. That meant, firstly, that it was difficult to compare across inidividuals and work areas (except by the number of people supervised), and secondly, the responsibility terminated with the end of the project or project phase. The additional responsibilities did not necessarily signify job enhancement or permanent progression in the hierarchy.

Engineers and technicians were frequently offered training and skill upgrading, but these opportunities were not linked to a change in grade, a promotion or a pay rise. Most of the training opportunities were short-term intensive courses to give employees the knowledge to handle a specific new task or new technology.

Management had prioritised and invested heavily in quick fixes of training for short-term adjustment to market and technological changes. New technical personnel and highly skilled and experienced employees were sent on technical courses throughout their employment in a firm. The courses typically lasted only two to five days.[38] Managers in all the survey firms encouraged and sponsored technical employees on specialised technical upgrading courses arranged outside of working hours. Employers also sponsored some professional workers to take degree courses part-time.

Technical employees expected training opportunities as part of their employment contract and viewed them as important benefits in highly competitive occupations. These new opportunities gave them up-to-date information on the newest technologies, making them more saleable in the external labour market. Company managers financed continuing training opportunities for technical personnel who were critical to ongoing and future operations of the plant as benefits and rewards to enhance their jobs and to retain their loyalty.[39] Providing training and upgrading gave these workers career development opportunities inside the firm, discouraging their need to move to competitor firms to get better jobs. However, there was no automatic link between gaining additional expertise and a pay increase or promotion.

The leaders in the region's high tech industry had, in addition to the efforts inside the firm, actively lobbied for more training opportunities and shorter courses appropriate to industry needs. Through petitions to the British Government, participation on public industry-related boards and curriculum development committees and countless informal communications with regional universities and colleges, industry managers had pressured public institutions to enhance and expand offerings for technical qualifications and shorter technology programs in a variety of formats. In addition one corporation had received SDA support to open a school to provide training for industry operators and assemblers. The course was intended for fee-paying unemployed workers who wanted jobs in the industry. They would learn basic electronics terminology, assembly technique and safety rules, all of which had traditionally been taught in company training workshops within the employment relationship.

The elimination of clear promotion and career paths and the severing of the link between training and job grade, title or promotion represented an important new development. The vast array of training options, new hiring practices and work structures hid the fact that the few paths out of secondary jobs had almost entirely disappeared and that many of the benefits associated with primary jobs had been eliminated.

6.2.6 Strategic Consideration of The Organisation of Work

In most firms the way employees were actually deployed was left to the discretion of function managers, so were often ad hoc responses to the capabilities of individual workers. In the Japanese semi-conductor firm, however, the structure of work was the result of corporate-wide strategic planning, and the deployment of labour was considered a major factor in the firm's global competitive success.

Technology-related tasks were distributed amongst all workers, rather than being reserved for those with formal technology qualifications. That meant all workers received longer, more in-depth training to support the devolved responsibilities. By shifting "contextual knowledge" (Appelbaum et al., 1986) and responsibilities down the occupational line, management aimed to gain plant-wide efficiencies and to reduce operational dependence on expensive university-trained engineers. Japanese managers' commitment to this structure of work no doubt developed out of their unique corporate culture and history. The modern tradition of Japanese conglomerates included continual investment in technological innovation in production and lifetime employment guarantees for their workers. Inevitably these policies fostered management-labour practices distinctly different from those in US firms. Large Japanese firms extended many of the benefits associated with `primary' workers to their entire work force and shifted the primary-secondary barrier outside the firm to both the periphery of small supplier firms in the Japanese economy and to firms in low-wage economies in the Far East. However, Japanese electronics firms, particularly high tech companies, had been much less reliant on secondary labour markets than US firms. Management of labour and work, given this history, was quite different in Japanese multina- tionals.

The operators, hired with a minimum of four `O' levels in science, maths and technology subjects, were chosen because of their potential to learn new tasks; many of them had Highers. Each was trained for a number of different (though parallel) jobs in chip assembly.[40] Managers selected experienced operators for more involved production jobs. These workers were then trained to be experts in their section of the manufacturing process and how to train and supervise new operators. Management also selected experienced operators for technician jobs. The firm trained them to understand one piece of equipment thoroughly and to be able to reset and perform routine maintenance and repair on that machine. Management called them `setters' to distinguish them from qualified technicians. The firm had hired only a few people with the formal advanced technician qualification to perform major equipment maintenance and repair. They were then trained in-house to assume specialised engineering roles.[41]

This firm's practice then was to offer all employees from the lowest production worker up opportunities for training and more responsible jobs. This in effect granted some of the benefits of primary jobs to all employees. However there was no promotion ladder or protocol. Decisions were taken unilaterally by management without formally specifying the criteria to employees.

The result was what Hirschhorn (1984) and Appelbaum et al (1986) would call a relatively robust structure of work. Appelbaum et al define robust and algorithmic work structures, the extreme ends in a structure of work continuum, in the following way. Robust forms of work organisation are

> "designed to promote learning, flexibility and adaptive behavior on the part of workers...The defining characteristics of robust forms...have to do with the relationships among employees at different levels of the firm. Confidence in workers at lower levels allows managers to hand off problems ...to lower levels for solution while freeing those at higher levels to develop new products and markets...[T]he more common, algorithmic form of computer rationalization accepts only preselected information and reduces worker initiative and knowledge of the production process... [C]omputers [are used] to limit the possibilities for decision-making and creativity in the jobs of operators,... technicians and service workers and to centralize and control these functions higher up in the bureaucracy" (pp. 14-15).

Rigid barriers between jobs and stark differences in working conditions, associated with dual labour markets, are inconsistent with the economic and operational aims of a robust organisation of work. Its strength and economic benefits derive from all workers sharing information and collaborating in quick decision-making. Continual turnover amongst groups of workers or denial of access to training resources, characteristics of conventional secondary jobs, would make communication and collaboration amongst workers across occupations and departments unwieldy or impossible.

This firm's managers had attributed a number of benefits to an integrated strategy that combined state-of-the-art-technology investments, training, employment security and a robust structure of work. First, it dramatically reduced the number of degree engineers needed on site.[42] A group of only nine degree engineers, only 5% of their 1984 manufacturing work force, could handle all the firm's complex engineering tasks when supported by a core of eight very experienced engineers from Japan. That compared to the industry average of 21% (1984).

Secondly, management viewed internal training and promotion as a way to build worker loyalty to the firm. Workers who know that the firm is willing to reward their good performance and invest in them will, it was assumed, stay with the company and strive for promotion. The intent of the strategy - not unlike that of most of the industry - was to replace oppositional management-labour relations with a company-first attitude. This policy of continuing training/retraining supported by a guarantee of lifetime employment aimed to minimise labour turnover.

Thirdly, the worker learns to see her/himself as a part of the process: s/he identifies job-related capabilities with the firm rather than allying with an occupation or group of people. The personnel manager explained that people with formal qualifications "feel they know it all....and that [would not] fit in here." Management wanted to avoid hiring people who would have strong views about what work they should do or, because of too much attachment to a job, who would resist retraining and new work assignments. Furthermore, training focused on firm-specific skills. This enabled the firm to individualise pay decisions for a work force without formal qualifications, as well as minimise reliance on the external labour market. It is difficult to argue for pay comparability without industry-recognised qualifications.

Company management in this firm was more committed to a flexible, robust structure of work than the rest of the industry. They accomplished it by hiring an entire work force that was academically accomplished - "ha[ving] been taught to learn" - and by training them internally to minimise reliance on the external labour market. Flexibility within the firm meant the company could respond uniquely to changing market demands.[43] Each worker could be taught increasingly complex technology-related tasks as needed: to achieve this the barriers between jobs and workers could not be as rigid as was the tradition in the industry. While this may at times be slower than relying on the external labour market, the corporation had a strategy that minimised technology and market surprise, allowing longer-term employment planning.

A critical difference between this firm and most of the US firms was that management had the advantages of extensive experience with advanced technologies and a strategy that intertwined technology, work organisation and labour management. While most of the capital investments of US firms were significant technology leaps and attempts to catch-up with world technology leaders, the Japanese firm had invested in technologies and labour processes that were only incremental advances over a similar plant which opened in California in the preceding year. The corporation was an international leader in developing and using the most advanced production technologies: corporate experience with state-of-the-art equipment minimised the chances of technological surprises. Skill needs could be anticipated, enabling management to design a coherent and adaptable structure of work and recruitment strategy. In contrast, US firms' allocation of technology-related tasks to lesser-skilled or experienced workers was in many cases a hurried response to too many changes and too much growth too fast.

The system was not, however, one of significant autonomy for or control by workers. While it gave all workers a more interesting job, as well as guaranteed employment, it came with costs. To ensure flexibility in redeploying workers, management effectively eliminated skill transferability. The absence of formal qualifications eliminated guidelines for fairness in promotion. Simultaneously, workers lost some degree of mobility and inevitably leverage over pay.

6.2.7 Summary of Findings

The proportion of technically skilled labour in subsidiary employment had increased and surpassed what would be expected in offshore branch plants. Firms had hired the personnel necessary to ensure the company could accomplish the technologically sophisticated tasks demanded by the world market. The demands of rapid and large scale expansions led managers to recognise the necessity of collaboration and good will within the workplace: only in such an environment would workers be willing to deal creatively with a wide range of technical problems and to accept long hours and high levels of stress to meet deadlines. To establish this atmosphere and to benefit from a well-trained labour force, most employers had eliminated job demarcations, particularly between engineers and technicians, and were restructuring the allocation of work between the two occupations to exploit the capabilities of formally-trained technicians. Job descriptions and formal rules for promotion within the technical work force disappeared. Individual merit- and personality-based relationships with supervisors replaced rigid rules and class-based internal labour markets of most manufacturing industries.[44] Also, managers had decided to minimise dependence on experienced technical personnel: they hired people they could train and promote into jobs as their performance merited. In most firms this meant recruitment priorities emphasising suitability and potential over formal qualifications, in some cases substituting the former for the latter.

These practices were designed to exploit the capabilities of trained engineers and technicians without regard for conventional demarcations in order to cope with short-term start-up and expansion pressures and the demands of rapidly changing and growing markets. Bringing down the barriers between engineers and technicians and separating workers from identification with their occupational group allowed managers to squeeze greater information and productivity returns from each level of trained worker (not unlike increasing the intensity of labour time).

The barriers between technicians and operators had also in many cases changed, but not to the same extent. Some firms had redesigned and enhanced the production worker's job to exploit the time freed up by new technologies. However, these workers were still largely cut off from higher-level jobs. They were not offered the mobility within the work structure available to highly-motivated technicians. The new flexibility provided them only limited opportunities for more interesting, responsible work.

The Japanese firm however had redesigned the entire employment structure to take advantage of the pool of technology-related skills in the Scottish labour market. Management had structured work in the Scotland plant to upgrade all jobs with respect to occupational conventions. The motive was to reap the long-term benefits of increased flexibility in deploying labour. Managerial prerogative replaced traditional credentials and class-based conventions in allocating work and mobility opportunities within the firm. The more robust structure of work provided both short-term and long-term cost advantages that management considered important in achieving a highly competitive market position.

As a result of industry efforts to achieve flexibility, there was little evidence in this sample of the highly bifurcated work force widely reported as the result of incorporating new technologies into traditional and high tech industries (Rumberger and Levin, 1984; Bluestone and Harrison, 1984). They had found a significant gap of middle-level jobs: employment was concentrated in highly skilled technical professional jobs and in deskilled production work. Research in Scotland's high tech industry found this pattern only in small, domestic firms.

Another result of management giving priority to flexibility and stability was a shift in which workers were considered the most appropriate for the industry. Opportunities provided by the local labour market were instrumental in framing *who* was considered the most suitable - not just for a job, but for long-term employment in a firm and for the character of the industry. During the survey period there was a marked shift in who was hired and who was expected to meet the new demands of the industry. Recruitment focused on hiring young people with little or no work experience and on hiring men, even for those jobs formerly considered women's work. The unique and powerful role of the local labour market in altering the long-standing gender and age expectations for industry workers will be thoroughly examined later in the chapter. First, the competitive value of flexibility is reviewed.

6.3. THE COMPETITIVE IMPORTANCE OF NEW EMPLOYMENT STRATEGIES

The industry crisis outlined in previous chapters clearly forced corporate management to develop new strategies to deliver more sophisticated, more variable product faster and better to an extremely volatile market. The preceding chapter contended that heavy investment in more advanced technologies was part of a solution: new equipment made possible unprecedented speed and accuracy within batch manufacture. However, the technology does not in and of itself determine the structure of work: decisions about the organisation of work arise out of/result from the social and political relations at the level of the company, the industry and the economy (Noble, 1979; Shaiken, 1980; Cooley, 1982). This section begins to examine why the industry adopted the strategies described above in Scotland at this time.

Market pressures for variable if not custom-designed product and for improved product quality from formerly mass production firms imposed new demands on the performance of a firm, thus on the nature of capital investment and the use of that capital. By investing in computerisation in manufacturing, an installation of capital could produce small batches to varying specifications. Computer monitoring and controls simultaneously offered a higher degree of reliability. Further, the engineering information embodied in the equipment's microprocessor made the changeover between batches relatively fast and easy, in contrast to complicated and time-consuming retooling in traditional manufacturing systems. The ways these capabilities are actually adopted within a firm are then shaped by the particular competitive conditions driving the industry and the firm and by the capital-labour relation, a reality ignored by many theorists infatuated with the new technologies.

Hirschhorn (1984) provides a discussion of the potential of the new microprocessor-controlled technologies to transform the organisation of work. His analysis proves particularly valuable for assessing developments in the high tech industry because the chemical and nuclear industries of his research similarly have a reliance on extremely sophisticated technologies, high information content in production and economies achieved through continuous processing.

New microprocessor-controlled technologies are extremely complex manufacturing systems which, in chemical and semi-conductor or computer production, link together formerly separate processes. Because the response of one process to a change or problem in another is unpredictable, the integration of processes increases the sources of error. Electronic controls cannot possibly be designed to anticipate and correct all possible, much less unforeseen, complications. Hirschhorn asserted that the human content of work associated with the new technologies must centre on technological discontinuities - understanding and responding to the use of new materials or product modification, potential failures, etc. The computerisation can take over the routine monitoring and control tasks: the workers' jobs must be to respond to unanticipated errors.

He argued that the complexities of integrative technologies require workers throughout processing to solve problems; this in turn places new demands on the organisation of work and the worker. To understand completely and respond quickly and correctly to a system disfunction, any worker must know a lot about all the processing steps, the nature of the product and the responsiveness of the equipment in the work environment. A problem appearing at one worker's station may have been caused at a much earlier stage in production. The worker's capacity to learn and to adapt and to regulate the controls is critical to the quality of production and the productivity of the equipment. Contextual knowledge of work on the shopfloor, not simple rules or procedures (If a green light comes on, do this.), determine successful production (eg low defect rates, high capacity utilisation).

According to Hirschhorn, two conditions produce this outcome: flexibility and stability. The flexibility is that of individual workers' responses and of the organisation of work allowing workers individually or collaboratively to intervene quickly in operations beyond the confines of their station. Stability refers to the continuing employment of workers within the firm. He considered employment stability critical to enabling the work force to learn and apply the contextual knowledge associated with experience.[45]

> "Flexible systems can adapt quickly only if information is widely shared and diffused within them. There is no hierarchy to problem-solving: solutions may come from anyone, anywhere. In flexible-system enterprises nearly everyone in the production process is responsible for recognising problems and finding solutions. (Reich, 1983; quoted in Stern, 1985; p.14.)

As implied here, Hirschhorn contended that the number of job classes must be reduced to allow greater collaboration and fast response, and workers must be given greater control over her/his activity to reflect the more integrated responsibilities. The technology transforms the *structure* of work: the relationship of employees becomes one where shared information and responsibilities replace hierarchical and routine protocol and procedures.

Technological change demands that a robust structure of work replace the conventional reliance on algorithms.

However, Hirschhorn's analysis was one of a technology determinist. In fact, a technology can be adopted in many ways. The survey in Scotland demonstrated that there is no inevitability in the pattern of work associated with computerised technologies. Hirschhorn's transformation of the workplace must be seen as one end of a continuum of strategies for structuring work. The same technology can be adopted in a firm relying on a highly algorithmic organisation of work (ie based on hierarchies and routinised procedures) if the employer cannot reap or recognise the benefits of greater flexibility. The extent to which a firm adopts a robust work structure or an algorithmic one is mediated by the market context of the firm and industry and the vision and experience of management.[46]

For the high tech companies in Scotland, the competitive conditions that stimulated investment in advanced technologies and the economics of operating in Scotland shaped the decisions about the organisation of work. Managers in the Scottish subsidiaries had to oversee the installation and rapid start-up of sophisticated capital equipment to take advantage of unexpected market growth. At the same time, they had to meet newly pressing objectives that would both expand potential markets and reduce unit costs - providing more and better field service and technical assistance, reducing downtime and product turnaround time - all in a market that had previously been served by branch plants. This growth and change happened quite rapidly. Managers turned to qualified technical personnel to meet these demands (at least in the short-term): as a result, company recruitment and employment policies in US firms favoured engineers and technicians.[47] The pressure of time convinced management that they could demand more of people with lesser qualifications to meet short-term pressures. Companies removed or softened established demarcations betweeen jobs and hired lower on the skill chain to get production moving.

This gave calculable financial returns. Recruiting a qualified electronics technician to do an electronics engineer's job saved firms approximately £1200 in annual salary (1984; calculated from SDA electronics wage survey). While the differential is relatively small, the savings would significantly influence the cost of a major expansion.[48] This practice helped mediate the effects of the global escalation of electronics engineers' salaries. Interviews, however, gave the impression that management valued the incalculable flexibility this gave them in project and team management as a much more important benefit than payroll savings.[49] Technicians could be expected to take instructions more readily and were less likely to have the professional expectations that would inhibit their doing any tasks.

However, a demand-side argument is insufficient. It can only establish the parameters for management employment strategies. The survey confirmed that recruitment and employment strategies in Scotland differed from the rest of the multinational (including plants in the home base economy). Managers in Scotland recruited younger people and `hired lower on the skill chain' than was conventional practice within the corporation. While the industry had historically considered Scotland little more than a relatively inexpensive rural labour force inside the EEC, changing competitive conditions forced a reassessment of the local labour supply. The specific conditions of labour supply, not technology alone, shaped how the industry could meet pressures to reduce unit capital costs and to respond quickly to capricious markets.

6.4 THE DYNAMIC INFLUENCE OF SCOTLAND'S LABOUR MARKET

A number of features of the labour supply in Scotland promoted the industry's employment growth and reshaped employment between 1979 and 1984. The most important factors distinguishing Scotland from other possible global locations, listed below, will be discussed in turn in this section:

- high and rising unemployment;
- a highly educated labour force and, more specifically, a significant and growing technical labour supply;
- a resilient national culture and community;
- gender as a factor in the workplace and in the external labour market; and
- state labour market intervention to stimulate the industry's growth.

6.4.1 High Regional Unemployment

The region's unemployment rate rose steadily in the late 1970s, then escalated sharply in 1980, tripling during the 1975-1985 decade. During this period Scotland carried a significantly heavier burden of unemployment than Great Britain, as indicated in Table 6.6, maintaining a lead ranging from 16 to 42% (though the gap narrowed during the early years of the Conservative Government).

A rapidly rising male unemployment rate dominated the trend. The long-term decline of the region's traditional industries (mining, fishing, shipbuilding, metalworking, engineering and vehicles) made increasing numbers of men redundant throughout the 1970s. The growth of the electronics industry had created predominantly women's jobs, providing few employment opportunities for the swelling ranks of jobless men. The recession of 1980-1

TABLE 6.6 THE UNEMPLOYMENT RATE IN SCOTLAND AND GREAT BRITAIN

Percentages
Annual Averages

	Scotland	Great Britain
1975	5.0	3.9
1976	6.7	5.4
1977	7.7	5.7
1978	7.7	5.6
1979	7.4	5.2
1980	9.1	6.7
1981	12.4	10.2
1982	14.0	11.9
1983*	14.9	12.7
1984	15.1	12.9
1985	15.3	13.1

SOURCE: Annual Abstract of Statistics, (1987): Central Statistical Office; Table 6.6, p.114.

* The data beginning 1983 reflect changes in the provision of the 1983 Budget that changed the way unemployment was measured and which groups qualified for benefit (eg excluding some groups such as men aged 60 and over from having to sign on at Unemployment Benefit offices).

aggravated the disparity between male and female rates: Table 6.7 shows that the male rate exceeded the female rate by more than 6 percentage points. Rising male unemployment was met by a contraction in regional employment opportunities for men. Male employment fell by more than 15% in less than ten years (1974 - 1983), while the region's service and electronics industries boosted post-recession female employment.

Deteriorating employment opportunities in so many traditional industries focused public concern on youth: close to half of the region's unemployed were young people. Forty-two percent (on average) of those claiming unemployment in the early 1980s were people under 25 (calculated from Table 2.6, Employment Gazette, various issues, 1980 through 1985). The steel, mining, shipbuilding and metal-turning industries no longer provided jobs for the region's male school-leavers.

Employers in the growth industries (electronics and services) had been hiring predominantly married women for their new jobs. Youth

TABLE 6.7. SCOTLAND'S MALE AND FEMALE UNEMPLOYMENY RATES

Percentages
Annual Averages

	Male	Female
1976	8.4	4.3
1977	9.3	5.3
1978	9.1	5.7
1979	8.7	5.7
1980	10.7	7.1
1981	15.0	8.9
1982	17.1	9.8
1983*	18.0	10.7
1984**	18.4	11.0

* See Note to Table 6.6 above
** Five-month average

SOURCE: Employment Gazette (1983,1984) Table 2.3, S25 -26

unemployment, particularly male youth, had become a serious problem.

These developments created a singular opportunity for high tech employers. The collapse of traditional industry had created new, compliant labour reserves in the same location as the burgeoning microelectronics industry. This allowed continued industry growth without kindling the upward pressure on wages or worker strength associated with labour market shortages (for lesser skilled labour). Employers could also increase their selectivity in hiring without bidding up wages. This relatively costless growth broke the historical pattern of relocating to find new labour markets when rising wages or political constraints hampered growth (Massey and Meegan, 1979). Scotland gave the industry the opportunity to expand in a familiar business climate by tapping new, high unemployment labour segments. This gave employers the leeway to alter employment strategies and to hire selectively from a pool of qualified applicants. Managers were extremely pleased with these surplus labour markets. One firm received 7000 applications for 45 assembly jobs (1982); in this case 12 to 20 people were interviewed for each production job.[50]

The shortage of alternate employment opportunities in the region and elsewhere in England, the historic haven for job-seeking Scots, had altered workers' vocational plans and expectations. The desire to get a job in the high tech industry had transformed the labour force. Middle class young people with credentials to enter university had instead chosen to gain technical qualifications to compete for the industry's jobs. Qualified engineering and science majors were willing to take conversion courses and jobs for which they were overqualified to get into the Scottish industry. Untrained young people flocked to courses that were any sort of preparation for electronics industry jobs.

6.4.2 A Highly Educated and Technically-Trained Labour Force

The region's educational system had earned a reputation amongst corporate managers for producing a literate, well-educated labour force. The "above average educated local population" (Interview with semi-conductor executive in California) was an important advantage Scotland offered over many other possible locations.[51] High tech employers could safely raise the academic requirements for entry-level jobs without losing the labour surplus they enjoyed when recruiting. Further, the willingness of school-leavers amongst others to take vocational subjects or complete post-school training programs relevant to the industry (eg the publicly-funded Training Opportunities Programme - TOPS) gave firms the option of recruiting computer- and electronics-literate young people even into unskilled jobs.

However, the sizable and rapidly growing supply of technically-trained labour was a most important factor distinguishing Scotland from most other labour markets. During the late 1970s the region's educational institutions yearly graduated approximately 250 electrical and electronics engineering degree students and on average 1205 electrical and electronics technicians.[52] Paralleling the growing economic importance of the electronics to the region, enrollment on most of these electronics engineering courses expanded steadily throughout the 1970's and early 1980's. Many of the region's eight universities and further education and technology colleges expanded their electrical and electronics engineering degree courses in 1975/6, leading to a rapid growth in student intake (a 55% increase in the four academic years that followed) and corresponding increases in graduates (MSC for Scotland, 1980). There was a similar increase in physics, maths and computer science degree students over the same period: graduates from these fields were recruited for process engineering in the semi-conductor industry and for software development and programming. The pressure to produce qualified people led to a faster than expected increase in the electronics and related degree engineers during the early 1980s. Intake on electronics engineering degree courses increased by 30% in only 2 years (1981/1982) and the number of graduates grew by more than 80% in the five years from 1979/80.[53] Given the international competition for technical labour, the growth of this labour pool was a very important factor in high tech growth in the region.[54]

Electronics technicians were also supplied yearly to the local labour market. Even though intake fell slightly in the early 1980's, higher pass rates and higher proportions of completers remaining in Scotland produced a steady annual supply of technicians.

There was a change in the nature of the technical labour supply that occurred alongside its growth: there was a shift of non-degree techology students into more academic courses. There was a sharp drop in enrollment in and availability of traditional trade and part-time programmes for engineering technicians (eg City and Guilds and ONC qualifications), the courses that had primarily been for working class youth serving apprenticeships.

Simultaneously, enrollment in full-time courses for diplomas and certificates rose. These courses had more academically rigorous entry requirements and curricula than the C&G and ONC courses and in a growing number of cases required full-time participation for two to three years. As a result, opportunities for working class youth to gain a qualification while earning a wage within an industry apprenticeship dwindled. In addition, because of the increased competition for access to industry jobs, enrolling in these courses had become more difficult, bidding up entry requirements.

The region's long record of producing a rich supply of technicians with both a broad and deep knowledge of electronics technologies is important to this discussion. Technicians have historically had a more important role in European manufacturing than in the US. The ratio of technicians to engineers in UK manufacturing was 4 to 1 (1970) while US manufacturers employed less than 1 for every engineer (0.62: Starnes and Hacker, 1985). Technicians in the UK with an advanced qualification had historically straddled the line between professional and working class status in engineering industries (Whalley, 1985). For example, many in Scotland had become managers of their own firms (Interview data). US corporations located in Scotland adapted to profit from this source of flexibility.

The HD graduates, because of the academic nature of their course were a particularly important component of the local labour supply. These graduates - technically technicians - were hired into the industry both as technicians and engineers. It was a fast-growing market segment. Diplomates of this three-year full-time course more than quadrupled from 1977/8 through 1982/3, encouraged by the industry's interest and increasing competition for the industry's jobs. Though admission required at least two Highers (a Scottish school examination similar to an English A level) in Maths, Physics or English, competition for places had bid up the qualifications of successful applicants. Enrollees at one well-known college had on average 3.2 Highers and many of them had more than that. Increasingly, students capable of attending university had enrolled in these courses to get access to industry jobs (Interviews with heads of electronics engineering departments at Bell College of Technology, Paisley College of Technology and Glenrothes College of Technology).[55]

This trend of increasing numbers of middle class students to be represented amongst those with non-degree technical qualifications may have been important in fostering greater willingness amongst managers to hire technicians for engineering work. Eliminating the traditional class antagonism between working class skilled youth and the middle class professionals, these young people could be expected to fit into the engineering team, to collaborate easily as paraprofessionals and to move into professional responsibilities. Another reason managers may have preferred to recruit technicians for more complex work is that they were perceived to be less mobile than degree engineers.

> "I think it's certainly true... that people in recruitment recognised that graduates seem to think of themselves in a more mobile way than college diplomates...The diploma holder rather than the graduate does get the reputation for staying near home...Most of them stay in Scotland."
>
> - Interview with Dr. Ian Beaton, Head of School of Electrical and Electronics Engineering, Bell College of Technology

They represented a more stable and satisfiable work force than university-trained engineers.

Furthermore, regional concerns about shortages of engineers likely influenced managers in their employment decisions. Regional surveys had reported that firms had experienced recruitment difficulties and shortages of qualified degree engineers in microelectronics and computer science in 1979 [SC(D&I), 1979] and forecast a shortfall through at least 1985 (SEPD, 1980). While managers in the survey multinationals had not experienced significant shortages, that was to be expected: as multinational firms, they were the region's best-paying[56] and most attractive employers and powerful contenders even in a competitive labour market. However, all managers said that engineers' salaries had been escalating much faster than inflation, and at least two executives claimed the regional competition for engineers, including poaching, and the associated cost increases had gotten out of hand.[57] Efforts to curb company dependence on degree engineers may have been a response to this perceived problem.

Access to Training Resources

The range of technology-related skills available to the region's industry was growing fast. To add to the expanding supply of labour with formal technical qualifications, the schools and colleges had begun offering new industry-relevant programmes to teach youth technology subjects more quickly. In schools for example the new `16 to 18 Action Plan' initiated curricula to teach technology subjects in short modules.[58] In this program students would choose the modules they wanted rather than following the traditional prescribed curricula of a two- or three-year course for qualification. The motive for the program was to produce very quickly a supply of young people `literate' in electronics and computer technologies (Interview with Scottish Technical Education Council adminstrator). Industry managers had pressed educators to set up this system to produce a technical labour supply faster than was possible under the traditional training/education system. This regional programme would give the industry a yearly pool of workers that had a rudimentary understanding of the technologies and without formal qualifications. The lack of degree, certificate or diploma would mediate pay expectations and job quality demands.

Because of the region's high and rising unemployment and the relative scarcity of job opportunities, the industry had succeeded in increasing the regional supply of labour with a range of technical knowledge and in shifting the responsibility of that training to the individual and the public sector. The electronics technology courses in all the region's technical colleges were fully if not oversubscribed, in spite of the substitution of full-time pre-employment participation for part-time/day release study within employment. Educators expected the new modular courses to be popular though they provided neither grades nor qualifications. The industry had even socialised training for production jobs. Government Skillcentres and technical colleges had in recent years established short (eg 13-week) courses in electronics assembly for participants in the Youth Training Scheme and for the unemployed. Further, one of the semi-conductor multinationals had received SDA and other public financial backing to set up a high tech training centre for basic production training to *fee-paying* workers seeking assembler and operator jobs in the industry. These facilities provided the basic training that employers had traditionally offered in in-house training workshops. As indicated in the discussion above, qualifications even for lesser skilled production jobs had been bid up and unemployed workers facing severe competition for these jobs were willing to enroll in programmes that gave them any advantage in their job search.[59] The recently established training opportunities had succeeded in drawing more and more people into pre-employment public and private sector training that offered no formal, transferable qualifications.[60] As a result, managers had a wider choice of applicants when they recruited and greater flexibility in job assignment.

A major source of industry 'flexibility' was college and university provision of technology short courses for introducing and upgrading skills. Academic faculty in all the region's higher education institutions and in centres like the Microelectronics Educational Development Centre (MEDC) at Paisley College of Technology (Supported by state funds) were custom-designing two to four-day courses to meet specific industry needs. With every firm near a regional technology college, firms could send employees on short courses whenever a new expertise was needed or a new technology introduced.

Open Tech was another major training programme to support the high tech industry: this was an extensive distance learning programme.[61] By all accounts the Open Tech workshop in Scotland had been lavishly stocked with a wide array of advanced new technologies geared for the needs of the region's high tech employers. The array of short courses and the option to `retool' employees through Open Tech gave industry management a variety of ways to graft emerging skills onto their existing work force without hiring additional or highly specialised professionals.

6.4.3 The Value of Cultural Cohesiveness

More fundamental than its geographical containedness, Scotland has a deep and enduring national culture and pride. Natives are part of lasting family and friendship networks and a culture that, while conquered by England, remains distinct from the rest of Great Britain. Most Scots have a strong attachment to their country and many would prefer to settle in Scotland. The industry found in Scotland a stable (and hard-working) labour force.[62]

Multinational management appreciated the advantages this offered. By hiring relatives of their employees, managers in effect hired an internal system of pressure and discipline that ensured low absenteeism and good work habits. They also acquired a willingness of employees to cover for one another at work and at home, eg providing child care in a region where institutionalised child care was non-existent.[63] Managers also discovered a supply of

Scots working overseas - mostly in the US - who were willing to move back: these were the experienced techical professionals that the industry so seriously needed.

6.5 THE ROLE OF GENDER

In an industry with such stark occupational gender segregation, gender relations must have influenced the labour market shifts in recent years. While the survey could not directly address such a sensitive issue, the discussion explores how gender issues seem to have influenced management efforts to achieve flexibility in staffing and work organisation and why employment opportunities for women had narrowed even further. Two distinct, though inseparable, factors focus the discussion - male dominance of the technical labour supply and management expectations in making staffing decisions.

As mentioned earlier in the chapter, men overwhelmingly dominated the region's education and training courses for the industry's technical jobs.[64] In interviews, managers blamed the absence of any female engineer employees on the maleness of the labour supply. A review of the ways educators, parents and peer pressure have steered young women away from technology and scientific professions is beyond the scope of this discussion.[65] The discussion here explores only one aspect of women's participation in the technical labour force - women retraining as electronics technicians.

Technicians are critical to maintaining plant manufacturing activity, and their importance grows with the increasing complexity of and investment in new technologies. In addition, the job of electronics technician seems to offer opportunities for growth and development. The actual gap between the work done by the technician and the operator has been narrowed both by the new technologies and the design of work on some shopfloors. The experienced operator's knowledge of the product and the fundamentals of the process before it was automated is important to the technical work associated with that equipment - resetting, maintaining and repairing the machine. Retraining operators as technicians to tap their product and process experience seemed an expedient way to get knowledgeable technical personnel quickly. Deciding to get training in electronics theory also seemed an obvious way for women semi-skilled production workers to improve their earning potential, their job satisfaction and, given the threat of automation, their employment security. Employers, claiming to invest heavily in their workers and to encourage upgrading, would have been expected to sponsor the training of their women workers.

6.5.1 Barriers to Upgrading

In fact very few women workers volunteered for retraining. Interviews with women workers and technology educators indicated that it was extremely rare for the industry's women to pursue upgrading opportunities on their own. The logistical, financial and psychological barriers proved too great.

Management's unwillingness to allow institutionalised training during work time (Select Committee of Science and Technology, 1984) meant that retraining required evening classes; a part-time course took from three to six years. That is a long time to study outside of a full time job, and was impossible for workers on evening, night or twelve-hour shifts.

Transportation was a major barrier. Technical colleges were usually on the edge of town or a few towns away, and in one-car families, women rarely had drivers' licenses and/or access to a car.[66] Public transport in Scotland was infrequent, and getting from a housing estate to anywhere except the centre of town was cumbersome, time-consuming and simply infeasible for evening classes.

A further disincentive was management staffing policies. All of the survey firms had frequent and unpredictable overtime usually due to understaffing. Managers expected, if not pressured, workers to do frequent overtime.[67] Transferring workers to other shifts to cover for absences and demand changes was also a feature of employment in a number of firms. In an industry where attitude as well as performance determined wages, promotions and job security at times of redundancies, workers felt pressured to oblige. Women expecting to work an hour or two more per day or frequently on weekends could not commit themselves to regular attendance at evening training classes.

The absence of institutional child care was a considerable problem: taking evening classes required making additional arrangements with the husbands or relatives who invariably had taken care of children during the workday. None of the companies provided child care or transportation or stipends to cover these expenses for workers wanting retraining.

Furthermore, women workers in many of the firms were very pleased with their employment situation. They were delighted to be employed in a region of high unemployment and appreciated that they worked for some of the highest paying employers in the region. Most of the workers interviewed were satisfied with their employers. Many had extremely good benefits for the manufacturing industry and were well-paid for women workers in the region. In fact the average hourly pay for the industry's semi-skilled production operators, light assemblers and senior assemblers (assembling complex units) far exceeded the average hourly pay of women manual workers in footwear, clothing, textiles and hotels and catering both in Scotland and in Britain, as shown in Table 6.8. While approximately 90% of women production workers in clothing had gross weekly earnings of less than £100 (including supplementals; New Earnings Survey, 1983), most of the Scottish industry's operators and senior assemblers earned on average just over £100 (£101 and £106, respectively) before adding overtime, productivity bonuses and shift premia (calculated from weighted plant averages; SDA, 1983). Their pay was better than they could have earned in most other industries.

Gaining a non-advanced technical qualification would have enhanced their basic earnings by only 15 to 23% (depending on their occupational category; calculated from confidential survey of eastern Scotland's high tech multinational corporations, 1983). Table 6.9 suggests the differential may actually have been much larger - anywhere from 38 to almost 50% and widening yearly. However, these calculations are based on average pay without any overtime.[68] Lucrative overtime (double pay on weekends) and shift allowances as production workers further erode that differential. While it is highly likely that women workers did not know the true extent of the differential, it was very clear from interviews that they did not consider the higher earnings of upgraded jobs sufficient reward for the years of difficulty that retraining would impose.[69]

In addition women wanting to upgrade their skills had to be able to finance themselves. Working class women tend to spend their earnings on child- and household-related expenses (Whitehead, 1981), not on themselves. Moreover, the high and rising unemployment had made many of the industry's women workers major if not sole breadwinners for their families. Investing in their future was not feasible for women in financially constrained households.[70]

The considerable fears of going back to school were also a major barrier. Women workers who had considered retraining (or who had been encouraged by union shop stewards) expressed doubts they could manage academic study. Technician courses required examinations in higher maths and technology subjects, a formidable venture for school-leavers, particularly older workers.

Furthermore, the industry's unprecedented growth during the early 1980s concealed most of the signals that might have warned women that their jobs were in jeopardy. Most had little knowledge of industry-wide developments that would have indicated that the long-run security of their jobs was threatened. While a few of the firms had

TABLE 6.8. WOMEN'S WAGES IN ELECTRONICS AND OTHER INDUSTRIES EMPLOYING PREDOMINANTLY WOMEN

- Britain and Scotland -

(£ Sterling)

Scotland's Electronics Industry

Semi-skilled production operators	2.59
Light Assemblers	2.53
Senior Assemblers	2.72

Source: SDA (1983)
Weighted by plant employment
Excludes overtime and premia

Women manual workers in footwear, clothing	
Scotland	2.01
Britain	1.98
Women manual workers in textiles	
Scotland	2.11
Britain	2.00
Women manual workers in hotels and catering	
Scotland	1.84
Britain	1.88
Women non-manual in insurance, business services and finance	
Scotland	2.68
Britain	3.10

SOURCE: New Earnings Survey (April, 1983) Tables 120 and 122.

TABLE 6.9. PAY IN THE REGION'S ELECTRONICS FIRMS

Average Wages and Salaries*
(£ Sterling)

	1983	1984
Electronics Engineers	8888	9436
Sr. Electronics Engineer	11258	11480
Electronics Technician	7599	8280
Semi-skilled Production Operator	5252*	5624*
Senior Assembler	5516*	5962*

* Calculated from hourly wage, based on 39-hour week, including no overtime.
** While the survey sample is claimed to represent the region's entire electronics industry, the majority of included firms (70%, 1983; approximately 85%, 1984) are the high tech electronics multinationals that are the focus of this study.

SOURCE: Calculated from SDA Annual Survey, (1983, 1984).

made production workers redundant due to restructuring or market slump during the study period, the industry's overall expansion in the region was generating new job growth. That combined with guaranteed employment in many of the firms implied a secure employment future for the industry's workers. Amongst the women interviewed, only those in companies facing severe market difficulties recognised the vulnerability of women's jobs and the importance of retraining. This view was not widespread.

6.5.2 Employers' Training Decisions: Preserving the Male Work Environment

Rather than waiting for volunteers, managers could have actively recruited their women workers to retrain as technicians. Most managers had, after all, expressed a serious commitment to continuing training for their work force. In addition they fully anticipated the impact of automation on operators' jobs and the increasing importance of technical skills throughout production. In the survey managers were asked if they had upgraded their women employees to qualify for emerging jobs. The incidence was in fact extremely rare. Only *four* employers indicated that they had *at some time* in recent years retrained semi-skilled workers as technicians. That represented a *total* of only a handful of employees.[71]

This was indeed surprising. There seemed to be clear economies to retraining these workers - reduced hiring and redundancy costs and economies on workers' experience and product knowledge in information-intensive production. There were, however, many reasons why this was not a popular method to gain technical skills.

Evening classes for technician retraining usually were part of a course for a lower-level qualification, such as a Certificate. Employers had already decided, however, either to hire technicians with a more advanced qualification or to recruit unskilled people with no qualification and train them on the job. From the managers' viewpoint, the lower-level qualification had lost most of its usefulness in advanced manufacturing facilities. Older women with a non-advanced qualification would be seen as overqualified for the lesser demanding technician tasks, and not trained well enough for the more complex tasks.

Further, a woman worker studying part-time would need two to three years for a lesser qualification and up to six for an advanced one.[72] Managers were having difficulty forecasting staff needs two to three years ahead. The long lead time for this kind of retraining proved problematic because it implied a job guarantee far in advance of an identified need.

More fundamentally, technical jobs were assumed to be male. Managers seemed to consider men more suitable for that work. Many of these executives and their managerial staffs had never worked with women technicians and engineers. They consistently and unconsciously referred to their technical personnel as guys and semi-skilled production workers as girls. Maintaining the maleness of technical jobs also offered a degree of comfort in an industry strained by high demand and many dimensions of uncertainty. Maleness had nourished the communications and sociability so important to company productivity. Men could more readily join in the collaborative technical problem-solving, professional chitchat, and after work softball games and trips to the pub. Men understood the challenge and the necessity to stay late when a production run had to be finished or a problem solved. Furthermore, with almost every engineer a manager, men were perceived to be better at managing other men than women. The uncertainty and potential problems from introducing women as part of the team in this often highly stressful situation made managers wary.

Management disbelief that women production workers were appropriate for technical work was another barrier. While no one explained precisely why they had not upgraded operators, the conversations implied that women operators were not intellectually capable of technology-related tasks. Perhaps it was because many were hired before recruitment standards required academic achievement. With experience of women workers only as production or clerical staff, managers had little experience to contradict this class- and gender-biased view. They attribute the experience they have had with women as subordinates, eg assemblers, to all women in the labour market.[73,74]

These perceptions, whatever the cause, were very important in the recruitment and training alternatives the firm adopted. While managers suggested that the length of time it took to retrain operators was considered a disincentive, they frequently hired young, unskilled school-leavers and they were willing to train them as technicians. This represented a training commitment of at least two to four years. For instance, a 17-year-old unqualified young man was hired to operate a semi-conductor firm's most sophisticated, most expensive piece of new equipment (a $1 million laser trim machine). Training included first a three- to four-week intensive course at the equipment vendor plant in the US, then two to three years on-the-job training, supplemented by day release study at a local technical college. An industry labour market analysis confirmed the impression that this was a common practice. Approximately one-quarter of the total regional stock of electronics technicians in the wider electronics industry were trainees (1979-80), a high ratio compared to other industries (MSC for Scotland, 1980). Prime multinational employers and small firms alike did this where there was an insufficient supply of very local technicians and the alternative was the potentially high price of hiring qualified personnel on the 'national' (Scotland-wide) labour market.[75] The new employees were all hired because managers had been impressed by their social skills and ability to fit in. They also were viewed as good risks as stable employees; in these positions management wanted people who would soon be supporting mortgages, etc., thus committed to their job and employer. They were also all young men.[76]

The study's multinational firms had, in fact, a higher share of women electronics technicians (approximately 9%) than was found in the UK electronics industry (4.4%; EITB, 1984). For example, one large regional employer, apparently concerned about women's position in the industry, had included 8 women in their apprenticeship programme of 21(1984).[77] This firm had a progressive policy; however, this isolated attempt to change the gender balance was clearly overwhelmed by industry-wide practices and the barriers of ease, convention and preference. More commonly, managers consistently allocated their discretionary resources for training and upgrading in technology-related work to male, not female, employees.

According to male managers, the absence of women from technical occupations was because there were no trained women to be hired from the external labour market. It is a supply problem: that relieves management of responsibility.

The reality is, of course, much more complex. Even where there are qualified women available, the exclusion mechanisms in hiring and in the workplace, eg denial of further training and promotion opportunities, are very powerful, and as has been shown in the US, eclipse the supply-side problems (National Science Foundation, 1986). Managers still expected women to leave the labour market for marriage and/or child-bearing, jeopardising the company's return on any investment in training. This was a great concern amongst this industry's employers because the value of the training depreciated very quickly with the fast pace of technological change. That women technical professionals in electronics had demonstrated more commitment to the labour market and the firm than this had not yet informed management's expectations of women workers.

> "Work is still seen...as a stop-gap before marriage and child-bearing, and the interruption that the latter brings is clearly a disadvantage in anybody's career. Many employers would prefer not to promote a woman for that reason, and do not realise that the woman engineer often gives her employer more years of service before the break than the man who will readily change his employment for his own betterment after two to three years",

according to Dr. Elizabeth Laverick, an electronics engineer and a leader in electronics education (National Electronics Review, 1983). Management's expectations, expressed below by a JobCentre manager responsible for channeling candidates to the region's industry, still guide employment and training policy.

> "When a man [is hired], usually family troubles don't bother his work. But if a woman [is hired], she gets pregnant and she leaves. But if you've got a man and he's happy and you're happy, he can be there for a long time."

In this case, as in the question of competence, the qualities they attributed to women and the resulting policies that excluded them from good employment opportunities were ones that conveniently maintained the status quo and male comfort.[78]

These expectations were widely shared. The industry's female work force had internalised and accepted that men were more suitable for technical jobs. Trade union shop stewards who had tried to persuade production workers to take upgrading training consistently met disinterest and resistance. A few women workers commented in interviews that they thought semi-skilled women who were curious about the technologies were stepping out of line. At the same time they accepted without resentment that men assigned to production would eventually be promoted to more technical work. In closeknit communities like those in which most of these companies are located, risking criticism from friends must have inhibited women from wanting to try untraditional jobs.

Further, there was widespread community concern about the financial and personal/household problems resulting from high and rising male unemployment. Women workers wanted to see their sons, husbands, brothers, etc. getting jobs in the industry. None of the women interviewed expressed concern or resentment that men were given training opportunities and access to the technical jobs.[79]

6.5.3 State Labour Market Intervention

The state actively intervened to support the creation of a labour force suitable to the industry's needs. The SDA considered the industry and particularly foreign multinationals as the region's best potential source of employment growth, so set out with a new mix of policies in 1979 to attract foreign investors. Increasing the supply of technical labour was a priority (BAH, 1979). The region's high tech training provision was viewed as a major attraction in marketing Scotland to international investors.

> "In particular the scope for long-term profitability with all the educational and infrastructural advantages that

Scotland offers, especially for industries in high technology, are overridingly strong selling points which must be marketed..."

(Committee on Scottish Affairs, 1980)

The activities of the SDA, the New Towns and the educational authorities, acting to promote a stable, flexible labour force, in no way challenged the existing gender exclusion of the industry's male jobs. In fact, state intervention was explicitly directed to creating more jobs for men.

The SDA, the Scottish Technical Educational Council (SCOTEC), the MSC for Scotland and the individual colleges and universities had all contributed to expand the vibrant education and training infrastructure tailored to high tech industry needs. The system expanded the numbers of people getting technical education and training of all sorts - both as primary professional and vocational education, as retraining and as upgrading. Grants from the Central Government and financial incentives and pressures channelled resources into developing curricula and new linkages with industry with one aim, "namely the effectiveness in meeting the needs of industry and commerce" (NEDC, 1982; also ITEMS, 1984).

While the SDA had widely publicised the region's efforts to turn educational institutions into "resource centres for industry" (House of Lords, 1984), the colleges in particular had been allocated little if any additional funding for planning or implementing new, speculative courses (Williams, 1984) or ventures.[80] In fact, financial freezes or cutbacks were in many cases the stimulus for new industry-specific ventures. Faculty at many of the region's colleges in particular had been forced to acquire external, private sector funding to sustain their own research activities. University and college faculty created revenue-generating projects - short courses and teaching companies to bid for research and development contracts[81] - while the numbers of student grants were reduced, publicly-funded courses were cancelled and resources for expanded workloads were constrained if not cut. Efforts to get industry attention seemed to have been relatively successful because the commercial and informal links between technical education and industry in Scotland (via frequent communications and collaboration and subcontracting) had fluorished, distinguishing it from high tech industry in England and Wales as described in Oakey (1981) and Oakey et al., (1984).

The New Town Labour Supply

The region's New Towns, formerly central in UK housing policy, had become major instruments of industrial policy: the major attraction of these "industrial growth points" (SEPD, 1981) was their contained and stable labour forces. Acute housing shortages in the major cities dissuaded workers lucky enough to be rehoused in New Towns from considering moving again. This provided a captive labour supply for lesser-skilled jobs. Also, New Towns gave newly locating firms access to affordable housing in physically pleasant communities which satisfied the quality of life standards of their professional employees. The housing authorities placed all employees of a town's new high tech firms at the top of the placement list, easing the way for inward investment. These employees usually brought family that added to the town's captive labour reserves. This was quite a relief from the increasingly crowded, polluted, high cost and high turnover situation in Silicon Valley.[82] New Towns also offered important financial and infrastructure support discussed in the previous chapter.

With these inducements, the Scottish New Towns had been quite successful in attracting high tech multinational investment. Nine of the twelve new computer and semi-conductor firms that had located in Scotland since 1980 set up in New Towns and all of the four multinational manufacturers planning facilities in Scotland announced that they would locate in New Towns.[83] One New Town, Livingston, had been particularly successful: it attracted one firm per month in 1983 - creating 1000 jobs, yet its unemployment rate was 18% (Van de Vliet, 1984).

Regional efforts to generate additional employment in the region were not neutral. Concern that the electronics industry created predominantly female jobs had surfaced as early as 1974 (Firn, 1974, 1975A). Official worry recurred in the late 1970s and early 1980s as high tech activity had expanded yet had provided few jobs for the region's unemployed men, either unskilled youth or those made redundant from the continuing decline of the region's traditional industries. Internal reassessment of development strategy led the SDA to prioritise investment initiatives creating 'real jobs' - that is, jobs for men (Interviews with public sector officials and regional industry experts). The SDA could communicate the urgency of this priority to firms directly: this was the agency that negotiated with potential investors over the actual financial assistance they would receive for direct investment in the region. This pressure must have influenced companies' recruitment of operators and engineering aids.

Gender-Segregated Education and Training

At the same time the education system continued to train an almost all-male technical labour supply. There was no attempt to make the industry's more interesting technical jobs accessible to women. This was not a priority. Meeting industry's fast-changing needs quickly was. Training in a hurry, under financial and resource constraints, and responding under pressure to meet industry's labour expectations left no time or resources for affirmative action programmes. College educators estimated that women's participation in the region's non-degree engineering and technology courses - only 2% in 1979/80 (EOC, 1982) had not improved in recent years. They suggested in fact that it had worsened. Only 4 women received a 1981 electrical and electronic engineering degree out of 1046 awards in UK colleges; in the university system only 1.8% of almost 19,000 electronics engineering degrees were awarded to women (1980; CNAA statistics department; Department of Education and Science statistics department).[84] More than half of the eighteen advanced information technology courses (ie high technology specialisms such as microprocessor conversion courses) at universities throughout the UK had three or fewer women students in 1983/4 (Gordon and Pearson, 1984).

In addition to degree programmes, the state provided a wide range of publicly-funded programmes to subsidise if not supplant industry investment in training. For example, the UK Department of Industry financed the entire first year's training budget for firms locating in designated Development Areas, many of which were in Scotland, and the EEC Social Fund gave firms up to £7000 for each employee they trained to use new technologies.[85] Firms had complete discretion over training provision. Without monitoring or any equal opportunity goal, the courses seldom included women.

Also the MSC's TOPS programme, which had historically provided retraining opportunities for adults, particularly adult women, was drastically reduced and its remit altered in the early 1980s (Finn, 1984; Goldstein, 1984). TOPS-funded programmes for more advanced skills in electronics and competition for the smaller number of placements increased. Further, training providers, fearful of losing erratic and dwindling MSC funds, focused selection of applicants on their success potential (ie the likelihood that could easily cope with a demanding, intensive course and get a job) rather than need, work history or affirmative action goals. This in effect excluded from publicly-funded training women wanting to make a job change: as unconventional students without an electronics background they were more likely to have academic problems and less likely to seem suitable candidates to industry. The administrator of a special TOPS-funded electronics engineering technician course reported that he did not remember any women students in four years of running the course.[86]

Overworked university and college faculty admitted that they had no time to plan or implement programmes to recruit young women to their courses. No resources or faculty time had been allocated to assist women students in whatever difficulties they might have faced in competitive, predominantly male courses.

The absence of affirmative action policies or resources and the shift of state support away from adult unemployed and low-wage populations to highly employable groups guaranteed the continuance of male domination of the region's technical education, training and employment.

6.6 SUMMARY

The findings reported in this chapter have demonstrated a few simple yet important developments. The economic world that produced the economic rationale for divided labour markets - a world satisfied by mass produced, standardised products - had radically changed. Corporations with rigid structures and rules could not find ways to deal with the character of crisis in the early 1980s. Corporate management had to learn to respond swiftly and creatively to fast-changing technologies and sharp, sudden competitive market shifts. Information, having become a costly and competitively important intangible input, had to be captured and fully exploited within the company. That potential depended on the stability of the entire work force and its collective knowledge and expertise. Employment stability and flexibility in deploying workers produced for managers the cost-minimising opportunities in the competitive world of the 1980s. The rigidly segmented employment of the DLM model cannot deliver well-coordinated, highly integrated production, fast product turnaround and highly customised product because these required close communications and responsiveness amongst the stages of production and distribution and the involved workers. They also demand consistent mechanisms of control throughout the corporation. The production technologies and the new relationship to the market demanded rapid response throughout the organisation. The deep hierarchical structure, the differences in control mechanisms amongst job segments and the inherently conflictual relationships of workers treated very differently in DLMS could not produce the fast adjustments and throughput economies needed to compete in these markets.

Secondly, the industry's development in Scotland during this period confirms the importance of global labour market differences in shaping multinational corporate activity overseas. The supply conditions of the local labour market shaped the strategies adopted to replace the hierarchies and rules of corporation and work structure. The conventional business view that technologies and employment strategies are determined by corporate management prior to and without consideration of local factors (Interview with Professor Rosenbloom of Harvard Busines School, 1983) did not (if it ever had in the past) accurately reflect reality. To ignore the influence of individual labour markets around the globe on firm and corporate structure and on the structure of work and quality of jobs denies the sources of flexibility and economic advantage that drive the development of the modern multinational corporation.

Thirdly, the rapid growth and change in the regional high tech industry clearly displayed the dynamic interrelationship of the demand and supply sides of labour market operations. Labour market analyses which locate problems solely on the supply or demand side are myopic and simplistic (Bruegel, 1984; Humphries and Rubery, 1986). The specific conditions of the surplus labour supply shaped management employment strategies which themselves influenced how people in the labour market viewed their employment options.

Within this dynamic, gender proved to be an important factor. Strategies were honed explicitly or unconsciously to favor the employment of men over women in order to promote at least the short-term interests of capital. These efforts were reinforced by conditions that were prior to or independent of the sphere of capitalist production - market and non-market structural barriers and socialised behavior and expectations. Without prime responsibility for children, women workers might have pursued retraining opportunities and, by changing the gender balance in the technical labour supply, transformed the technician occupation (or at least exposed the sexism of recruitment). Fears of mounting social problems from the rising male unemployment compelled public officials to intervene to create jobs for men. Without this capital might not have responded at least so quickly to the male labour surpluses. Gender-related expectations and gender politics shaped the ways corporations found to maximise operational flexibility and the speed and ease with which corporations adjusted to change.

This chapter has attempted to show that occupational segregation by gender (and other factors) cannot be considered static or permanent. Further, demand-side analysis cannot adequately explain either the competitive strategies or the changing international profile of multinational corporations. Gender, and more generally, global labour supply conditions frame the capabilities and the outcomes of capital's response to crisis.

CHAPTER 7: STRUCTURAL FLEXIBILITY: THE COMPETITIVE IMPORTANCE OF GENDER AND GLOBAL LABOUR SUPPLY DISTINCTIONS

7.1 INTRODUCTION

This chapter reviews the major findings of the research on industrial change in high tech multinationals in Scotland. To interpret the importance of the findings, the research and the industry must be viewed in context. A section of the chapter is devoted to providing this perspective by outlining the limitations of the research and the analysis. The chapter closes with an assessment of the challenges this research poses for existing and evolving theory on the organisation of the corporation and modern industry. The discussion focuses on the `missing middle' and post-industrialism arguments as particularly important and widely supported views.

7.2. REVIEW OF THE RESEARCH

This study has revealed a new, more complex pattern of multinationalisation in US firms than that usually presented in the literature on the product life cycle or the global division of labour. The fast-pace and quality emphasis of the industry's product markets and the unpredictability of the international economy forced a reconsideration of corporate strategies in the US microelectronics industry and a reshaping of the corporation. The conventional model of a multinational corporation proves inadequate for producing successfully for the markets of the late 1970s and early 1980s.

In particular, a structure that disperses rigid mass production facilities around the globe while confining all R&D and corporate control to the home base could not supply technologically-advanced products to a sophisticated, diverse and global market. To supply markets with customised information-processing products at competitive prices, US firms were forced to concentrate resources on investing in expensive physical capital and information resources and then to use them to develop new ways of reducing unit costs.

US firms in these markets had to aim simultaneously for continuing new product introduction and economies in the use of the capital and information necessary for continual innovation. To achieve these economies of throughput, managers turned to investing in the most advanced and capable production equipment and to depending on the knowledge, experience and commitment of technical employees, the idea-people, the problem-solvers in the organisation of production and product design. To confine these actiivities to the home economy and far away from important markets, as had conventionally been the case, would have prevented firms from selling well in those overseas markets. Electronics, almost from the beginning, has been a truly international market place; overseas customers learned of new technologies at the same time as everyone else (through trade fairs, journals, etc.). By the early 1980s,these customers realised that technical support and re-supply options within a few hours' travel time were critical in their use of high tech products. And the producers realised that standardised products would no longer work in sophisticated applications markets. Even leading firms which had historically profited from the mass production of standardised products were compelled by the market to become `service' companies - educating, designing for and serving the specific needs of the customer. This kind of approach was essential to capturing market share in Europe, considered by major US and Japanese multinationals as an important untapped market.

Shifting more activity to prime markets also offered firms greater cost and price stability in a regime of floating and rather unpredictable exchange rates. In particular, the fairly predictable currency relativities in the European community meant firms which had located high value added activities inside the EEC had some measure of price protection. This potentially provides an advantage over competitors supplying the EEC through exports.

This study confirmed that new technologies and responsibilities for product and process had been devolved to the subsidiary in Scotland to serve the important European market. Most firms had invested in very advanced if not state-of-the-art technologies, had established more highly integrated facilities to replace part-process plants and had regional if not world responsibility for the corporation's newest and most advanced products. All the survey's firms were involved in process development. In many cases this involved nothing more than assessing incremental changes and reporting the results for corporate-wide use. However, a number of firms were testing new systems and developing entirely new software products for internal needs. A number of subsidiaries had product development responsibilities; professionals at others were lobbying to acquire that responsibility.

An increasing reliance on technical labour accompanied the shift to more advanced, integrated and flexible technologies: technological knowledge and experience and a stable work force were critical to achieving rapid payback from investments in new equipment. Gaining new economies in the use of capital equipment and information inputs (eg rapid set-ups for new product batches, reducing wastage of supply inputs) were made possible by technically-qualified people, designing products and guiding the processing to achieve lower defect rates. Increasing investment in expensive capital with a great deal of flexibility compelled managers to reassess their strategies of employment and work organisation.

Because the severe competition in the industry put pressure on individual firms to apply technical information as rapidly as possible, there was a close association of information and experience with responsibility at both the individual and plant levels. Technical personnel with an idea for a better product or for a cost-saving process improvement frequently were encouraged to develop that idea into a viable product or operation. Executives at corporate headquarters could not assume responsibility for or command long-distance control over all projects, particularly in a booming market: to get a fast turnaround time, those with the idea were given responsibility to pursue it. For example, the technical staff in a semi-conductor subsidiary in the survey designed and developed testing software that was needed, which it later sold to the parent firm: this was an unplanned decentralisation of responsibility that resulted from the industry's fervour for rapid market response. Software professionals in another firm turned the software they had developed for an automated warehouse in Scotland into a product for the global corporation to sell. New product responsibilities were similarly devolved to subsidiaries: headquarters awarded new products to the facilities demonstrating both the capital and labour capabilities (in terms of productivity and cost performance). The subsidiaries of the study's multinationals were particularly successful in winning new, sophisticated product investment.

The market forced this decentralisation to the subsidiary in Scotland. Customers expected the subsidiary to have both the expertise and authority to take decisions and implement them. The field survey revealed many examples of technical professionals in one firm consulting with the supplier firm both to get technical asssistance on product usage and to get products designed/redesigned to their particular needs. With some firms locating product design etc. in Scotland, there was competitive pressure on others to provide it. A long, international sign-off procedure to get this technology-related information would have sent customers to a competitor. Devolving value-added activities to the subsidiary in Scotland created better relationships with the market and generated new product ideas, faster turnaround times, sales and productivity improvements that could be applied throughout the firm and faster turnaround times.

The market was not the sole determinant of corporate structure. After all, advanced development and manufacturing plants could have been located anywhere inside the EEC, not just Scotland, to serve the European market. Decisions to devolve product and production technologies to Scotland resulted from the dynamic between the industry and the local labour market. The regional labour supply offered clear advantages over many other locations for firms to succeed in their simultaneous objectives of improving product and minimising unit costs. In addition to the supply of technical labour from the region's institutions, the interesting jobs associated with greater technological responsibilities attracted technical personnel from outside - both young and experienced. The new structure of the industry in Scotland shaped a labour market segment that made industry recruitment of highly skilled and experienced people easier. This in turn made investment in new technologies more economical.[1]

The rigid, hierarchical employment structure associated with branch plants was not consistent with the objectives of decentralising responsibilities. For the firm to reap the benefits of market-responsive production capabilities, work had to be structured to make information feedback mechanisms effective and to encourange rapid applications of information. The emphasis on deskilling and the dependence on relatively unskilled labour associated with branch plant production was no longer appropriate. For example, while the new technologies had capabilities to deskill some of the work of a computer field service technician,[2] to deskill the job or the worker would have jeopardised a key link between the market, the product development staff and the testing division. To understand the customer's technical concerns and to be able to report to professionals in other departments with sufficient sophistication, the field service technician needs solid technological training. Product repair often meant going beyond making the product work to making it work for a particular, complex application. To do this, a technician had to be able to talk to and sometimes do part of the job of various engineers. An example, cited earlier, demonstrates the potential benefits from effective communication with the customer and within the supplier firm. In the course of repairing equipment for a major customer, technical personnel at one of the survey computer firms identified the customer's need for a new product; the R&D department then designed it and the firm manufactured it in-house.

A change in which workers were appropriate for the industry's jobs was associated with and, more importantly, seemed instrumental in, the changing structure of work. Recruitment and employment decisions were framed by local labour markets conditions. The availability of a highly trained technical labour supply and a growing pool of male youth in Scotland proved to be particularly important to the economic development of and the definition of work in the industry.

While a departure from the industry's past, management's willingness to allow a less rigid and segmented work structure overseas is not all that surprising. US high tech executives, many of whom were once entrepreneurs had always believed that easy communications and autonomy were essential working conditions for their technical employees. This was the only way to ensure that ideas would become products rather than die within a bureaucracy of memos and decision-making. The same fluidity would be necessary inside a subsidiary with technology-intensive responsibilities.

Devolving sophisticated technological responsibilities also demanded effective inter-firm collaboration: the transnational structure of the corporation had to change to permit lateral communications amongst plants and to maintain the industry's `technological dynamism' at the level of the corporation.

Projects shared across countries were not unusual. Communications and collaboration amongst personnel with the relevant expertise in a number of major facilities across the globe were frequent. Technical personnel in the subsidiary (usually engineers) were given management responsibility over particular projects or part-projects: these professionals working in Scotland were just as likely as someone in a home base plant to control a corporation-wide project in their field of specialisation.

This kind of communication and collaboration could not be handled in corporate meetings of managing directors or closely controlled by headquarters executives. That would have slowed down the potential return. Many of the firms had in recent years flattened the hierarchy within the subsidiary in Scotland and within the home base companies to facilitate this lateral flow of information. They eliminated many middle management positions to remove layers of bureaucracy that block easy and rapid communications.[3] Devolving technological responsibilities to the subsidiary in Scotland, then, to some extent required restructuring work to promote faster learning within the subsidiary and between the subsidiary and other major corporate facilities and to reap the returns on that information.

7.3 LIMITATIONS OF THE STUDY

The interpretation of these findings is, as outlined in the introduction, limited by the methodology of the research. While cross-checking and corroboration was attempted, the research rests primarily on interviews with managers. An interview does not allow the time or the rigour to distinguish clearly managers' hopes from their actual policies or differences across companies in policies that hide beneath similar jargon. The indicators or interpretation of findings from this kind of research cannot provide precision, absolute consistency or complete reliability. The attempt has been to offer a snapshot that profiles the developments in a new and fast-changing industry that inspite of a very public `persona' have largely remained hidden from view.

That snapshot, though, captures only one point in time. A change in a corporate directive or a shift in the market would likely have altered the economics of existing policies and might have led to a change in the balance of centralisation/decentralisation between corporate home base and the Scottish subsidiary. The study period was one of market growth, resulting in unprecedented capital investment and optimism. The massive market downturn that followed in 1985/86 surely affected the Scottish plants. The data reported here, however, cannot help predict or interpret company adjustments to the recession. This, the industry's most severe downturn to date, is clearly an important one for further study: tracing the investment patterns and allocation of work at the subsidiaries in Scotland through the recession would contribute greatly to a clearer understanding of just how much economic and financial importance corporations assigned to opportunities for greater flexibility and employment stability in Scotland.

The results of this study reflect the character of the survey firms. They were market-leading corporations producing some of the high tech industry's most advanced products. The findings refer to the compelling economic and social relations of production and distribution resulting from (for the most part) sophisticated information-intensive products and catering to demanding customers. The findings here do not contradict evidence that the economics of the electronics industry's historic international division of labour continues to provide important cost-cutting opportunities based on extraordinarily cheap labour. I do not argue (as Hirschhorn, 1986, does) that the observed tendencies of a decentralised structure of work are generalisable to all industry. The recent growth of multinational electronics plants just across the USA border in Mexico (part of the maquiladora programme) and the further fractionation of production amongst myriad subcontractors attest to the still irresistable advantages of this relative cost difference. That option, however, is a viable one primarily for highly standardised (or at least 'componentised') low technology products that can be manufactured by relatively low-skilled labour. The results reported here emphasise the importance of the nature of the product and its end-user markets in establishing an industry's economics of production and distribution. So, while limited in its implications, this study does suggest that the economics and the resulting spatial pressures of rapidly-changing information-intensive product sectors are different. If the markets succeed in increasing the information content and efforts to impose 'permanent innovation' on other industries, the results reported here may have wider application.

Finally, the study is limited by its focus on only one region in the world. The data reported here provide no insight into developments of these same corporations in other parts of the world, particularly the debate about corporate decisions to use new, more automated technologies to relocate activities from the Far East to the home base economy. The only contribution this research offers to the subject of export-dominated multinational investment is to emphasise the importance of both end-user markets and heterogenous local labour markets in framing those relocation/reinvestment decisions.

7.4. CONTRIBUTION TO CURRENT DEBATES

7.4.1 The Missing Middle

Prominent contributors to the literature on technological and industry change in high-tech and other industries have found an increasingly bifurcated labour force. Employment growth and labour demand are concentrated in very highly skilled often professional jobs, and in low level jobs, frequently deskilled by the adoption of new technologies (Bluestone and Harrison, 1984; Rumberger and Levin, 1984; Morgan and Sayer, 1983).

Middle level jobs are eliminated. This "missing middle" (Bluestone and Harrison, 1984) represents an unbalanced distribution in the benefits of economic change and growth.

The shape of growth in the industry in Scotland was much more evenly distributed. Management responsiveness to the specific conditions of the Scottish labour market led to a restructuring of work and as a result a different pattern of employment and recruitment. The quality of the regional education system and the availability of young people with a record of academic achievement assured management of an intelligent labour force that would be receptive to training. Managers were willing to risk recruiting unskilled but well-educated youths and giving them chances to assume more and more responsibilities, including working toward a skilled job without prior training. Furthermore, the vocational system, undergoing significant change at the time of the survey, was expanding its offerings to teach the basics in electronics technology in schools: these efforts were to increase quickly the supply of technology-literate young people to the industry. This labour supply, lacking the established formal qualifications, would presumably be recruited at lower pay. Inspite of entry level jobs and pay, these workers would have at least been introduced to the technology's problems, preparing them to learn more complex tasks.

The higher education system, including technology colleges, provided courses leading to a range of industry-specific qualifications. All these supply developments meant managers could distribute some of the tasks formerly grouped as the job for a highly qualified technician amongst lesser qualified workers. Employers "hired lower on the skill chain" (Interview with director of Institute for Manpower Studies) because it freed up qualified technicians to do more demanding, engineering work and, as a result, releasing specialised engineers for more complex tasks. It also minimised the firm's reliance on the external labour market, cushioning it from the regional, national and international competition over and salary acceleration of degree engineers. In both cases the firm minimised its total wage bill while expanding the amount and sophistication of the workload per worker. Public sector support of the industry, in particular, industry-specific training and education, bolstered this relationship with the local labour market. The strategy to hire lesser skilled people at all levels and train them inside the firm meant that - at the firm and industry levels - there was no gaping hole in the occupational distribution and mediated the employment increase at the highest, most specialised levels.[4]

7.4.2 The Current Debate on Post-Industrialism

The research findings of this study expose some of the shortcomings of a current debate in academic circles in the US about the changing shape of industry and employment. Led by Hirschhorn (1984) and Piore and Sabel (1984), the Post-Industrialists argue that there is now a new industrial economic regime in which all manufacturing is or will be organised to provide production flexibility and continuing innovation. This requires an enhanced contribution by all production workers in terms of skill, contextual knowledge and responsibility. Hirschhorn argues that the technology - the particular nature of complex electronics control mechanisms - commands this labour process restructuring. Piore and Sabel contend that the markets require it: global markets will not support mass production of a standard product.

Competitive success demands variable product (both over markets and time periods) which depend on both a craft-like labour process organised around small batch production and an industrial infrastructure that links and supports company specialisation. Hirschhorn, Piore and Sabel insist that firms and industries should, even must, adopt this profile of a new industrial order to remain competitive. However, their mistake was in equating a small batch process with a craft-labour process. The new technologies allow new conceptions of work and the labour process to produce small lots of variable product.

Furthermore, both arguments fail to address the factors that will shape _if_ and _how_ the restructuring of work and employment will take place. Their propositions suppose that a demand-side decision, a memo from corporate headquarters, will dictate the change. Firms will then invest in the appropriate recruitment and/or training/retraining. With their single minded belief in one necessary outcome, they failed to realise that the changing competitive environment can create a range of outcomes in the organisation of work. In particular, they are blind to the dynamic relationship between the labour supply and the structure of the firm and work. The social relations of production, not the technology alone, frame the structure of employment and the firm's response to competitive pressures. Ignoring these contingent factors left them open for the criticism of Kelley (1987), Shaiken, Kuhn and Herzenberg (1986) and others that supply-side institutional factors - particularly management-union/management-labour relations - mediate the process of associating skills with new technologies and of organising work.

However, this criticism did not go far enough: there are powerful social relationships other than that of skilled, unionised workers and management that influence the outcome. The findings of this research underline the importance of two previously ignored dimensions to the post-industrialist debate - the internationalisation of capital and the role of gender.

7.4.3 International Differences

The variety of organisational cultures and histories of multinational corporations makes the inevitability of the post-industrial model unlikely. For example, the Japanese firm structured employment to rely heavily on eight senior engineers who were experienced in starting up other plants around the world. The experience these engineers brought to the new start-up to a great extent substituted for hiring a large contingent of expensive degree engineers. The purpose of seconding these engineers to Scotland was to prevent the development of plant autonomy, particularly to impede potential independent action by highly trained engineers. This cadre of engineers from corporate headquarters set the bounds of the technology responsibilities for the plant and simultaneously outlined the allocation of work amongst the workforce. The result was a more robust organisation of work for lower and middle level employees. However, this was dictated from the top down. This was one conception of flexibility without the autonomy of and control by craft workers that is the model and the objective for Piore and Sabel.

A firm operating as a multinational has a much wider range of supply conditions and opportunities to exploit those conditions than a one-country firm. Given a world of opportunities, the specific supply conditions of any location of a firm can significantly influence the structure of that firm. Management in these industries had been eagerly looking for ways to reduce unit costs without sacrificing quality or innovative potential to cope with a severe industry crisis. The specific conditions in the local labour markets promoted an organisation of technology and work that in many cases had no precedent in the corporation. Firms had shifted the allocation of tasks amongst jobs and workers both at the more skilled and the lesser skilled ends of the production process to take advantage of a labour force that was well-educated at all levels and a culture of engineering that attributed professional capability to upper level technicians. Management adapted their employment and work policies in response to the qualities of the labour supply and in particular the size, growth and variety of the technical labour supply. Both Piore and Sabel and Hirschhorn present a demand-side model where firms are compelled to alter the work structure: the supply-side has no place in their work except to serve management in a functionalist way. However, this study of the high tech multinationals in Scotland clearly indicates that labour supply factors do shape the organisation of work and management's willingness to reconsider employment policies.

There were clear corporate financial benefits to restructuring employment and work in the Scottish plants. The labour costs for an advanced semi-conductor assembly and test facility in Scotland with a full complement of highly, though perhaps differently, skilled workers was only three-quarters of the cost of operating the same facility in the US. Wages for a high level technician in Scotland were only one-third the salary of a young degree engineer in the US and one-half that of a US technician. Salaries in Scotland for equivalent young electronics engineers were only 43% of those in the US, as indicated in Table 7.1. Furthermore, the regional development authority, with a directive to improve the technological sophistication of the region's industry, was able to offer an array of incentives, subsidies and financial bribes to persuade firms to increase their technological commitment in the subsidiary and to shift the balance of their employment to technically trained labour.

These decisions were also the result of management's assessment of the situation and confidence in the potential of a policy of hiring `lower on the skill chain'. Most of the subsidiary managers were Scots: they knew well the quality of the region's educational system and the advantages offered by the increasing specialisation of programmes in industry-specific fields. They were also familiar with the fact that high level technicians were widely considered engineers and historically had had jobs and experience that allowed them to rise to management positions or start their own firms.

TABLE 7.1. COMPARATIVE WAGES AND SALARIES IN THE US AND SCOTLAND

	Weekly Salaries, 1983		
	US	Scotland+	% Scotland/US
Electonics Engineer	$608*	$259	43%
Electronics Technician	$406*	$222	55%
Engineering/ Scientific Programmers		$352**	47 - 88%
Entry^	$400-525		
Experienced^	$500-750		
Semiconductor Processors (Based on 40-hr. week)		$153	48 -85%
Entry^	$180-220		
Experienced^	$500-750		
Electronics Assemblers		$150-161	47 -94%
Entry^	$160-200		
Experienced^	$240-320		

SOURCES:
* Weekly earnings: Monthly Labor Review, (1985), p.55-6.
\+ SDA Annual Survey (1983) and confidential survey data Earnings based on salaries or hourly pay. US dollars calculated at the exchange rate of $1.5159 to the £ sterling (1983); Statistical Abstract 1987 (Table 1470).

^ "Selected Occupations, Wages and Outlook," Labor Market Bulletin, San Jose (California) Job Service; first quarter, 1983.

** Systems analysts employed in the region's electronics manufacturing firms.

In addition, managers had expressed confidence that even relatively unskilled workers would prove eager, striving employees as much because of the persistent unemployment in the region and the UK because of the well-known work ethic of the Scottish culture.

Managers' willingness to experiment in assigning and training inexperienced and sometimes untrained recruits for demanding jobs attests to the strength of local labour supply characteristics in decisions about the association of skills and responsibilities to jobs and workers, even when the benefits of a change cannot be quantified. If the region's more robustly structured plants prove more successful competitively than other subsidiaries, as Appelbaum et al. (1986) claim should be the case, Scotland may continue as a locus for high tech growth and the plant in Scotland an ever more important part of the global operations of these corporations.

7.4.4 The Role of Gender

A second major failing of the post-industrialism analysis has been to ignore gender. Gender is a fundamental, if often unarticulated, aspect of the social relations of a plant, firm and industry. It has been ignored in this debate. This exclusion results either from the writers' belief that gender is inconsequential or from the assumption that gender is not operative in the male-dominated workplaces that have most often been the focus of study.[5]

The research findings of this study here affirm, however, that gender relations shaped management efforts to structure a new flexibility in the workplace. The availability of a new male labour force - unemployed male youths in particular - enabled management to hire men into formerly female areas of work giving them wider responsibilities than formerly alloted to a semi-skilled production worker. The fact that they were men checked the potential for comparison with previous jobs and workers and limited complaint by women workers. Further, male managers tended to have different if not higher expectations of their male workers in terms of worker expectations of a job and their commitment to paid employment.

As a result, they opened doors for these workers, and often enhanced their jobs. While they in most cases changed the job title to make this easier, there were also cases where male workers in positions directly comparable to women workers were favoured. As is so often the case, men were assumed to have a long-term commitment to the labour force while managers worried about the employment stability of women. With a priority to improve the stability of their entire work force, management looked to the male labour force. The shift in the gender balance toward men would also foster the improved communications and the collaborative atmosphere so important to keeping complex information-intensive production processes operating. The availability of a male labour force made restructuring work even with an established work force an easier and attractive opportunity for management.

'Tacit skills' then had become very important to the labour process and those 'skills' important to stressful and continuous complex production were defined fundamentally in gender terms. Male managers attributed to men the abilities of communicating and understanding technical information, being comfortable in non-hierarchical relationships, and joining in and fostering shopfloor camarderie and teamwork. These attributions were shaped by past experience and long-standing assumptions, and they were instrumental in management's willingness to open up the structure of work and to commit increased resources to training the men considered appropriate for the new situation.

The multinatinal corporations had reintegrated stages of work and enhanced work opportunities for workers to reap the direct and indirect benefits of a diversified (and relatively inexpensive) male labour force. These findings mirror the work of Beneria (1986) and Beneria and Roldan (1987) which showed how gender can be used to *fractionate* work and industry structure. They found that the availability of cheap women's labour in Mexico combined with the deskilling opportunities of new technologies to subdivide work and industrial organisation in a number of industries. The outcome was many-layered hierarchies of sub-contracting built on simple, dead-end jobs for women.

The specifics of the male labour force in Scotland proved very important. The local labour supply, in contrast to many others dominated by shortages, was in surplus and included available male workers all along the skill spectrum - unemployed unskilled but well-educated men, particularly young men, men trained in a range of industry-specific areas, and highly trained men with experience in high tech work. This labour supply was also considered a stable one: there was a high probability these workers would stay in the region. This was particularly important given the high turnover and instability of both technical and production workers in the US. Further, the region's shrinking employment base due to the decline in traditional manufacturing employment, the less costly standard of living (with respect to the US, Switzerland, a major world location of R&D labs, the London region, etc.), and the yearly increase in the supply of trained labour from the education sector meant that the cost of employing men was lower than in most already established advanced production locations. Furthermore, the annual renewal of the technical labour supply and local opportunities for upgrading would moderate the pressures to increase wages and salaries. This made capital investments safer: it was less likely that a company would have to relocate production, for example, to resolve labour supply or labour cost pressures. By taking advantage of this labour supply and the traditional fluidity between technical workers (Whalley, 1985), and by offering non-salary professional opportunities (eg training), employers could improve short- and long-term productivity in sophisticated technological work and minimise unit costs by hiring men into a more flexible work structure. While the direction of causation cannot be proven, that capability was associated with corporate decisions to devolve to these subsidiaries of new, advanced products and responsibilities and, supported by regional policy, the development of a more technologically sophisticated and more autonomous industry.

These developments were not the result of a simple association of men with new technologies. After all, there were a few firms in the survey where new process equipment had been introduced and the work structure assigned to those machines was algorithmic; that is, the jobs were simpler, severely limited, more monotonous and often more stressful than previous production jobs and completely cut off from enhancement or promotion opportunities. The production work force in these cases remained entirely female.

The determining factor in the gender, thus the nature, of the work was management's willingness to take risks and to invest in employing men. Using an example cited earlier, one employer expressed serious concern about employing men in a semi-conductor facility in jobs traditionally held only by women. The manager had carefully redesigned the usual female machine-minding jobs to satisfy the expectations of their predominantly male work force (which had previously worked on another product). The jobs for these workers included resetting, maintaining and repairing their machines. To retain these workers' loyalty and interest, company management had transformed the operator's job into a variable and semi-autonomous technical one. Management had a range of choices in employment and work structure, not a technological or competitively inevitable one. However, the value of a loyal, stable labour force - "the kinds of people who will be worried about making their mortgage payments" - to meet new pressures of production convinced managers to re-fashion jobs and titles to meet the expectations of those they thought the most suitable for the work - men.[6]

7.5 CONCLUDING POINTS

The sheer rapidity of technology and market change in the computer and semi-conductor industries pointed to a need to investigate how accurately two widely used theories on multinational corporate organisation and labour markets - the product life cycle and dual labour market theories - explain recent industry and corporate activities and events. This research has attempted to demonstrate how important the particular product and product markets are and how necessary it is to reassess the nature of competition in analysing industrial development. The economics of producing information-intensive products for a highly internationalised marketplace clearly challenge the explanatory powers of conventional, ahistorical theories that rely on rigid, hierarchical and general structures to promote capital accumulation and development. More importantly perhaps, this research has attempted to demonstrate that gender is a factor that must be brought into the analysis of industry structure and adjustment, areas of 'serious economic analysis' from which it has too long been excluded.

ENDNOTES

CHAPTER 1.

[1] Some computer firms are exceptions: their post-war growth included expansion overseas to get government contracts, eg, IBM and Honeywell in England. These exceptions will be outlined in the context of the history of the industry in Chapter 4.

[2] There were a number of important studies either specifically on multinationals or on electronics firms in Britain, of which multinational corporations were a part. But much of this work was done before 1979/1980 and/or assumed that the pattern of employment, the allocation of technologies and the role of the subsidiary within the corporation was essentially the same as in the past (McDermott, 1979; Massey, 1978; Massey and Meegan, 1979; Hood and Young, 1979, 1983). There were two exceptions: Pearson (1983) importantly recognised that multinationals targeted different labour pools in different locations, and Morgan and Sayer (1983) called attention to the changing make-up of the high tech work force in the UK and elsewhere. Neither, however, linked these observations to the structure of the multinational, or more specifically, to the international role of that subsidiary in the corporation.

[3] The definition of high tech is a source of disagreement amongst analysts. What 'high tech' industries have in common are a higher than average employment of engineering, scientific and technical personnel and a higher than average share of research and development expenditures relative to sales (DES, 1986). Many industries qualify as high tech, using these measures: aircraft, space vehicles and guided missiles, plastics and pharmaceuticals, for example, are industries that could be included. Throughout this document, however, high tech is used to refer to the two microelectronics industries under examination; while a simplification, the term is used to distinguish these sectors from electronics industries that are less information- and technology-intensive.

[4] See footnote 1 in Chapter 4 for definitions of integrated circuits and semiconductors.

CHAPTER 2.

[1] The Heckscher-Ohlin (H-O) theory of factor allocations dominated much of the academic work then. Heckscher and Ohlin targeted the two questions - what kinds of goods will any one economy import and export and what are the economic gains from free trade. Heckscher and Ohlin viewed the differential allocations of factors of production across the world's economies and the resulting comparative cost advantages as the stimulus for trade.

Their factor proportions model claimed that a country would export those products the production of which made most use of its abundant factors and would import products requiring relatively more use of its scarce factors. In its simplest two-factor form, that model predicted that the US would export goods whose production processes were more capital-intensive than its imports because the US was considered to be better endowed with capital than labour relative to other economies.

[2] Vernon's model, however, is fully consistent with the transactions theory of overseas investment reviewed earlier (Caves, 1982). Vernon considered that the calculation of costs did not take one far enough toward understanding the reasons ways firms became multinational.

[3] His work, a departure from the body of the trade debate, derived from a sense that the micro concerns drove the macro trends.

[4] While Vernon admitted that others had previously explored some of these factors, that work had been part of an explanation of overseas investment that was triggered by the persistent structural world dollar shortage of the late 1940s and 1950s. The dollar shortage forced US exporters to consider foreign direct investment because overseas customers were restricted in purchasing dollar-denominated goods. This analysis of foreign direct investment (eg Williams, 1953) was abandoned when the shortage disappeared.

[5] One of the values of Vernon's work, according to a number of analysts, was its explanation of the reputation for successful innovation in the US. He argued that the US market had a higher than average income relative to other countries, twice that of Western Europe, for example. An opportunity for high income products would first appear to someone who knew the US market. In addition the US had relatively high labour costs and unrationed capital compared to all other capitalist markets. Opportunities to develop products conserving labour would most likely appear to a firm in the US where demand was conditioned by these relative factor allocations (Vernon, 1966; pp.192-4). The absolute and relative size of the US market further supported successful product commercialisation in the US.

This analysis diverged from the factor proportions theory in that Vernon emphasised the importance of factor scarcities in stimulating innovation. The traditional theory, by considering information a free and mobile good, argued that factor differentials should in no way bias innovation.

[6] There would have been plentiful opportunities and time for other firms to copy the product and production technologies, so increased competition was considered likely.

[7] He did, however, admit that changing relative interest rates might influence the location of an overseas investment.

[8] Vernon argued that locating in a low-wage economy was triggered by the development there of a sufficiently large market for the product, due in part to the much reduced price of a mature product. The added advantages of manufacturing in that low-cost economy helped, almost incidentally, in management's overriding objective to gain further returns on its technology, even at that late date, in the home economy.

[9] Scibberas (1977), for example, found no evidence of delays in introducing and producing new products in his survey of smaller European semi-conductor multinationals operating in the UK in the mid1970s.

[10] "As an industry [in the past] matures, product design becomes standardized and the focus of competition shifts toward incremental manufacturing refinement and marketing." However, in a situation of rapid and continuing technological change, "[t]echnological innovation, which upsets established design parameters, refocuses the search for competitive advantage on new products and processes.

[The newest generation of semiconductors] represents the continuing technological innovation that cuts directly against arguments that the semiconductor industry is `maturing'."(Borrus, 1983).

[11] Profit-maximising employers will, according to the model, understandably hire men rather than women for jobs that are skill-enhancing and for jobs that offer long-term career development benefits because they do not expect women to be a stable work force.

[12] Also, employees in these jobs were more likely than secondary workers to be unionised.

[13] While many, ascribe primary and secondary jobs to core and periphery firms, respectively - the former, large, powerful corporations, the latter, small firms (eg, Harrison and Sum, 1979; Friedman, 1979; Tarling, 1981), it

is just as possible for workers in the two types of jobs to work on the same shop floor (Piore, 1975).

[14] Piore (1975) indicated that the secondary job level cushions the firm and its primary workers. The company's standardised production and its associated primary sector workers depend on stable demand. The employer assigned secondary workers to the tasks, part-products or products that were subject to flexible or unpredictable demand: because these workers were easy and inexpensive to fire and rehire, the firm could cope with demand swings by trimming secondary workers. This also proved to reassure primary workers of their relative employment security, reinforcing their commitment to the employer.

[15] In contrast to Doeringer's useful theorisation of the relationship between the external labour market and the employer's willingness to train, he underestimates here the extent to which the external labour market can turn these decisions around. A surplus external market can place an employee in direct competition with outsiders for an available job vacancy, particularly if product demand is high. A surplus external labour market which is very finely developed enables employers to hire outsiders for a variety of very specific tasks cheaper than retraining employees.

[16] Harrison and Sum (1979) reported Paul Osterman's discovery of a type of secondary job that might lead to primary sector employment. In older industries, young unskilled workers in small job-shop, eg in metalworking and machine repair, might receive sufficient on-the-job training to qualify them for skilled production jobs in other firms.

Also Rosenberg (1980) found some evidence of workers moving from the secondary into the primary sector during cyclical booms, but indicated that most of the movement was reversed when the economy turned down.

[17] "Functionalism involves interpreting what exists as the outcome of what is needed by the ruling class" (Amsden, 1980; p.27).

[18] This discussion relies on the very thorough and expert analyses of women's participation in the labour market of Bruegel, 1982, and Humphries and Rubery, 1984.

[19] This mobility between the domestic sphere and the sphere of production, reinforced by the jobs and work places in which women are concentrated, have in the past made women workers less vulnerable to union organisation. Capitalists considered this a further boon. To allege that this is women's antipathy to unions or organising as dual labour market economists tend to do is to misread the past and the present. This history has more to do with the rigid framework of male-dominated trade unionism and the occupations that have traditionally been unionised

(Bruegel, 1982). In recent years women in white collar work has proven themselves more likely than men to be unionised and there are also numerous example of women production workers organising in spite of male opposition inside and outside the trade union movement (eg the Lee Jeans occupation and the Plessey Bathgate strike, Elder, 1979; Findlay, 1986).

CHAPTER 3.

[1] Three important electronics multinationals of US-origin were excluded from the survey, though they may have provided relevant information. One, Beckman Instruments, was excluded because it was primarily a medical and measuring instruments manufacturer. While computerisation of the product has made it exceedingly difficult to draw a line between an instrument and a computer, it was determined that Beckman's product market, and thus its market strategy, was sufficiently different to warrant its exclusion. NCR (formerly National Cash Register) and Timex were not included because of their products and production processes which - while electronics- were not advanced or high tech microelectronics, using an above-average share of engineering, scientific and technical workers in the work force as the defining characteristic (Massachusetts Division of Employment Security, 1985). These firms were assembling watches, calculators, low level home computers, accounting equipment and other electronic products, often on subcontract. They were all low end of the market products with low information content, primarily directed to consumer markets. While data from these firms might have provided a valuable contrast to developments in the high technology sector, resources were inadequate to expand the survey to include them.

While there were a number of Scottish- and English-based firms that were important to the development of the region's microelectronics industry, they were not included. The plants located in Scotland did not actually produce chips or computers as finished products. ALso, in spite of establishing a global presence, firms such as Ferranti Ltd. were still predominantly UK firms, not multinational corporations. More important, Ferranti and Racal-MESL, two large high tech firms in the region, were almost exclusively British defense suppliers: this significantly cushioned them from the pressures of global competition so important in driving the development of the survey firms.

[2] Cutbacks by the Thatcher Government on data collection contributed to this problem. Lower funding for Government surveys reduced the frequency of and, in some cases, eliminated data collection in these industries (eg, the Census of Production).

CHAPTER 4.

[1] A semi-conductor is an electronic device made of a number of possible substances that have the property of partly conducting electricity. Integrated circuits, a specific subset of semi-conductors, encapsulate many thousands of electrical circuits usually embedded in silicon crystal. One square chip can now contain hundreds of thousands of electrical components - transistors and diodes, capacitors and resistors. Chips are an advance on earlier electronic technology in that they are solid state or monolithic. That is, all the components are formed together by the same production processes, all embedded in a sculpted device. There are no moving parts, parts put together mechanically, or loose connections that can be sources of failures. They replace devices that wired together separate discrete components. The wholeness of the device makes communication - the movement of electrons very much faster.

While integrated circuit is the term that refers precisely to the product technology which is the subject of the study, the more general term, semiconductor, will be used frequently and interchangeably.

Chips have differing capabilities and different markets. There are three basic types of chips - logic, memory and microprocessors. Logic chips process information signals, memories store information, and microprocessors are complete computers on one piece of silicon. The three types can be designed and in some cases programmed to fill a wide range of (if, programmable, variable) functions.

[2] Other microelectronics terms used throughout the text include the following:

. dynamic RAM (D RAM): a memory chip which must be "refreshed" within a short period of time or it will lost the bits stored. It permits a very high density memory (a large number of bits in a single integrated circuit) and thus a very low cost per bit stored.

. EePROM: electronically-erasable programmable read-only memory. The code stored in this memory array can be programmed by the user, erased, and then programmed to a different code. These are important support chips for the microprocessor.

. RAM - random access memory: stores digital information temporarily and can be changed by use. It is the basic storage element in a computer.

. ROM - read only memory: permanently stores information used repeatedly. It cannot be altered.

[3] Computers too fall into three basic product areas -
mainframes - large, powerful information processors,
minicomputers - smaller processors that can be distributed throughout a work-place, and

microcomputers, including personal computers, a small, stand-alone machine (that can be linked to a bigger computer) for use at home or work.

In addition, the computer industry includes all the firms that produce or implement only one part of a complete information system, eg firms manufacturing peripherals like printers and disk drives, firms producing software, the programmes that make the equipment work or develop it for particular uses. Computer bureaus and consulting firms can also be included in the industry. These are firms that provide a range of services to assist the market in choosing and using computers.

The distinctions between the segments have blurred over the past years due to the phenomenal advance in the computing power of even the smallest computer and the downward pressure of prices for all hardware systems. However, a mainframe was considered a systme with a multi-level general purpose architecture costing £100,000 and up. They are still predominantly based on architectures that were developed in the late 1940s (Duncan, 1981). Minis are smaller. Now, however, there are "superminis," or an equivalent of a mainframe built as a mini, and "supercomputers," extremely fast and powerful mainframes. The micro, developed as a much simpler, mass production product for a desktop, has become much more powerful, making it much more difficult to distinguish it from some lower-end minis (Snoddy, 1983).

4 Hardware and software have, in fact, a dynamic technological and economic relationship. For example, the increasing complexity of the systems has for various reasons driven up the costs of developing the software. With integrated circuits able to handle so much more information, many producers have embedded some of the operating instructions in the chips to reduce total production costs. This is called firmware.

5 Together these markets achieved 1973 sales of $41,165 billion (Scibberas, 1977; p. 50).

6 Growth averages mask significant downturns. The world market slumped in 1972, 1975, 1981 and 1985/6.

7 It is important to note that Japanese computer firms' involvement in the industry, particularly in the US market, has been to a great extent hidden by its OEM (Original Equipment Manufacturer). Leading Japanese producers supplied US firms with equipment that were marketed under the brand name of the US dealer.

8 Many independent producers were bought up by large, end-user companies. Of the thrity-six independent firms established between 1966 and 1979, only seven were still independent by 1979 (Markusen, 1985).

[9] Intense industry competition propelled technological change. In only a few years there was exponential growth in the number of transistors and circuits that could be embedded in a small chip of silicon. The table below distinguishes the successive generations of chip technologies and complexity.

Generations of Integrated Circuits

	No. of Transistors	
Small-scale Integration (SSI)	10	
Medium-scale Integration (MSI)	100	1960-1974
Large-scale Integration (LSI)	10,000	1970-1982
to	20,000	
Very Large-scale Integration (VLSI) (eg, 64K DRAM - 64,000+)	20,000+	1980-

NOTE: Transistors are the fundamental component of a circuit, the switch that directs or amplifies the electrical signal.

[10] The competitive importance of the mini as a major product improvement in the computer industry will be explored in detail below.

[11] The market also required every producer to establish a second source for its product to innsure that one firm did not have a monopoly on its supply. This meant giving the product technology to a competitor. The second source firm frequently improved on the product, patented the improvement and offered it to the market. In some cases, the secondary supplier gained market share at the expense of the original producer.

[12] While some firms specialised in custom rather than mass markets, these firms usually limited their involvement in special order markets. The high costs of developing one specialised design for an individual customer could not be covered by the revenues from the low volumes usually purchased (Borrus, 1983).

[13] US computer producers bought 35% of the chips shipped by US producers in 1978 (USITC, 1979).

[14] As Tom Watson Jr., president of IBM, explained:

> "Too much proprietary information was invovled in the circuitry production....Unless we did it ourselves, we could be turning over some of the essentials of our business to another group." (Billings and Hogan, 1979, p. 83).

IBM had set up captive chip production years earlier - 1964 (Billings and Hogan, 1979).

15 The attempt by IC firms to sell computer systems was a further discouragement to established computer producers from initiating any major technological collaboration with IC firms.

16 Just such a crisis developed when IBM released a major new product in the mid1970's. In retaliation for a technological advance introduced by one of the BUNCH, IBM introduced a new system at greatly reduced price/performance ratio from its existing products. Not only did replacement revenues plummet, but also many customers decided to lease rather than buy thenew machine in case IBM offered further improvemens in the near future. Theretreat into leasing cut IBM's yearly revenues dramatically. In the following years, IBM strategy was to introduce new equipment with a price/performance ratio generally in line with existing models (Billings and Hogan, 1979).

17 Most of the new entrants were spinoffs from the established industry firms. They were frequently started by engineering staff with a good idea that had not been well received in the parent firm or with a taste for the entrepreneurial role.

18 The benefits of minis to management included their ability to break up the information monopoly of the data processing department and the resulting higher wages commanded by programming professionals in these departments. This incentive to buy the new machines should not be underestimated.

19 The 32-bit microprocessor introduced in 1984/85 was four times more powerful than its predecessor. Just such a crisis developed when IBM released a major new product in the mid1970s. In retaliation for a technological advance introduced by one of the BUNCH, IBM introduced a new system at greatly reduced price/performance ratio from its existing products. Not only did replacement revenues plummet, but also many customers decided to lease rather than buy the new machine in case IBM decided to release additional improvements in the near future. The retreat into leasing cut IBM's yearly revenues dramatically. In the following years, IBM strategy was to introduce new equipment with a price/performance ratio generally in line with existing models (Billings and Hogan, 1979).

20 More powerful machines could be produced in smaller cabinets, with smaller, less expensivepower supplies and cooling fans, smaller, fewer support structures and fewer boards. This led to significant savings in the cost of computer hardware while miniaturisation of the chip meant that the cost of the ics on a copmputer took up a larger proportion of total hardware costs. The price of chips

continually spiraled downwards. All these changes meant that better, more powerful and flexible machines could be marketed more cheaply, creating new applications and widening potential markets.

21 Computer manufacturers, even in the 1960's, allocated 9% of their total expenditures to R&D. This compared with an average allocation of 7.2% by firms in other industries that also had high R&D commitments (Billings and Hogan, 1970).

22 Oakey (1981) defines semi-skilled work as a job requiring two to six weeks' initial training withoutrequiring or leading to a formal qualification. There is a growing and important body of literature that recognises `skill' as a social and political construct, where the gender of the holder plays a significant role in determining the skill level assigned to the job. This important debate is beyond the scope of this dissertation. The text here will adhere to the conventional ascriptions and usage of skilled, semi-skilled and unskilled forreading ease. This is not intended in any way to undermine the contention that the labelling is highly gender-biased. The issue will be addressed indirectly in Chapters 5 and 6.

23 The value of offshore assembly in all developing countries was $61 million in 1966; that grew to $393 million by 1969 (Chang, 1971; p2).

24 Even niche producers sent their chips to be packaged in the Far East. Their specialty strategy did not protect them completely from price competition. They could also significantly reduce the cost of their products which, like standard chips, depended to a great extent on labour costs.

25 EEC imports of many finished and part-time products faced a 17% tariff.

26 The dispersal of labour-intensive low-technnology operations to low wage economies in the semi-conductor industry encouraged the global spread of computer firms. By the late 1960s, a computer firm locating in the Far East could be near major chip suppliers. Also many of the large computer producers which had `captive' chip production (eg, Hewlett-Packard) had set up chip assembly and packaging in the Far East. Expanding those into other assembly work was easy and relatively inexpensive once a corporation had gained experience there.

27 Honeywell centralised these activities in Minneapolis and Burroughs, in Detroit.

28 This discussion relies heavily on the excellent work of Saxenian, 1980; 1981; and conversations with Lenny Siegel of the Pacific Studies Center.

[29] By 1971, twenty-one of the 23 large semiconductor firms were direct offshoots of Fairchild (Markusen, 1986). This section leans heavily on the excellent work of Annalee Saxenian, (1981).

[30] One million dollars financed a start-up in the early period of the industry.

[31] Bellew (1984) reported on company competition in Christmas parties: in the late 1970's firms hired 50-piece orchestras rock and roll stars and spent $700,000 and more. The explanation was "If you can't entertain your employees,...you'll lose them to someone who will" (1984).

[32] No data was available that would give a picture of the county-wide employment of the two SIC industries. The data quoted refer to the San Jose SMSA, which isthe core of the Valley's microelectronics activity, so likely represents trends and percentages of the region fairly accurately. Also Census of Employment data is quoted: this obviously will less successfully capture the changing employment structure in the Valley.

[33] In the semiconductor industry lesser skilled production workers dropped to 54% of the workforce by 1977, 20% below the norm for manufacturing industry, from 72% in 1966. The computer industry had 52% of its work force in production jobs in 1968, dropping to 44% in 1972 or approximately 66% of the manufacturing norm (Markusen, 1986).

[34] This may overstate the share of lesser skilled production workers, as it includes maintenance workers, many of wqhom would have electrical or electronics technician training and qualifications.

[35] For a more detailed analysis of the industry's labour demand, see Saxenian (1980; 1981), Snow (1980), Green (1983), and Markusen (1986).

[36] Silicon Valley housing became the costliest in the US. Saxenian (1981) attributes the housing inflation to the code restrictions on land use that were meant to preserve the quality of life that attracted high tech professionals to the area.

[37] It was not simply a matter of finding a labour market with wages lower that in the US: such opportunities abounded. The offshore wages had to be so low that, when the duty of the value added was figured into reimported part-products, producers still had significantly reduced unit cost.

[38] The figure that Grossman quotes refers not only to high tech employment but also employment in consumer electronics. Also it includes the employment of domestic firms that developed to support the foreign electronics

sector; she indicates that the majority of the employment was in offshore multinationals.

[39] In Penang, Malaysia, for example, four-fifths of the electronics workers were women new to the paid labour force (Siegel, 1981).

[40] The older women were those who had been working in the factories only two years to five years. They were frequently called grannies because the strain of the work had forced them to wear glasses.

[41] Clearly this is the employers' view: women with eye problems and experience in the big city usually had difficulties finding other jobs or returning home to a rural village. By structuring employment for high turnover, these multinationals created significant gender-specific unemployment problems. Grossman (1979) explains these economic and social consequences.

[42] Women workers had to pay to stay in these dormitories, often surrendering 50 to 100% of their wage packet for a bed (Siegel, 1980). The nearby accommodation however practically guaranteed that workers would be on-time for work and that they would be shielded from the higher living costs in the nearby community, costs that might have influenced them to call for higher wages.

[43] The offshore phenomenon was, however, not without problems. With the exceedingly rapid growth of an installation or Zone, firms at times did experience labour shortages. "Even in those regions in which a concentration of world market factories had developed to such an extent that the availability of young unemployed women has been drastically reduced, no change in the structure of employment occurs. Instead the firms react almost without exception by relocating production to new sites where this particular type of worker can still be easily hired." (Froebel et al. 1980; p349). And their rapid development in underdeveloped economies led at times to soaring living costs and wage inflation. Even worker absenteeism and turnover grew to be a problem for some workers. Management response was frequently to move to another country. They opened up similar plants in other Asian countries, tapping more peripheral or as yet unexploited labour supplies. Signetics, a US semiconductor firm, closed its factory in the Philippines due to mounting costs and expanded facilities in Thailand and South Korea (Iscoff, 1985). This experience, repeated in a number of countries, led to concern about "footloose" multinationals.

[44] It is important to recognise that all of the plants in all of the Far East locations were not structurally the same. The development of these offshore colonies (and political concerns such as that above) had stimulated growth and policy responses. Some of the Southeast Asian

economies grew into significant markets for the end-product. Some of the Governments introduced incentives and restrictions on foreign direct investment to spur multinational investment in and transfer of production technologies. Also after many years of operation the multinationals employed a core of experienced technical workers. Management in some cases began to reconsider the allocation of technology and responsibilities to that part of the world. In the late 1970s some firms upgraded, expanded or newly invested in facilities that performed more highly technical functions.

Singapore, for example, set up state-sponsored training centres and university programmes to train people for the industry's more skilled occupations. Singapore soon developed into an Asian locus for more highly technical multinational operations. Synertek located its most capital-intensive and rigorous final testing plant in Singapore, while the Thai plant was restricted to manual assembly and testing. The Singapore plant also served as the customer engineering services centre for customers in the Far East (Iscoff, 1983). The Apple Computer company in California decided to buy its entire supply of circuit boards, the brain of their computers, from a factory in Singapore that "make[s] nothing; they add expert value to the labour of others. The facility tests the boards that are stuffed by subcontractors: one third of the work force had electronics degrees and the rest had at least several O levels (Large, 1983). The economies of the Far East developed into a geographical hierarchy of high tech offshore operations (Personal communication with Rachel Grossman, 1983): the division of labour within the Far East economies reflected differences in access to major product markets, labour market resources and state policies. Exploring the history and economics of these differences is, however, beyond the scope of this research.

45 "...The labour cost share seems remarkably small in light of the eagerness of US firms to move their operations to other countries. An explanation might be found in the fact that other costs are less amenable to control than is labour cost. The price of materials is not subject to much negotiability. A standard complement of capital equipment is necessary to produce a given output, and depreciation charges would thus would not be greatly variable. This leaves overhead as a controllable cost category. Its magnitude in the typical cost pattern is quite large, and doubtlessly could be squeezed in most firms. It remains the mental habit, however, to regard labour charges as the most controllable; hence the tendency to emphasise even relatively small reductions of labour is bolstered when one's competitors do so...[With] foreign labour rates rising...at some point significant economies must be searched out by actively restricting overhead. A 10% reduction in foreign labour cost in the above example reduces total product cost by 1%, but a 10%

slice in overhead would achieve a 3.7% cost reduction." (Hildred, Nadler and Bengston, 1978)

46 The state had both the funds and the data processing demands for the large, complex and very expensive machines of the 1960s and early 1970s. In the UK state contracts accounted for one-third of computer sales in the 1970s.

47 Government agencies and nationalised industries (eg, telecoms) were required to buy capital equipment from domestic producers. Though the firms were clearly multinational, having a production facility in the UK qualified IBM, Honeywell Information Systems (as well as Motorola and National Semiconductor much later) and others to tender bids for state contracts.

48 While a few US firms established chip design centres in Europe, usually in Geneva or southern France, their primary aim was to keep up with the technological developments of European chip producers.

49 Many of the firms also served Africa, the Near East and some Asian markets from their EEC locations: inside the EEC they qualified to participate in the preferential trade relations within EFTA and in Commonwealth trade agreements.

50 Intel's earnings, for example, dropped from a $22 profit on its operations for every $100 of sales (before taxes, tax credits and interest) in the late 1970s to $10 for the first half of the 1980s. Similarly, National Semiconductor's profit fell from an annual average of $10 on $100 of sales to $6 over the same period (Sylvester, 1985).

51 In testimony to the USITC, the Semiconductor Industry Association (SIA) claimed that Japanese firms sold 16K RAMs in the US for $6 at the end of 1978, while the price in Japan was twice that or more. US producers's prices at that time ranged from $7 to $8. (USITC, 1979; p70)

52 Semi-custom refers to a number of different design and production technologies for chips. What they have in common is that the chips can be designed and produced predominantly with standardised inputs. The `customisation' can be achieved with a minimal share of resources devoted to the unique specifications. For example, the ULA (Unlimited Logic Array) pioneered by Ferranti procedure designs and produces a standardised logic device. With customer specifications, a final layer can be designed and superimposed in wafer fabrication that will direct the underlying channels to perform the needed functions. All special order requirements are met in the last stages of production.

53 By 1982 minis accounted for 35% of Honeywell's UK revenues (Connor, 1982).

[54] The stories about Apple and other companies starting in a garage were true, yet maintained a powerful mystique long after this was no longer a normal or easy way to get into the industry.

[55] The microcomputer could be designed to specific uses and its power and information exchange could be augmented by linking it with a business's mini or mainframe system. This method of distributing computing power throughout a business could be much cheaper than investing in a number of minicomputer systems.

[56] Clive Sinclair reduced the price of his home computer by 40% within one year at least partly by replacing 18 standardised chips with one custom-designed chip (Economist, 1984). Industry experts claimed that he had decided to base all his new product designs on ASICs.

[57] For example, designers could develop unique designs by putting together standardised parts of circuits to give a customer the desired capability.

[58] For example, Ferranti Ltd., a relatively small UK firm, gained a world class reputation by developing and exploiting the ULA technology. It held the lion's share of the ASIC market during its first years. "No less than 15 new chipmakers have attained sales of over $10 million in the past three years." (Keyhoe, 1984B)

[59] This is called `foundry' service.

[60] Borrus suggested a third strategy: a producer could rent its production facility as a foundry service to produce a customer's or a design subcontractor's designs. Many of the volume producers, including survey firms, did this as a short-term measure. However, management rarely found it satisfactory as a longer-term strategy. It eliminated the potential economies of being involved in developing market-defined designs and was a reactive rather than aggressive approach to developing future markets. While managers were happy to commit surplus capacity on older fabrication equipment to these customers, a total dependence on foundry work would impede investment in the production technologies for the next product, excluding the firm from future markets (Interviews with several managers, 1983 and 1984).

[61] Computers accounted for at least 50% of their sales by 1984.

[62] Software enhanced the possibilities of product convergence. Software can be designed to make a manufacturer's machine "behave as if it were an IBM 3270 terminal" (Cane, 1983A) or other product. Machine's made for one use can be adapted by software to compete in other markets.

63 There were cases of captive producers marketing their chips in the external market. That potential could certainly grow in a market with surplus capacity.

64 A major IBM selling pitch for its PC was teh reputation of IBM. "Price will not be a factor in the success of this machine. The name on the front is IBM and the companies that will buy this machine could not care less what they pay," according to an IBM dealer quoted in Meredith and Cane (1983).

65 The need to be able to customise chips further pressed this necessity for mass production chip firms. With the growth of semi-custom markets, that support had to expand to include specifying and designing chips: "[T]he development of custom markets may turn a growing segment of the semiconductor industry into an engineering service." (Borrus et al., 1983).

66 The technical explanation why this is the case follows in the next chapter where each stage of production and its requirements are carefully scrutinised.

67 This was supported by an interview with the one Japanese producer in the survey group.

68 The absence of strategic alternatives derives from the specific economies of chip production. For example, more sophisticated wafer fabrication equipment can perform two important functions: different chip designs can be made on the same wafer, economizing on wafer space and input unit costs and the more tightlyy controlled the processing the more good die will be produced on each wafer. Without increasing wafer output, better production technologies can reduce unit input costs and improve the yield, both reducing unit product cost.

For example, American researchers claimed that a producer could have reduced the total manufacturing cost of a 16K RAM memory chip (1983) by 62% (from $2.81 to $1.06) by using more precise, more expensive production equipment (Parsons and Stowsky, 1985; p54).

69 The growing commercial importance of the software in a computer system is reflected by corporations devoting a growing share of their R&D budgets to software development. The figures that follow are derived from the budgets of four the largest mainframe and 3 of the leading mini producers.

Percentage of R&D Budget Devoted to Software Development

	1981	1985
Software	35%	55%
Hardware	65%	45%

Source: Paine Webber Inc., reproduced in Business Week, January 14, 1985, p97.

70 IBM, for example, took advantage of a large and growing pool of creative entrepreneurial talent in the software industry by inviting independent software designers to design software for the introduction of the comapnay's new PC. The company's aim was to create as wide a variety of applications thus new markets for the PC. It treated the PC's technology as an open design to nourish this process. The diversity and quality of the software products were major factors in catapulting the late entry of the PC to the top of the market.

There were two competitive responses. Apple Computer, the displaced market leader, was forced to respond in kind. The firm commissioned both internally and externally a wide range of applications software for their computer to compete with IBM, particularly in business markets. Continual software development to upgrade and retain control over a market niche and to exploit new niches is a critical competitive strategy for a computer hardware firm, lest the product's market disappear (O'Connor, 1985; DeJonquieres, 1981D). Secondly, because the IBM product technology was open and it had become the market leader, a proliferation of IBM-compatible products entered the market. They gained sales on the crest of the rich body of IBM-specific applications software they could run. Being IBM-compatible became a necessary market strategy. Clearly these "clones," as they are known, challenged IBM. They offered cheaper and technically more inventive equipment and ate into IBM's PC sales, which as a volume product, operated on a low margin. While IBM eventually developed a new product market strategy,70 it maintained its product's connection to the software market it had essentially created.

In recent years, IBM progressively lost share in the mini and mainframe market. The problem stems from the advent of distributed processing and the necessity to make different models of a firm's computers as well as others' computers communicate with one another when they are added on. This is essentially a software problem: the software structure of the machines must be parallel and compatible and there must be an effective software system, called a local area network, to coordinate the entire system. IBM's customers, according to claims and quotes in the trade press, became increasingly discouraged by 1986/7 by the non-compatibility of IBM's many machines and by the recurrent failure of the firm to produce a software network that would make them work effectively together. While the extraordinary expense of switching from one software system to another will discourage a customer from buying a different computer system, this also works to place much greater importance on a producer's record with its customer base. The experience of the quality, flexibility and expandability of the software and the servicing record of the manufacturer both count heavily in a purchasing decision by existing and potential customers. The market's concerns about IBM gave DEC a major market advantage (and an increasing share at IBM's expense) throughout the 1980s. The company's most acclaimed selling point - its design of hardware models around an effective software network - won it both new buyers and old IBM customers.

71 These costs include the expenditure on research and development of software to operate and sell the system and on maintenance costs.

72 Software maintenance grew from about 20% of small systems in 1970 to approximately 30% in 1985. Over the same period hardware costs dropped from 57% to 30% of total outlay (O'Connor, 1985).

73 Software development in essence is the structuring and manipulation of information and logic: it did not lend itself easily to systematic 'Taylorist' work organisation as a strategy for increasing productivity and reducing unit cost (Ernst, 1983).

74 The focus here is the competitive life of a product. The chip is a near indestructible product and can maintain flawless performance for perhaps hundreds of years. However, the saleability of a product and its potential to earn high revenues are drastically reduced once new products with better performance and cheaper functions are introduced.

75 By the mid1980s customers were demanding equipment upgrades in even less than two years' time [Interview with managing director of an engineering microcomputer firm].

76 However, this can also have contrary implications for the length of the product cycle. With the fast pace of innovation and the relative inexperience in both the private and public sectors in organising effective use of computer systems, potential buyers may moderate or postpone computer purchases. When they are ready, they are unlikely to consider what would then be "old" systems. In addition, producers in this market depend heavily on customer testimonials for generating additional sales. Without sales to big buyers, manufacturers would stand to lose their investment in an entire generation of product.

This is essentially the argument forwarded to explain the crash of the computer market in 1985. Computer manufacturers found their expected sales growth vanished when business froze or postponed new equipment: they wanted to make past investments more productive and to wait to see the usefulness of the market's new technological innovations. The life of much of the equipment then on the market came to an abrupt end, as did some of the producers.

77 The continual pressure to increase sales volume derived directly from the progressively more powerful ic and its cheaper price per bit of information. Duncan offered this hypothetical case. "For example, a system builder launches a processor which performs one million instructions a second. It sells 1000 systems over its economic life of 36 to 40 months giving it a total installed power of one billion instructions. The price of the processor was £500,000, giving a total turnover of £500 million. During the life of the system the price/performance ratio comes down exponentially: when it was launched the processor was on the ratio of providing an instruction a second for 50p whereas at the end of its economic life the industry standard had dropped to 20p an instruction a second.

"The new system that the vendor is developing would have to be built to provide about half as much again processing power as the old one, about 1.5 million instruction [sic] a second. To fit on the industry price/performance curve so that customers of the old systems will almost automatically order the new system it will have to be priced at £300,000 - 1.5 million times 20p. At £300,000 just over 1000 such systems would have to be sold to retain the previous turnover level of £500 million from the system. The existing user base of 1000 will therefore have to be expanded by 600 new customers." (Duncan, 1981; p90-1)

78 The firms were willing to trade narrow profit margins for market recognition and share.

79 For example, the cost of the 64K RAM was quite high when it was introduced in early 1979, while the cost per bit of information of the then dominant product, 16k RAM memory, was falling. By the end of 1980, less than two years later, the cost per bit of the newer product was significantly below the lowest cost achievable on the older product (O'Connor, 1983).

80 The Financial Times claimed that the cost of semi-conductors was falling at a faster rate each year. The cost of components needed to supply one megabyte of memory in a computer cost $32,000 in 1974, $7,000 in 1977 and less than $2300 by 1980. The forecast cost for 1984 was only $500 (1980).

81 IBM, for example, did not suffer unduly from the failure of a new lower end PC product, the PC Jr., a victim of the times.

82 In England and Scotland Honeywell and Burroughs both are exceptions: as long-established corporations in the economy, their work forces were organised from early on by the unions important in the electrical industries during the 1950s, 1960s and early 1970s - AUEW, AUEW-TASS, EPT. While the unions have won important victories for their memberships over the years, the non- and anti-union status of the rest of the industry has, among other factors,

limited their effective power. At both firms the unions sustained dramatic reductions in their memberships due to heavy layoffs since 1979 and have found their parameters of operation and bargaining increasingly narrowed during recent years.

[83] See, for example, Duncan's analysis of the crisis at ICL (1981).

CHAPTER 5.

[1] Official SDA figures are not current, and the figures for firms included in 'the industry' vary widely. In 1983, the SDA reported 215 firms, an increase over the 105 in 1978. In March, 1984, it was reported that the region had 270 electronics-related companies (Rosie); one year later, the Financial Times claimed there were over 380 industry firms. This 40% growth, while not impossible, seems implausible. What is interesting, though, is that all the employment estimates are similar in spite of the vairance on number of establishments, suggesting that much of the `infrastructure' discussed below is composed of very small firms.

[2] This was in spite of the fact that the industry claimed only 2% of the region's employment in contrast to the 12% in traditional manufacturing (Employment Gazette, 1985).

[3] Motorola, for example, set up manufacturing in Britain because without it, it could not sell to 60% of the UK market.jf

[4] Chapter 3 reviews the survey methodology amd Appendix 1 and 2 list the primary survey firms and supplemental interveiws that provide the data for this and the following chapters.

[5] These are the machines that align the many layers of microscopic circuit patterns on the silicon wafer and, using a photograph-like process, transfer them onto the silicon surface. Previously an operator had to align them manually by looking through a microscope.

[6] "[Our setup] used to require loading the wafers into an oven, removing them, putting them onto a tract which first layed the photoresist then baked it on, removing them from the track, putting them under the aligner, removing them, putting them into a machine that washed them, then putting them into another over. Now many of these process tasks are amalgamated into fewer machines, needing only three transfers." (Manager interview, 1984)

[7] He implied that he was personally involved in its development and would install the system as soon as it is available.

[8] The data here again does not allow precision. "Automated" insertion can be done by machines that require someone to place the circuit board into the machine and turn it around to position the chips or by a machine that performs all movements automatically. Also older machines were usually only able to insert one chip on one board at a time; newer ones have at least two heads, doubling the speed of insertion. In addition managers speaking of automatic insertion may now be referring to the use of a robotic arm that is able to insert odd-shaped components in non-standard patterns, thus automating more tasks than possible with semi-automatic equipment. Managers would

not specify the capabilities of their `automatic' inserters; however, many of these plants had just recently installed new automatic insertion equipment, suggesting at least multi-headed inserters for standardized components.

[9] The automation was achieved both by vendors improving their production technology and by producer firms rethinking their production strategies. One market-leading producer, intent on a strategy to automate production as completely as possible, switched from using chips designed and producing in-house to buying chips on the commercial market. The chips produced in-house were unual shapes and had many more pins (legs) than standardised chips; commercially available insertion equipment could not handle the non-standard components. Managment had achieved 100% automatic insertion of components by the time of the survey by using commercially-available automatic insertion equipment for standard chips and purchasing robots that could be programmed to insert the few remaining irregular sized components.

[10] The pressures to automate are likely to build as new technological possibilities are incorporated into production. Surface-mounting was the newest technology on the horizon at the time of the study. This process places chips on epoxy pads on a printed circuit board rather than inserting all their little legs through holes into the board. That change eliminated the steps of checking and straightening all the pins and drilling holes into the board (a very expensive part of the process) and the expense of enabling equipment to insert all of those pins precisely in the right places. Surface-mounting had pride of place in trade journals and equipment trade shows and managers expected that they would have to adjust their assembly operations within the following six months to two years. Surface-mounting had additional capital-saving advantages. The chips prepared for this procedure are smaller, so the board size can be reduced, having the cost of the printed circuit boards alone (Levine, n.d.). Levine indicated that producers had no choice but to automate assembly when using these chips: the parts are too small to be handled manually.

[11] Solder is liquidised metal that is used to glue components onto printed circuit boards.

[12] Examples are varied and must include the actual design of the plant as an effort to automate. The production space was kept very small; production workstations were arranged in a circle and were close together. The last one placed only feet from the shipping department and bay. The design was to reduce the handling and transportation necessary between production steps.

[13] Like the rest of this analysis of industry change, the decision to invest state-of-the-art technologies in

Scotland is not based on one reason alone, but a number of factors simultaneously. This description has centred on the pull of competition in maintaining technological sophisticiation. But always in this market the gap between cost and price is a driving force instructural decisions. The fast mounting expense of test equipment worried managers: in 1984 test accounted for 30% of the total cost of producing a chip and that was expected to rise to 70 or 80% quickly (It may already be 90% of a military market device.) Only two to three years earlier test was only 10% of total production cost (GEIN, 1984). Managers had decided they were willing to incur this expense because the cost of overlooking a fault and the cost of tying up partially-processed product - because of the slowness of existing test equipment - were considered prohibitive. Test equipment adheres to the `rule of fives': "If it costs a semiconductor manufacturer $5 to catch a faulty chip during burn-in, it will cost him $50 to replace it once it has been installed in a system, and $500 to replace it in the field, where it has to be serviced by a technician", according to an executive from a test equipment vendor (Quote in GEIN, 1985). Management had decided that the firm could not risk those costs and, as discussed in the previous chapter, end-user firms had begun to refuse to accept insufficiently tested product.

14 The level of purity of the production room in the National Semiconductor offers further evidence of the `cutting edge' nature of their technology investment. The cleanroom for wafer production was to meet Class 10 specifications, or no more than 10 particles per cubic foot of air (Large, 1984). The industry's cleanrooms on average had lower standards for impurities, Class 100 or higher.

15 Fast rising value of inventory (eg, sophisitcated chips) and the resulting high cost of storing it (ie the prevailing high interest rates of 10 to 15% p.a.) compelled managers to tighten up production scheduling and reduce stocks. This strategy promised substantial savings. Hewlett-Packard publicised the results of a system it had designed, reduced its work-in-progress inventory by 82%, improved its plant productivity by 50%, reduced floor space used (by 70%) and lowered its defect rate by 30% (Computing, 1985). Significantly, this was achieved in a small batch, low volume operation that depends on thousands of parts.

16 Even some of the smaller, domestic computer producers were feeling the pressure of industry competition to automate both inventory and assembly to speed up turnaround. These firms had maintained labour-intensive assembly operations because they did not have the volume to support expensive capital investment or the long-term market security to take on debt. Their strategies had been to design and market extremely clever or specialised computers: they relied heavily on the creativity of their

engineering staffs and the price premium their ideas created. However, managers in the two domestic producers in the survey confessed that market pressure for greater production precision and lower unit cost (as well as high turnover of engineering staff) threatened this strategy. In both cases managers admitted that they would soon have to automate much more of inventory control and assembly.

17 The function of the interface computer is to upload and download device programs, track lot histories, machine process parameters, machine utilisation and performance, and line loading and balancing. This computer usage optimizes material flow and loading and to improve utilisation by analysing the causes of downtime. Computerisation reduces unit costs accounted by capital usage by providing flexibility rather than rigidities from automation (Rose, 1984).

18 IBM for example had a team of Scottish engineers that worked jointly with a US team to develop its state-of-the-art automated manufacturing system. At the end of the development phase, those engineers returned to employment at the Greenock site to install and oversee the system.

19 Management strategy to automate to reduce production costs cannot be entirely divorced from an interest to establish greater production control. Setting up twin facilities will protect IBM from any threat to halt production at either of these plants. This is the Ford `world car' strategy. Due to the flexible nature of these computerised systems, however, the strategy will work not only for standardied product but also small batch, customized output.

20 IBM had established a wide global network to produce the components of its products. In the 1970s,

> "`[A] particular computer installation in one country today might consist of some peripheral units made in Greenock and Sweden linked up with a central processing unit made in Havant, Germany or France linked up with some other equipment made in Italy perhaps. It is quite a complicated rationale but we obtain economies of scale from that mode of operation.'" (Select Committee on Regional Development Incentives, 1983)

21 While design and development activities can be distinguished conceptually, that is much more difficult in practice. Design modifies an existing standard product technology to fit particular uses. Development is the "translation of technical and scientific knowledge into concrete new processes, products amd services through detail-oriented technical activities...This is the step, usually very costly, of solving the technical problems

required to apply an invention or to improve a technology" (Amsden, 1985B). While the interviews attempted to clarify the multinationals' investment in each of these activities, the responses were in many cases not clear. This is at least partly due to the fact that customer design requests for these complex products easily tend to require a significant time investment by staff which effectively leads to a new product.

22 In interviews in the US and Scotland, a number of industry experts indicated that they considered this firm a strange firm. This unique global strategy was likely the result of the firm's faltering competitive and financial position. The aim of management strategy seemed to be to minimise the number of global corporate investments and the spread of their risks.

23 There is one other exception: National Semi-conductor, also a chip producer, had in the past produced digital watches in Scotland. However, management found that the economics of rejigging production yearly to suit the highly changeable desires of the consumer market incompatible with volume capital goods production. While the corporation has developed other sustained efforts at vertical integration, eg NAS, a subsidiary which produces point-of-sale datacheck machines, these efforts have not involved the plant in Scotland. NAS simply distributes in England machines made in the US.

24 This discussion is further hampered by the imprecise and inconsistent answers from the survey interviews when managers' were asked about their products and the time delay between production in the US and production in Scotland.

25 Determining the specific extent of customisation, that is, distinguishing product modification from prototyping to a customer's specification, was beyond the scope of the survey. The distinction is not, however, trivial. Particularly in the semi-conductor industry, the various methods of customising a product are associated with different design and production technologies.

26 Here again the implications of a custom-oriented output have implications for the organisation of the technology and work, but different ones from those in the chip industry. Customisation of computers depends primarily on trained computer engineers and programmers to develop the software to make fairly standardised hardware work for a particular application. The customisation is in designing and testing the operating system and application software, rather than in the production of the hardware.

27 Improving the chances that each channel on each chip will perform perfectly as designed after the wafer has undergone so many processing steps requires more careful design and tighter controls in all the processing stages.

Steps taken in engineering and supervising production can improve production yield. Seeking better yield currently drives management strategies; they target different points in the entire process to improve yield depending on the product, the plant, and the time period. For example, tightening the precision of processing in the fabrication stage will have greater importance during the early part of life of the product because these costs are then the largest proportion of total product costs. The cost priority shifts as the yield of the wafer improves and backend costs grow as a proportion of total costs (Hildred, Nadler, and Bengston, 1978). However, minimising the defect rate at the wafer stage of production remains critical as an important way to lower unit cost. A small drop in the yield of producing a current generation chip (1984) from, say 70% to 60%, causes a significantly larger increase in cost - +17% (Unpublished corporate location study by one of the firms in the survey). Yield can be improved by reducing the size of the circuit: making it smaller both improves its performance (the current can move around faster) and reduces the chance of defects (Noyce, 1977). However, miniaturisation makes the tasks of forming and building the circuit much more difficult, working to much smaller dimensions, needing more precise, automated production equipment to reduce the number of defects.

28 The trend of rapid replacement of testing equipment might have been a relatively recent one for firms in Scotland. It was suggested that these same firms had not always maintained up-to-date equipment. The current priority to improve testing turnaround might have been necessary just to try ot catch up with the rest of the world industry. Managers comments suggested, however, that the market would no longer let a fall behind in test capability. Significantly, testing is being modernised in Scotland, rather than relying on existing capability elsewhere in the corporation.

29 Some of the subsidiaries designed their own equipment. Furthermore, these two firms had actually reformulated the testing process. They built self-testing capability into their products. At a fairly advanced stage of completion, the computer product itself would run testing software to check for any faults. Using the state-of-the-art computing capability in the product reduced the need for investing in fixed production capital.

30 Both the managing director and the personnel officer of one of these firms bluntly stated that the plant's products were `slightly obsolete.' One firm was in fact subcontracting a product design to get back into the banking market.

Events in the two years following the study confirmed the instability of the corporations' competitive position. In one case the parent corporation took over another computer multinational in 1986: major reorganisation of their international operations followed. The other parent corporation diversified out of mini-computer production in 1986: that decision would have to have been followed by disinvestment and/or restructuring of the production facility in Scotland. An interview with the economics editor of Electronics Purchasing (1985) provided further confirmation that the other firm was having problems in world competition with its computer products.

31 The policy of subcontracting out work that was labour-intensive was not limited to sluggish companies. IBM had a policy of maintaining a 100% buffer of direct employment; that is, supporting as much employment outside the company as existed inside the company by encouraging local firms to produce components for the IBM plant. These firms, which included sheltered workshops, assembled cable harness, cabinets, etc. using predominantly manual methods. While management explains this is to demonstrate the company commitment to supporting the local economy, the company's dependence on external suppliers is more likely due to the fact that most of this work would be awkward and expensive to automate. At the same time, the company could weather market ups and downs by shifting the impact to the buffer economy while maintaining its no-layoff policy for company employees.

32 According to Perez (1985), a new Kondratiev wave was also a major stimulus.

33 It was surprising to find how tenacious the ideology of workers as the source of management problems still is among managers. For example, the same engineer completed his explanation by saying that the new system markedly improved worker productivity. In this case, the worker does much less than before, merely watching the processing, not doing the same or more faster. However, management still conceptualises and chronicles the value of technological change by - in this case - noting the improved number of wafers per day per operator. The entire improvement, however, is within and due to the capability of the new capital.

34 Haug, Hood and Young (1983) offered a similar analysis for their findings when looking at the wider electronics sector in Scotland.

35 The research was not designed to rank the importance of these features or assign causation between any one factor and the shape of corporate investment.

36 The vast majority of the supply firms were small companies. While these firms were important to the shape and speed of the industry's development in Scotland, more than four-fifths of the industry labour force were employed in the region's multinationals in 1984 (Lambert, 1984).

37 "The success of [high tech industry] is often more dependent on the availability and quality of components, subcontract assembly, and supporting services than on the central high-tech product. So, the competitive production of personal computers is as much determined by the ease of obtaining low-tech plastic components, metal frames, printed circuit boards, cables, keyboards and leadframes as by the central microprocessor chip." (Firn and Roberts, 1984).

38 In the hope of creating employment, the Government encouraged private sector investment not only with funding but by omitting any controls or quid pro quos. " We must be careful not to impose on high technology industries the same kind of detailed controls which are imposed upon traditional industries," said Mr. Patrick Jenkin Environment Secretary last September. "Understanding and flexibility are crucial." (Lawson, 1983).

39 The grants were £48,000 in 1979 and £646,000 in 1983 respectively.

40 Five Government programmes in addition to regional development grants and regional selective aid offered financial support for technological changes appropriate to the high tech industry. The Microelectronics Industry Support Programme (MISP) gave grants up to 25% of capital costs for research, development, and launch of new product and process technologies. The Microprocessor Applications Project (MAP) helped firms assess, specify and invest in new microelectronics technologies. Grants covered up to 50% of the costs of developing and equipping outside courses to train engineers in the use of micro-electronics, and up to 25% for in-house training. Also feasibility studies could qualify for grants. Moreover, the Government would pay up to one-third of the capital costs of modernising through another programme, the Government subsidised up to one-third of the development and capital costs for computer-integrated and robotics systems. To encourage the diffusion of computers into all parts of production, grants were available for feasibility studies, development efforts and actual investment in CADCAM and CADMAT (computer-aided design, manufacture and testing) systems. These subsidies were complemented by economy-wide tax incentives for business. Capital allowances enabled firms to write-off immediately 100% of capital expenditure on plant and equipment and 79% of the costs of new industrial buildings against corporation tax (NEDC, 1980). However, the dramatically reduced allowance announced in the 1984 Budget may have moderated post-1985 capital investments in the high tech industry (Karlin, 1985).

41 The local industry had in the past had to deal with equipment vendors long-distance (Most vendors are in the US and Japan.) both in purchasing and servicing equipment. That meant ordering equipment to specifications for the

facility in Scotland had had to be done long distance. Also machine breakdown presented a firm operating around the clock with troublesome and costly downtime. The new company both leases office and demonstration space and warehouses spare parts so that vendors can service the semi-conductor industry around the clock.

42 A National Economic Development Office expert on the semiconductor industry claimed that the 100% tax allowance on capital equipment had also been an incentive to capital spending for the industry in Britain. However, the 1984 Budget introduced the reduction and eventual repeal of this incentive.

43 A point that most development corporation officials and many managers mentioned was the quality of life - the reasonable cost of living, the lovely countryside, etc.

44 A newspaper advertisement listed the coincident critical factors:

"Now Nippon Chip in Their $100 Million ....Several billion dollars has already been invested in the electronics industry in LLothian...Nippon Electric are the latest, with almost $100 million to be spent on their new plant at Livingston. Not surprisingly, Mippon are not just here for the scenery. For their sort of money, you'd expect something pretty special....Like a workforce that has literally grown up with electronics....Like easy access to the whole of the European market, and beyond by air, sea, road and rail...Like two universities and five technical colleges providing a constant source of top class employee material. And the world famous Wolfson Micorelectronics Institute, with a 60-strong research and design staff and a highly advanced silicon chip production facility - all available to industry....Like the full cooperation of Lothian Regional Council - so much so that it sponsored, back in 1979, the UK's first Chair of Miroelectronics at Edinburgh University....Plus the sort of working environment that key personnel are happy to settle in....Mitsubishi, too, are here with their first manufacturing operation in Europe and so are Ferranti, Hewlett-Packard, Racal, ICL, Burroughs and MFE. If you come to Lothian, you'll be in very good company!"

45 By contrast industry management claimed to be concenred about further investment in Ireland. The exceptional financial incentives were not paired with these crucial factors: the supply of appropriately trained technical labour was considered inadequate and the region lacked appropriate design, services and sub-supply support (Keenan, 1983).

46 The survey findings did show, however, that firms had found and pursued some opportunities for standardisation and scale economies.

[47] The caveat is included because there is increasing concern within industry that flexible equipment is not as flexible as anticipated (Salzman and Mirvis, 1985). The set-up can be long and unpredictable because of software problems; the range of product changes the equipment can handle reliably has too often been very limited. The technologies, particularly in the extremely precise manufacture of integrated circuits, have not yet been perfected to support the manufacturing flexibility that is touted.

CHAPTER 6.

1 The primary/secondary or core/periphery division depends to some extent on the particular industry in question. While it was quite clear historically in electronics firms, assembly workers in some auto plants have been considered primary workers and machinists in garment factories secondary.

2 The share of technical labour - engineers and technicians - who were the main primary workers in the industry, had similarly increased in the region's wider electronics industry, a trend analysts expected to continue. Technicians and engineers were 12% of electronics employment in 1979 (does not include software engineers and technically trained management); that share was forecast to increase to 17% by 1985 (Calculated from MSC for Scotland data presented in Hampson and MacLeod, 1983). Fife Regional Council similarly predicted that new electronics employment would shift to technicians and away from semi-skilled labour (mimeo from office of WG Taylor, Director of Planning; 1984), though more labour-intensive, less technologically sophisticated firms dominated that region's electronics industry.

3 The changing occupational profile was not simply the result of industry growth, but resulted in part from significant contraction in jobs for semi-skilled labour during the period. Primary jobs accounted for an increasing proportion of the employment growth in survey firms (almost 3000 new jobs). Employment in primary jobs increased 91% on average between 1979 and 1984 amongst the survey firms. As available data does not reliably reflect company employment in financial, marketing and other professional jobs, this undoubtedly estimates this growth., at least were primary jobs. These same firms eliminated nearly 1300 jobs, and almost three-quarters of this contraction was accounted for by operator and assembly jobs. Firms also eliminated clerical jobs whenever possible, but available company data does not allow measurement of this job loss. Engineering and technician job loss accounted for only 10% of the contraction.

4 The distinction between engineer and technician refers both to educational background and employer expectations. An engineer would usually have a bachelors of science degree and a wide theoretical background. In addition s/he could be expected to perform assigned projects with a degree of independence, outlining his/her own tasks and perhaps those of technicians and other asssistants. A technicians would be expected to understand and follow the correct procedures for assigned tasks, narrower in scope than an engineer, and usually within a close functional relationship with engineers and supervisors.

[5] The greater dependency and investment activity of the high tech industry on sophisticated capital equipment in comparison to the wider electronics industry may explain the SEPD's underestimation of technician employment. However, this difference might just as readily have led to greater than anticipated growth in engineers' jobs, but this did not prove to be the case.

[6] One semi-conductor firm, expanding very fast, evidently had (at least in the short-term) compensated for a shortage of experienced engineers with the work assignments for engineer recruits and students working during university holidays. Students, for example, had negotiated order for new equipment for the plant. While this was not necessarily good practice, discussions with industry experts indicated that, especially during upturns and expansions, such opportunities for job enhancement were common.

[7] The Engineering Industry Training Board (EITB) had found this job category most frequently in high tech electronics firms. The Board estimated that approximately 16% of all technicians throughout the UK electronics industry were these technical support personnel without qualifications (1983; EITB, 1984).

[8] This practice also served as an incentive to qualified technicians to be prepared to assume additional responsibilities as the company developed. Expecting and striving for job enhancement opportunities was thought to be important to job satisfaction, thus further benefitting management by reducing turnover.

[9] While few survey managers considered it a problem, some regions had to some extent experienced a shortage of electronics technicians. Interviews at colleges of technology and employment centres, however, indicated that these were predominantly problems of timing and labour quality (including the specifics of work experience) rather than a quantifiable labour shortage. That is, employers may have perceived a shortage because they had had difficulty recruiting top graduates of top programmes as soon as a technician vacancy was identified. There also were some geographical barriers limiting the success of firms in particular areas in recruiting qualified technicians, even in the context of region-wide surplus.

[10] The survey data is inadequate to report precisely how many firms had altered their work structures in this way. This innovation was an unanticipated discovery during the field survey. As a result, all managers were not consistently questionned on this issue.

[11] Managers explained that in some processes the technician's close oversight of equipment allowed him/her to watch production too, eliminating the need for an operator.

12 Employers sometimes transferred workers from other areas to work on new technologies. According to the women workers interviewed, the pattern was to bring in someone new rather than upgrade production workers, if the organisation of work around the new technologies diverged from the specific process the operative had previously handled. The only cases of upgrading reported were those where there was union representation with women shop stewards who promoted their workers for retraining as testers and technicians.

13 Training for the new job lasted six to 12 months on-the-job, but the company could hire unskilled people for it because they could perform satisfactorily on the new machines within two weeks. Older equipment had required only two to 12 weeks' training.

14 This was not possible in the industry's few union shops where job rules and demarcations had been to some extent maintained.

15 Hiring more intelligent workers and `quality' skills had become a priority for the entire industry (National Electronics Council, 1984; MSC for Scotland, 1980; Grubb, 1984).

16 Here as elsewhere there was diversity amongst the firms. One large semi-conductor firm, while setting no academic requirements, preferred wives of skilled or white collar professional husbands, using their upper working class status as a proxy for intelligence, carefulness and motivation (Communication from J. Foord, 1983).

17 The recruitment policy was explicit: a personnel officer for one firm said that the company only hired engineers with first class honours degrees.

18 The contention of a computer firm personnel manager was repeated by many others: "Quality [in this regard] is more important than numbers. If we can't find someone [with a sufficient high level of academic achievement] who is a good long-term bet, we won't appoint". The extent to which this truly reflected recruitment practice is difficult to determine. However, public officials claimed that the shortage of technical personnel alleged by the industry was a shortfall of sufficiently high quality graduates, not of people with the necessary qualification. This is supported by the fact that managers had found it necessary to extend their milk round visits to universities and colleges in northern England and to advertise throughout England for engineers.

19 The personnel manager of a fast-growing computer start-up firm emphasised that "The range of skills [needed] has developed away from technical skills to social skills...You have to have the social skills to convince

people that you're doing the right things. A QA [quality assurance] person who can talk directly with a customer [for example]. In our industry the social skills outweigh the technical ones." Morgan and Sayer (1984) and MacInnes (1984) also found that behavioral qualities had gained overriding importance in industry recruitment.

20 There were a few reports of operators in survey firms having mixed the wrong chemicals together, creating explosives. A few of the gases used in semi-conductor production were naturally volatile, potentially explosive with careless handling. Employers' answer to preventing these potential disasters was to try to screen out workers with sloppy habits and with difficulties handling stress.

21 Many had money reward schemes for employees who brought in new workers.

22 The personnel director at one of the region's largest employers commented that they had many mothers and daughters and aunts and nieces etc. on their staff. The family connection had become so important in recruiting that one long-term worker at another firm remarked that, "It used to be that the work you had done and what you could do was what got you the job. Now it's who you know. There's not a [new employee] that walks in that door who's not related to someone in here." Maguire (1984) also found reliance on family networks important in the Irish electronics industry.

23 Minimising turnover was clearly a management priority: in interviews this discussion was invariably concluded by a comment that the consequence of this strategy was foregoing the best quality candidates.

24 For jobs that required no formal technical qualification, personal and work background were obviously very important.

> "[The company recruiters] try to be as thorough as possible to get the person who will have little sickness or none at all, who will accept the terms and conditions of employment, who can work under pressure and will virtually do anything that is asked of them,"

explained the manager of a JobCentre that screened applicants for a large multinational employer. There was evidence that interviewers probe for trade union sympathies or experience. As a managing director explained, personal questions of this kind are legal in the UK, while outlawed in the US. Further, firms usually required medical exams for new employees; these exams in a number of cases included urine tests to insure the woman was not pregnant.

25 This practice was not only a trial for applicants; by reminding employees how many people wanted a full-time

permanent job, the temps effectively kept absenteeism low and productivity high among the regular work force.

26 One firm said their new facility had achieved the productivity of a nine year old sister plant in Eire after only two years. Another had achieved twice the productivity of other facilities in the UK, and two others performed significantly better than comparable facilities in the US.

27 In spite of efforts to minimise it, poaching from competitors and regional research institutions was the way employers hired experienced technical labour. Raiding other firms as a strategy, however, depends on a vibrant industry. That the high tech industry and research centres had developed sufficiently in the region to create a high quality market of experienced personnel was in itself considered a sign of success and a stimulus for further development of the industry. Managers were worried about escalating salaries for experienced professionals (especially as a result of the sharp expansion of capacity in 1983/4) and "paying more than they are worth," as a personnel manager complained. However, raiding was a superior tactic to importing professionals from other parts of the corporation on extremely expensive temporary contracts, a frequent practice in the industry.

28 Some firms did not exclusively hire youth: personnel managers at least two firms claimed they hired youth to fill approximately half of the vacanices in production work, and 'married women' filled the rest of the jobs. In one case the practice was explicitly to maintain better work behavior and discipline: the older women would keep the silly behavior of school-leavers under control and were themselves easier for supervisors to manage.

29 A study of labour requirements for the industry in England, Scotland and Wales similarly found that the opportunities for mature graduates with technological qualifications were limited, reported in at the end of 1984 (Gordon and Pearson, 1984). The report also claimed that the industry's employers tended to avoid hiring graduates whose first degrees were not in electronics and related technologies.

30 This policy was certainly not without controversy. In the unionised plants, long-term women workers complained that young workers had been willing to bargain away hard-won privileges, such as tea breaks, for a few extra pounds. They also had accepted redundancy quickly without struggle because they (understandably) thought they would have no trouble finding new jobs.

31 At the level of collective consciousness, these were still considered women's jobs. In the words of a JobCentre manager who recruited for the high tech industry,

> the "ideal person would be a married woman betweeen the ages of 30 and 37 with a couple of children... [T]here is a very strong argument that this type of employment is more suited to women."

Women workers said that when young men were recruited into these jobs with them they were not expected to stay long, because they just were not appropriate jobs for men.

32 It would be particularly useful to examine the gender breakdown of production jobs in all the newly automated facilities. Firms, other than those mentioned in the text, did not provide appropriate data.

33 In those cases where management had maintained the job of supervisor, it was no longer necessarily linked to the work area or the workers being supervised. In many of the firms, these vacancies were advertised throughout the plant; open competition usually brought someone from another section of the company. There were reports of managers assigning selected workers from other areas to these jobs without posting or allowing the affected workers to compete. Further, one firm had made the supervisor job a paraprofessional one by recruiting from the external labour market to fill vacancies. Once hired, supervisors were then sent to a US plant to learn the manufacturing process s/he would oversee.

34 In fact, in one case reassignment to a lower-paid job resulted in reduced pay. A worker had to accept the pay for the job to which one was temporarily transferred, though management promised that these transfers-down would not exceed 20% of a worker's work time.

35 In one firm production workers were taught to do every step of microcomputer assembly and were transferred to a different station daily if not hourly.

36 Employers claimed that operator training lasted 8 to 12 weeks, especially in some of the complex steps of chip processing. In fact this period was management's estimation of how long it took for an operator to achieve speed and minimum productivity and quality targets (and thus a period of probation). Actually learning the tasks usually took less than two weeks.

37 It must be noted that this was an import of the 'culture' of high tech from Silicon Valley; the tradition in capital-intensive manufacturing in Britain had been for engineers and technicians to be unionised and pay; job descriptions and advancement were matters for collective bargaining.

38 Shortness was the key factor in whether management would send staff on available courses. The director of a

highly-esteemed microelectronics technology centre claimed that they no longer planned courses to last more than four days because corporate managers had told him, "`If I can do without an employee for two weeks, I can get along without him forever.'"

39 These job enhancements may have gained value for technical staff in relation to the more traditional job benefits and perks. The Government made employer-paid health car, life assurance policies and other paid benefits taxable in the early 1980s.

40 It is not possible to determine from interview data (with the personnel manager as the source) exactly how different these jobs were from those for operators in other firms. Many firms trained their operators in a variety of tasks but these most often remained relatively unskilled. Management in this firm seemed to truly value good experienced operators, implying their jobs were more complex than the industry average. The personnel manager explained that they had brought experienced operators from a home base plant to Scotland and had sent senior Scottish operators overseas for training because experienced operators - not engineers - were the only ones with sufficient expertise necessary to train.

41 Management allowed lesser skilled workers to work toward a formal technician qualification, but acknowledged that the pace would be slow - up to six years. Management did not encourage it.

42 The personnel manager emphasised that the company's state-of-the-art technology was a critical part of the strategy. The firm can build a lot of collective expertise, that is, past experience, into the equipment through computerisation. That reduces the number of engineers needed.

43 The corporation's investment strategy was a critical factor in their organisation of work. The corporation had a long-term policy of pursuing the most advanced possibilities for production automation: the plant in Scotland was the most advanced in a line of progressively advanced assembly and test facilities.

The automation and computerisation itself frees up personnel. The automation replaces the manual activity of the operator so that s/he can perform tasks other than simply minding the machines. In addition, the installed microprocessor incorporates years of engineering information and experience, allowing a lesser skilled but appropriately trained person to be the first line of technical response.

Further, the corporation had set up a sequence of semi-conductor plants around the world, each with a lag of one to three years. This allowed each facility to be more modern than the last and to avoid the problems encountered earlier. Four plants were making integrated circuits at the time the corporation began investing in a fabrication plant in Scotland.

Because of the company's long experience and gradual progression through new technologies, the necessary technical responses were more predictable and controllable than for those firms leaping uninitiated into new production methods. In addition a group of eight extremely experienced engineers were assigned to the new plant in Scotland for five years: their collective knowledge and experience further reduced the expensive technological trailblazing that can be associated with introducing new technologies.

Where many other firms had used the new technologies to assign operators to mind many more machines or to perform fewer tasks faster, management in this firm preferred to use the technological advantages of the equipment and a resident cadre of experienced engineers by upgrading the role of operators and minimising the staffing needs for more highly skilled workers. The new technology installation of Fujitsu provides quantitative evidence of the staffing benefits of this strategy: computerisation of an advanced manufacturing plant in Japan enabled the company to transfer 33% of the previous plant's jobs from engineers to less qualified workers (Duncan, 1981).

44 Also most firms had 'single status' benefit policies to remove the traditional divisions both between management and the rest of the work force and between white collar and blue collar workers. To promote a company spirit and a friendly atmosphere most employers also sponsored company-wide social events, baseball teams, competitions, etc.

45 While not widely discussed, others beside Hirschhorn - such as Hood and Young (1980) recognised the value of employment stability locally and internationally when adopting new highly integrated technologies.

46 Again, the management-labour relation will crucially shape the labour process, but the almost virtual absence of organised labour in any effective form in this industry means this reduces to the competitive conditions of the external labour market. This is the focus of the next section.

47 The focus on zero defects, for example, accounted for a reduction in inspector's jobs and the hiring of quality assurance engineers who inspected and redesigned procedures from design throughout production. These people were intended to prevent the quality problems from happening, as well as actually overseeing workers.

48 The three largest employers in the survey together employed 653 engineers and 533 technicians (1984 survey data).

49 The annual reports on wage negotiations of the Scottish Honeywell group, documented in Income Data Services (IDS) because the firm is unionised, supported the impression that flexibility was more important to management than pay. A succession of reports in the early 1980s recorded agreements that awarded significant flat wage rises plus supplementals to production workers to eliminate grades and restrictive work rules (IDS, various issues, 1980 through 1984). This has certainly proven to be the case in recent years in many other industries, as well.

50 A JobCentre manager confirmed that "[the employers] don't mind spending their time, energy and effort to get the right person." The guarantee of no redundancies would demand that managers have this range of selection to minimise hiring mistakes.

51 A corporate study comparing the economics of locating semi-conductor production in a number of European locations ruled out locations with lower operating costs because of the training and discipline problems anticipated from a poorly educated population (confidential corporate document, 1983).

52 The calculation here and in the following text of the supply and demand for electronics technicians is particularly problematic. Specifically, this figure overstates the supply of technicians to the electronics industry because it includes those specialising in radio and television repair and maintenance. The problems in interpreting available data are more general, however: there are both the range and sources of qualifications to be considered and difficulties in comparing across years because of the fundamental changes in the structure of technician education. The Scottish Education Council (SCOTEC) revamped the curricula and the administration of technician education and changed the name and meanings of the various qualifications. These alterations took effect gradually during the early 1980s, making statistics-keeping difficult and comparing yearly data highly approximate.

53 This was approximately 20% higher than an earlier forecast (1980), indicating the labour market's responsiveness to the growth of and expectations for the electronics industry.

54 The engineers were also increasingly suited for entering work in the industry. The region's technology universities had expanded their teaching in technology-relevant specialisms. This meant that in recent years the universities had produced graduates with more specialised degrees tailored to the needs of the high tech employers. By the early 1980s firms could hire graduates with a specialism in microprocessors or analog or digital devices rather than simply electronics: this sharply reduced the in-company training necessary for new recruits. A Silicon

Valley semi-conductor executive explained that his firm hiring mechanical or chemical engineering graduates from universities had to then train them for at least two years in-house for the engineering work in the industry. Similarly one of the employers in Scotland had in the past trained for two years or so electronics graduates from regional universities in analog engineering and design, a part of electronics that higher education had ignored. By 1984 the technology and science universities, supplemented by special state funded programmes for skills conversion, were producing engineering graduates with industry specialisms - analog electronics and semi-conductor processing engineering.

Central Government had also directly supported the industry through lavish funding of the leading technology universities - Heriot-Watt and the University of Edinburgh in particular - to set up state-of-the-art micro-electronics and computer research labs. For example, the Electrical Engineering Department at the University of Edinburgh had a working semi-conductor fabrication facility.

55 Similarly science, particularly chemistry, graduates had practically filled another course designed specifically to convert engineering technicians for the electronics industry. This was a certificate course, traditionally for working class youth. However, its full-time format made it a shortcut for graduates to get an industry qualification.

56 All the survey firms aimed their engineering salaries to fall in the top quartile or decile of regional industry employers. At least one had a well-known if not advertised policy of paying top salaries for electronics and production engineers.

57 Perceived engineer shortages at the Scotland, national and international level did not preclude engineer surpluses in a few very local labour markets. Engineers were willing to accept these jobs because of the attraction in landing a job in these firms, especially given the region's high unemployment.

58 The modules were designed as forty hours of classroom instruction, much shorter than a class lasting the full academic year.

59 The manager of a regional JobCentre that aided a major high tech employer in its recruitment corroborated the finding that qualifications and expectations for production level jobs in the industry had been bid up. "Probably because of unemployment, employers obviously can afford to pick and choose...They are putting the standard a bit higher. People who traditionally were always employed in manufacturing...are now finding themselves unsuitable for manufacturing."

60 In fact management in one company, not in the study, had prohibited the local technical college from giving even a certiciate of completion to the workers who took an introductory basic electronics course. Managers were concerned to block any illusion that these workers had gained a transferable skill that even an unaccredtied, unrecognised piece of paper might offer.

61 Open Tech, modelled on Britain's Open University, was to provide individualised study programmes outside of working hours. Courses would include visits to workplaces by lecturers, videos for groups of employees, etc. to support independent study.

62 As a culture, Scots people have a reputation of being hardworking; many of the managers in the survey claimed they had found this to be true. A promotional document produced by the SDA around 1983 to counteract the region's other reputation of union militancy and associated labour problems is full of management testimonials to the hardworking and stable Scottish work force. For example,

> "The professional man [here] is more committed to his work than his American equivalent. Here they work longer hours." From National Semiconductor (UK) Limited.
>
> "Productivity increases have resulted mainly from a very stable set of work crews." From an engineering firm. (SDA, no date)

63 Workers, thus the industry, depended on workers' relatives, particularly grandmothers, as child care providers. Frequently working couples arranged to work on different shifts to cover domestic responsibilities, with the women taking night shift. This may have become more difficult as much of the industry had eliminated twilight and back shifts (6 to 10 pm) and moved to three eight-hour or two twelve-hour shifts to cover continuous production schedules.

64 Statistics on the gender of enrollments and graduates of university courses in the region were not available. However, at Dundee University only one woman per year entered the electrical engineering faculty during the late 1970s and early 1980s (National Electronics Review, 1982).

65 There is a rich and thoughtful literature on the subject; sources include Whyte and Smail (1982), Blackstone and Weinrich-Hast (1980), EOC (1982 and 1983) and Bennett and Carter (1983).

66 While the lack of a driver's license may seem a minor stumbling block, training for and passing the driver's test was a long time-consuming and expensive process. Just getting a license was not an easy solution for how to get

to classes next term. Women commonly depended on their husbands to drive them to work and appointments.

67 Applicants for production jobs were in some cases asked during the first interview if they would be available and willing to work overtime.

68 The differences in calculations of pay differentials is likely to be due to the location of the former survey. It is a well-developed but geographically isolated section of Scotland's high tech industry and a much poorer region than the areas surrounding Glasgow and Edinburgh.

69 The industry's employers promoted extreme secrecy in all pay-related matters. Supervisors persuaded workers not to divulge their actual pay to others, ostensibly to avoid unnecessary jealousy and problems, yet more important in maintaining the entirely individual and isolated framework for all pay decisions. In non-union workplaces, workers told me they had no idea how much their friends earned. It seems very likely that women workers did not know what technicians earned or that pay opportunities for technicians were improving.

70 Investing in retraining a woman worker for a more technical job also might not have been considered the most effective short-term way to raise household income. Because of management control over job levels, titles and pay, the pay increase for a retrained production worker as a tester or a lower level technician may not have been significant. If there had to be a choice as to who within a household should be subsidised for further education or training, the returns to training others would likely have been higher and reaped sooner. The potential income of a young person with a formal and more academic qualification was higher. An adult with a technical background and experience would have been able to add more than a retrained production worker to household income by taking a shorter updating or upgrading course through Open Tech.

71 Actual quantification proved impossible: of those firms reporting, one firm gave retraining data at the occupational level which could in principle account for a number of years while the others provided data for 1983-1984.

72 Because these courses had higher entry qualifications, the retraining period would probably have been longer. Women would undoubtedly have had to pass bridging courses in maths and technology to be able to handle the academics.

73 "Women just don't have the killer spirit that you see in guys...I was worried about weepy females [when I considered promoting a woman employee]," according to the head of an electronics equipment firm (Rapoport, 1983).

74 It is also important to realise that most of the industry's managers were trained as technical professionals, not as managers. Their lack of management skills and sophistication was clearly a problem at the regional and industry level. Part of their lack of sophistication was in dealing with women. Dealing with women as subordinate production workers was much easier than learning to manage them in more responsible jobs.

75 The greatly increased number of people completing technician qualification before entering the labour market during the early 1980s may have mediated the frequency of this practice. Small, domestic firms, however, pursued this strategy because they often could not compete with market-leading multinational employers over salaries, benefits or perks for people with high level qualifications.

76 The only cases (with one exception) where unskilled women were trained in-house were as technology aids, ie for the routine jobs requiring only cursory on-the-job training. Similarly the EITB found that in the UK electronics industry, the vast majority (80%) of women called technicians had received no formal training and only a short period of job-specific preparation. Further, the women electronics technicians in the EITB survey had on average a higher level of school-leaving qualifications and had stayed on at school longer than men of similar ages (EITB, 1984).

77 The managing director of another firm was pleased to report that two of the three engineers his company was sponsoring through a unversity engineering degree course were women.

78 For example, the managing director of a highly automated printed circuit board plant in the region argued, "that as plants like his Irvine operation become more automated the number of men employed will rise because of the range of physical maintenance work required." That seems to be true inspite of the fact that automation has eliminated most of the physical lifting and manipulating. Before automation he, and many other managers, explained that the exclusion of women from better-paying technical jobs was because of the weight and size of products - panels "awkward to handle." (Young, no date).

In addition, managers in my survey frequently referred to manual dexterity and patience as the reason women were best suited to operator and assembler jobs, even though automation had eliminated the physical manipulation of products (see also Wong, 1983; Tenne, 1982). However, Kaplinsky (1982) found evidence that women had been excluded from computer-aided design jobs because women lack just these qualities:

"Most management reported that

> typing skills were an advantage, given that all CAD systems have an alpha-numeric keyboard...But as far as management is concerned, attitude and flexibility are more important attributes...One system manager claimed that `females were less flexible and dexterous' despite the existence of many female CAD operators in the US."

79 The response would likely have been very different from women production workers who had been made redundant from some of these and other firms and found it difficult to find new jobs and saw men more likely to be hired in their places. In the case of the survey interviews, the displacement of women by men was concealed by the firm's continuous employment growth or contraction focused on old, distinctly different product lines.

80 In fact some of the cutbacks had reduced the bread and butter revenues that would have subsidised the additional work and expenses of designing speculative courses and establishing contacts in the industry. Further, the staffing at the technical colleges had been in effect reduced by hiring freezes and increasing faculty course and work loads.

81 Industrial Liaison Units had been set up at all the technical colleges and universities to open avenues for university staff to communicate with and gain contracts from the industry. The technology-rich universities had all spawned semi-autonomous teaching companies of faculty and research staff to serve the industry on a commercial basis.

82 It must be noted that the Development Corporations of the New Towns competed with one another and the region's industrial and science parks for inward multinational investment by also offering attractive financial and industry support packages.

83 Interviews in the New Towns suggested that local authorities gad attempted to shape and control the local labour supply to suit these industries. Many had a preference for `quality' residents when accepting applicants wanting to move out of the cities. Screening procedures tried to select highly motivated, serious workers, "people wanting to make a better life for themselves," as a New Town JobCentre manager explained. Also the authorities seemed to target potential inward investment and to plan housebuilding and resident inflow to maintain a surplus labour supply for the town's lesser skilled jobs. They wanted to limit job-hopping possibilities and to inhibit wage escalation resulting from too many employers competing for the same finite (in the short-term) labour supply.

[84] No comparable statistics were available at the regional level.

[85] Public money financed many other industry-specific training programmes. The MSC, SDA, Scottish Education Department (SED), the Scottish Economic Planning Department (SEPD) and the EITB had all funded electronics industry training courses as incentives for industry investment in more technical employment. For example, the SDA and SEPD administered funds to pay for the private sector training necessary to the success of the capital investment project. The grants covered 80% of the cost of workers' and instructors' wages and materials for up to 25 weeks (SDA publication, no date).

[86] This particular course was a full-time programme for adults to change fields/occupations to a technican within one year. It was designed to mediate a predicted shortage of technicians (MSC for Scotland, 1980). Entry required at least a non-advanced qualification in a science or technology field, which many women who might have been interested would not have had. Further, research had shown that the industry avoided hiring people whose first degree was not appropriate to the industry, even though applicants had successfully completed technology conversion courses (Gordon and Pearson, 1984). Women who would more likely have humanities or biology first degrees would have been greater risks and more than likely would have been discouraged from enrolling.

The regional vocational and further education authorities did not keep gender-specific statistics on enrollment or completion, so finding out exactly the extent of gender segregation of these routes to industry jobs is very difficult. Hence, the discussion must rely on anecdotal evidence from educators.

CHAPTER 7.

[1] This does not mean the labour supply developed in perfect response with perfect timing and geographical distribution to match the demand for labour. There was evidence that the insufficient numbers of experienced designers for advanced products - particularly integrated circuits - was a factor hindering further investment in design facilities in the region.

[2] It was widely held that the actual repair work of a computer service technician had been deskilled. The technology enable rapid identification of faults over the telephone. The technician had only to bring out the right circuit board to replace the faulty one on the customer's premises. However, a large proportion of computer problems are software problems, particularly those specific to a customer's application, which demand much more of a technician.

[3] The interviews revealed evidence of management's concern about the inherent contradictions between greater flexibility and the need for greater control, as Hirschhorn (1984) warned. It did not seem that the difficulties had yet been resolved. Managers experimented with training their engineers in project scheduling and setting structured deadlines to impose discipline on the R&D process. Also the computerisation allowed any executive in the plant or in the corporation to check the performance of any individual and the progress of work at any time; even when not used strictly as a control, this capability helped in locating problems in turnaround time. However, the antithesis of corporate cost control and the autonomy to develop an idea was clearly a major unsolved dilemma for executives at both the subsidiary and corporate levels. The study of this problem was, however, beyond the scope of this research.

[4] Interestingly, smaller domestic high tech firms had followed the pattern outline by Bluestone and Harrison and others. Their work forces were concentrated both in highly qualified, specialised engineers and semi-skilled production workers. That was at least in some cases due to their continuing dependence on older production technologies. Highly knowledgeable and experienced personnel were essential to oversee the operation of less versatile and sophisticated equipment. The equipment's lesser capabilities in information storage and processing made the machines less independent. Because total regional employment in these firms was small relative to that of the survey multinational corporations, they probably did not alter the industry occupational distribution significantly.

Importantly, the growth in the micro-electronics industry in the region had created divisions within the Scottish production labour force itself. Interviews implied that the pay, benefits, job security, as well as the definition of production work, in the region's multinationals surpassed that of the smaller firms with their more tenuous financial and competitive positions. So the industry's production workers were not all equal.

[5] Of course, Cockburn's work (1983) powerfully contradicts this contention.

[6] It is perfectly possible that in some cases there was little actual change in job content associated with the change in title for production jobs. Examining this possibility was beyond the scope of this research. However, to some extent it does not affect the power of the argument here how much of the altered structure of work was form rather than content. The new job title, module technologist, setter or whatever, because it was no longer associated with female work, was sufficient to attract young men and raise their labour market expectations of themselves. This alone made these better workers for management. An interview with a male computer assembler confirmed that he believed he would be supported by his supervisor in any expression of interest in further training or job advancement. Similarly, interviews with personnel officers and women workers in traditional women's jobs corroborated the association of and importance of expectations with the assignment of a male worker: men hired even into standard female jobs expected and were expected to move up, while the same was not true of young women. In addition, the obvious reality of easier communications and sociality with male technicians and engineers would in all likelihood enhance their work experience, relative to that of a woman in the same position.

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APPENDIX 1: HIGH TECH MULTINATIONAL CORPORATIONS IN SCOTLAND

Field Survey Interviews
1983 - 1984

Semiconductor Firms:

Burr-Brown Ltd.
Digital Equipment Corporation (DEC) UK, Ltd.
General Instruments (UK) Ltd.
Hughes Microelectronics UK Ltd.
Motorola Semiconductors Ltd.
National Semiconductor (UK) Ltd.
NEC Semiconductors (UK) Ltd.

Computer Firms:

Burroughs Ltd.
Honeywell Control Systems
Honeywell Information Systems
Hewlett-Packard
IBM (UK) Ltd.
Sperry Univac
Wang Labs

US AND JAPANESE MULTINATIONAL HEADQUARTERS AND ADVANCED PLANTS

SUPPLEMENTAL INTERVIEWS IN CALIFORNIA
September, 1984

Tom Roberts President	Fairchild Semiconductor Corp. Mountain View, California
Richard Clover VP, Technology Development	Intel Corporation Santa Clara, California
Nancy Pfund, Editor, Technology Newsletter	Intel Corporation Santa Clara, California
Austin Marx VP, Corporate Planning Division	Hewlett-Packard Corporation Palo Alto, California
Russ Childs Production Manager	NEC Corporation Mountain View, California
John Finch VP, Integrated Circuit Division	National Semiconductor Santa Clara, California

Richard Blanchard
Engineering Manager

Siliconix Corporation
Santa Clara, California

BACKGROUND ON SURVEY FIRMS

SUBSIDIARY COMPANY....Year Established in Scotland

- Pre1979 Activity
- 1978-1984 Investments
- Product Responsibility

COMPUTER FIRMS:

Burroughs 1958

- Manufacturing electromechanical accounting machines,
all components; transformed products into electronics
products in late 1960s.
- Transformed one plant into development/design facility, modernized assembly and test in other, for small business machines (eg computer bank tellers).
- Single source/world product market.

Honeywell Control Systems

- Manufacture, assembly and test of transfer designs for industrial control products (analog and mechanical products).
- Modernised plant to produce entirely digital microelectronics products; significant investment in automating assembly and product transfer; set up Solid State Applications Centre for product development (1983).

Honeywell Information Systems 1963

- Assembly and test plant for mainframe computers, including manufacture of peripherals (keyboards, etc.); assembly and test of minicomputers since 1967.
- Elimination of peripherals manufacture; assembly and test of smaller, more complex data processing computers from US designs, requiring investment in computerised assembly and test equipment.
- Europe and Middle East.

Hewlett-Packard 1967

- Design, assembly and test of telecoms testing instruments.
- Increasing responsibility for development of subsidiaries' products, requiring investment in design equipment as well as commitment to automating throughout production and distribution; investment in new facility on-site to assemble and test low-end telecoms products designed in US.
- World market responsibility.

IBM Pre1970

- Assembly of computer terminals, keyboards etc.
- Built new facility for totally automated production of microcomputers; modernising assembly and test of central processing units for mainframes.
- Europe, Africa, Middle East and Far East.

Sperry 1973

- Manufacture of punch and advance machines (discontinued in 1976); testing and repair for UK.
- Designated test, repair and refurbishment centre for minis and perihperals for Europe, with development and limited production capability.
- UK and Europe

Wang Labs 1984

- Volume assembly and test of office automation products; sales and marketing.
- Europe, EEC and Australia.

SEMICONDUCTOR FIRMS:

Burr-Brown 1983

- Design, assembly and test of hybrid integrated circuits and microelectronics systems; planning investment in fabrication in near future.
- World market responsibility.

DEC 1970s

- Assembly and test facility for microcomputers - personal computers and engineeringworkstations.
- Phased out computer assembly and test and invested in assembly and test of integrated circuits sent from US; investment in fabrication to begin 1984/5.
- In-house sourcing, Europe and US.

General Instrument 1968

- Advanced product development, design, fabrication, assembly and test of integrated circuits for consumer electronics and telecoms products; also marketing.
- Relocated all activities except fabrication to centralised sites for design (US) and assembly (Far East) in 1983; built three new fabrication facilities 1979-1984.
- World product responsibility.

Hughes Microelectronics 1951

- Production of diodes, military market components; began fabricating chips during 1960s; designed custom hybrid circuits; assembly and test for all chips and subsystems.
- Expanded hybrid circuit and systems product capacity - all design and production activities.
- World product responsibility.

Motorola Semiconductors 1969

- Assembly and test of memory chips; eliminated assembly and begain chip fabrication in early 1970s; also final test for specialised products - eg, military components.
- Expanded fabrication capability in 3 phases from 1980-1984, including capability for 256kDRAM/new generation memory and microprocessor devices; built assembly and test facility, 1984.
- World product responsibilitty.

National Semiconductor 1969

- Set up final test at another site in Scotland; relocated to current site in 1970 to fabricated chips; maintained limited assembly and test; sales.
- Rebuilt fabrication facility and added two new fabrication wings 1979-1984.
- World product responsibility.

NEC Semiconductors 1982

- Set up chip assembly and test; invested in fabrication capability for newest generation of memory devices (256K DRAMs) in 1984.
- Europe, with capability of supplying US and Japan.

APPENDIX 2. SUPPLEMENTAL INTERVIEWS - FIELD RESEARCH

1983 - 1984

Scotland-Based High Tech Firms:

Mr. Ian Dalton Director	CAS - Computer-Aided Design Edinburgh

Develops and designs computerised systems for precision engineering, control engineering and avionics applications; a spinoff from high tech research at Heriot-Watt University.

Mr. WA Archibald and Mr. Hugh Smeaton, Managing and Executive Directors, respectively	Fortronic Ltd. Hillend Dunfermiline

Designs and manufactures specialised banking and financial market computer systems sold through Burroughs and other large computer corporations.

Sir Monty Finniston President	FTS Beith, Ayrshire

Develops, designs and manufactures extremely fast microcomputers targeted to business usages.

Dr. John Gray Director	Lattice Logic Ltd. Edinburgh

Designs integrated circuits, sells their own compiler, a software program for circuit design, and brokers chip production.

Dr. Walmsley Director	Walmsley Microelectronics Ltd. Edinburgh

Designs chips, particularly analog devices.

Dr. A.D. Milne Director	Wolfson Microelectronics Edinburgh

Designs chips to customer orders as well as internal usage and designs specialised products using their devices; arranges marketing through other firms. Serves as technology consultant for industry and economic development agencies.

Supplier firms for the region's industry:

Mr. R. Bromley
Managing Director

BEPI Circuits Ltd.
Galashiels

Designs and manufactures cutomised printed circuit boards for computer, telecoms, aviation and military equipment usages; part of Cambridge Electronics.

Mr. GW Bowen
Managing Director

Compugraphics International
Glenrothes

Produces the masks or patterns used in the production of integrated circuits; is an independent company servicing many of the region's producers.

Mr. William Egan
Director

Plade Ltd.
Glasgow

Develops, designs and manufactures both standard and customised ventilation and plumbing equipment for the semiconductor industry. The only supplier in Europe and for some products the only producer outside the US. Markets own products and also sells through other suppliers (OEM).

Mr. Polson
Director of Sales

Prestwick Circuits
Mosshill Industrial Estate
Ayr

Manufactures both large volumes and small batches of printed circuit npards to customer specification for computer, telecoms and military markets.

Mr. Duncan Charity
President

Semicomplex Ltd.
Cyldeside Industrial Park
Glasgow

Leases office, training, repair and warehousing space to semiconductor equipment suppliers needing a base for marketing to chip producers in Scotland. Local staff provides a 24-hour inventory and repair capability for the industry.

Academic Experts:

Lorna Ahlquist
Industry Researcher

Department of Industrial Relations
University of Strathclyde
Glasgow

Stuart Anderson
Lecturer

Department of Computer Science
University of Edinburgh
Edinburgh

Ms. Jean Barr Director of Educational Services	WEA, Glasgow
Dr. Ian Beaton	Head of School of Electronics Engineering Bell College of Technology Hamilton, Scotland
Dr. Michael Borrus Economist/ Author	Berkeley Roundtable for International Economics, University of California at Berkeley
Craig Campbell Economist	Scottish Council (Development and Industry) Edinburgh
George Craig Regional Representative	WEA, Ayr
Peter Cressey Industry Researcher	Adam Smith School for Participatory Democracy Department of Economics Glasgow University Glasgow
Jo Foord Researcher, Semiconductor Industry	University of Newcastle Center for Urban and Regional Development Newcastle
Dr. Nigel Haworth Industry Researcher	Department of Industrial Relations University of Strathclyde
Jane Heskith Lecturer, Contract Research	Department of Computer Science University of Edinburgh
Dr. Sandy Knox Head	SCOTEC (Scottish Technical Education Council) Glasgow
Mr. John MacInnes Industry Researcher	Adam Smith School of Participatory Democracy Department of Industrial Relations Glasgow University Glasgow
Mr. Kenny Miller Lecturer Employment Law Specialism	School of Law University of Strathclyde

Mr. Kevin Morgan and Dr. Andrew Sayer, Industry Researchers	Department of Sociology University of Sussex Brighton
Mr. Richard Pearson Director	Institute for Manpower Studies University of Sussex
Professor Richard Rosenbloom Industry R&D Expert	Harvard Business School Cambridge, Mass.
Professor David Simpson Robert Crawford	Fraser of Allander Institute University of Strathclyde Research Program on Regional Electronics Industry
Mr. Ian Warnock	Head of School of Electrical Engineering Glenrothes and Bucknell College of Technology Glenrothes
Dr. Peter Williams, Director; and Dr. Walter Patterson, Senior Lecturer	MEDC - Microelectronics Education Development Centre Paisley College of Technology

Created and directed a centre that trains industry employees and independent students in the use of and applications development for microprocessors, microcomputers and industrial control systems.

Private and Public Sector Industry Experts:

Esther Breitenbach Author	Women Workers in Scotland Edinburgh
Hugh Cochran Deputy Editor	Glasgow Herald
Warren Davis Associate Director	Semiconductor Industry Association (SIA) Santa Clara, California
John Fairley Policy / Planning	Greater London Training Board, London
Steve Grant Regional Representative	Health and Safety Executive Midlothian, Scotland
Rachel Grossman Industry Researcher	Fortune Magazine Mew York City

Andrew Hargrave Industry Correspondent	<u>Financial Times</u> Glasgow
Louise Kehoe Industry Correspondant	<u>Financial Times</u> Palo Alto, California
Sally Kellner Industry Researcher	Electronics Capital Goods Sector Working Party National Economic Development Office London
Pat Lambourn Director	Santa Clara Occupational Safety and Health San Jose, California
Gareth LeSueur Director	Strathclyde Regional Council Industrial Development Unit Glasgow
Mic McLean Editor	<u>Electronics Times</u> London
Ron Miller Director	Scottish Equal Opportunities Commission Edinburgh
David O'Connor Researcher	United Nations Centre for Transnational Corporations New York City
Ewen Peters Statistics Division	Scottish Development Agency Glasgow
David Roberts Director of Planning Ian McLaren Electronics Division	Scottish Development Agency Glasgow
Peter Scrimgeouw Economist	Economic and Planning Unit, Scottish Economic Planning Department Edinburgh
Lenny Siegel Director	Pacific Studies Center Research Centre for High Tech Industry Mountain View, California
William Taylor Director	Fife Regional Development Council Department of Planning Glenrothes
Robert Whyte Economist	Manpower Services Commission for Scotland Edinburgh

Robert Wylie Electronics Industry Representative	Engineering Industry Training Board (EITB) Glasgow

Trade Union Representatives:

Steve Beckman Richard Prosten	Industrial Union Department AFL-CIO Washington DC
Gordon Craig Regional Representative	ASTMS Glasgow
Jimmy Dice	T&GWU Edinburgh
Mike Eisenscher Union Organiser	UE - Union of Electrical and Radio Workers San Jose, California
Frank Emspak Local President	IUE - International Union of Electrical Workers Lynn, Masachusetts
Tony Foley Norrie MacIntosh Regional Organisers	AUEW/TASS Glasgow
Mary Harrison	Women's Committee Scottish Trade Union Congress Glasgow
Jimmy MacIntyre National Training Officer	T&GWU Glasgow
Tina McKay Former Health and Safety Representative	Lucas semiconductor plant Birmingham
Joyce Smith Union Convenor and Fife Councillor Gina Cairns Shop Steward	GEC- Kirkcaldy Glenrothes
George Wilson Former Shop Steward	Plessey - Bathgate Edinburgh
Rand Wilson	Communications Workers of America, Organizer in High Tech Industry Boston, Massachusetts

Regional JobCentres:

Archie Osborne Director	Greenock JobCentre Greenock
Norrie MacGill Director	East Kilbride JobCentre East Kilbride
Ann Mitchell Director Margaret Davidson Employment Counselor	Glenrothes Job Centre Glenrothes

Industry Workers:

One woman - former production worker retrained in computer programming, Timex Ltd., Dundee

One woman from Plessey, Bathgate; sought employment in a number of the survey multinationals

Three women assemblers, Hewlett-Packard Ltd., Edinburgh

One Engineer, Signetics Inc., Santa Clara, California

Two engineers, Survey computer firm, Cumbernauld, Scotland

Three administrators from the personnel departments in survey computer and semiconductor firms, Glasgow;

Six production workers in IBM Ltd., Burroughs and Honeywell Control Systems/ Honeywll Information Systems;

One production worker in one survey semiconductor firm.

APPENDIX 3. FIELD SURVEY QUESTIONNAIRES

QUESTIONNAIRE FOR PRIMARY SURVEY FIRMS

I. Background Information
  A. Company Background
    1. What was the company's original activity?
    2. What is it now?
    3. 1st year?
    4. What are your qualifications?

  B. Current On-Site Activities
    1. Sales and Marketing
    2. Large-scale assembly and testing
    3. Fabrication
      a. all stages; including COB/subsystem
    4. Production of small batches to customer specifications
      a. full custom
      b. semi-custom
      c. gate array
      d. cell library
    5. Production of large lots
    6. Software production
    7. Design/product application
    8. Product development
      a. production of prototypes
    9. Process development
    10. Fundamental resources
    11. Warehousing/distribution

  C. Which management functions are located here?
    1. personnel training
    2. public relations
    3. marketing
    4. R&D
    5. finance

Have any of these changed from 5 years ago? Are any likely to change?

  D. What have been the products produced here in Scotland and when were they introduced? What markets (geo/end- user) were they intended for?
    1. Were they first introduced at low volume? then high volume?
      a. what kinds of adjustments are necessary to move to high volumes?
    2. Have any been discontinued? When?
      a. are any new ones being announced?
    3. What markets--geo or product--is each type targeted for?
    4. Has the plant narrowed its range of products or specialised in how they are produced? (eg finished versus partial)

E. List all product lines
   1. year of introduction
      a. low volume/date
      b. high volume/date
   2. target product
   3. markets (geo)
   4. year of discontinuation

F. Are there any divisions or branches of the corporation elsewhere in Scotland, England or Wales? or any associated companies?
   1. Where?
   2. What is their functional responsibility?
   3. When were they established?
   4. Have they moved or changed since then?

G. How important is the Scottish plant to the corporation's operations?
   1. reasons:
      a. only plant in Europe
      b. the largest of the plants in Europe
      c. most profitable of the plants
      d. manufactures products/components not produced elsewhere
      e. first established plant outside US
      f. only plant selling to certain markets
      g. the rationalisation completed or underway favours the Scottish plant
      h. European decision--production functions are centred at Scottish plant
   2. What might alter that position? Is that likely?

For Integrated Circuit Manufacturers:

   1. What proportion of your output sources end-users in Scotland?
      a. how has that changed over 5 years ago?
      b. how do you expect it to change over the next 5 years?

For Computer Firms:

   1. What proportion of your IC requirement is met in Scotland now? or specifically internally?
      a. has that changed in the last 5 years?
      b. do you expect it to change in the next 5 years?

J. Supply Networks
   1. What portion of your output/product supplies the IC producers in Scotland?
      a. how do you expect that to change over the next 5 years?

II. Technological Change

   1. Has the relatively rapid move into ULSI and the short life of each generation of chip required the

company to change the profile of its operations here in Scotland?

Examples:

1. Design: To accelerate turnaround, has the design capability changed/expanded?
2. Automation: has automation in production been necessary?
3. R&D: Has having and R&D capability at the production site become more important?
4. Planning: How has the design capacity changed?
   . Is that likely to change over the next 5 years?

2. Has there been greater auotmation of design?
   . to what effect?

3. Do you foresee reasons for greater cooperation in design with IC producers/end-users and customers that might lead to their responsiblity for design content or locating closer to them?

Automation

1. What processes have been automated? With what priorites? Over what period of time?
2. What functions are now in clean room conditions?
   a. IC producers
      1. wafer fab
         a. focused ion beam processing
         b. t-beam
         c. x-ray
         d. wafer steppers
      2. automated transfer of wafers?
         a. partial
         b. complete
      3. automated die bonding
      4. automated wire bonding
      5. interactive computer system
         a. monitoring
         b. control/correction
         c. other?
      6. diversification into systems
   b. Computer Firms
      1. CAD
      2. automated transfer of materials
      3. other transport
      4. automatd warehousing/stock control
      5. CAM
      6. automatic insertion machines
      7. FMS
      8. other
      9. diversification/expansion into
         a. ic production
         b. other sub/systems

3. What proportion of the software neccessary for these activities is developed:
   a. in-house
   b. in the company
   c. by the equipment supplier

R&D

1. What are the current activities of the R&D staff? Here? And the area of responsibility?
   a. production sales/servicing
   b. r&d on specific materials or applications
   c. product development
   d. fundamental research
2. how many are currently employed in these activities?
   a. how has that changed over the past 5 years?
   b. how do you expect it to change over the next 5 years?

Planning

1. How long do you expect a new product's life to be?
   a. how long 5 years ago?
2. Technically, how long do you expect an investment to last?

III. Personnel Policies

1. What are the hours of work at this site?
   a. shifts?
   b. are there part-time arrangements?
   c. has the company adjusted operating hours to meet expanding demand?
2. Hours of work
   a. production
   b. design
   c. administration
      1. Do these arrangments give you sufficient flexibility to respond in changes in demand?

Growth:

1. How has overall employment changed since 1970?
2. How has sales or turnover grown over those years?

Skills

1. What is the present skill mix of your workforce?
   . what is the percentage of men to women?
   . has that changed from 5 years ago?
   . if the company has recently expanded:
     . what was the skill-mix in employment?

2. Have the changes you mentioned required any new skills or job categories?
3. Has the content of any jobs changes noticably?

Recruitment

1. Where do you recruit and how for each of the skill areas?
2. Do you have any age guidelines or restrictions on hiring in any of the categories?
   . any preferences for particular jobs?
3. Have you had to adjust your recruitment practices over the past few years?
   . for techs, operators, or engineers?

Wages and salaries

1. Are your wages above or below the average for the industry?
   . how are they negociated?
2. benefits
   . are benefits offered to all employees?
3. Are there additional benefits offered to professional staff?
4. explain your bonus structure.
5. Other: Do you have mechanisms for dealing with employees' personal problems? Please explain.

Labour Demand

1. Have you experienced any of the effects of skill shortages?
   . how is the company coping with this?
2. Have you found the labour force here offers you the qualities necessary for the flexibility the company needs?
3. What qualities does the company look for?
4. Has training up/upgrading helped meeting the shortages?
   . how many have been trained up over the past year?

III. Summary

1. Has the company faced any constraints here in Scotland in its development plan, ie:
   . raw materials, equipment servicing, infrastructure limits, changes in government policy, etc.
2. Have any of these affected the type or pace of development? How has the company dealt with these concerns?
3. Are there any aspects of development and organisation of the industry here that have constrained this company's growth strategy?
   . what changes would you like to see?

QUESTIONNAIRE FOR DOMESTIC FIRMS -

Computer Producers, and Supplier Firms to Both the Computer and Semiconductor Industries

1. How have sales and employment changed over the years since 1970?
   1. Scottish site
   2. UK site
2. What are the proportions of the following occupational categories in your current workforce at this site? Please include porportions of men and women in each category:
   1. managerial
   2. administrative
   3. computer professionals
   4. secretarial/clerical
   5. engineers--design
      a. first degree
      b. PhD
   6. engineers--production
   7. technicians
   8. assemblers
   9. operators
   10. test personnel
   11. others
3. Has the employment in each category changes from five years ago? How do you expect the demand to change over the next five years?
   . how would an an increase of, say, 20% be reflected in the numbers you employ?

4. Could you give a financial breakdown of your total employment using such categories as finance, quality control, production, maintenance, R&D, etc.?

5. What significant changes have occurred in production technology at this site over the past 5 to 10 years?
   Was it a process used extensively elsewhere or was it a new one?

6. Have there been signifcant changes in the layout and organisation of the production process? Please specify when and the reason for the specified changes.

7. Please indicate how long it takes to train an employee for each occupational category in the company. Please also indicate the averageper annum turnover your company has faced in the past few years.

8. Do you have company training programs to upgrade th occupations where you've experienced shortfalls? In what occupational areas? Who would be eligible and how long do the programmes take?

Questionnaire for Government JobCentre Managers

1. Why are companies in the semi-conductor and computer industries advertising in the Jobcentre rather than through newspapers, etc.?

- when did this begin?
- do all of the major electronics industries register vacancies here? For what occupational categories?

2. Does the Jobcentre send all interested people directly to the company for all occupational vacancies or does the jobcentre screen them first?

- for those occupational areas where the Jobcentre offers preliminary screening:
    1. what guidelines are followed?
    2. what is the ratio of applicants that are sent to the number of job openings that exist?
    3. does Jobcentre staff interview or does the company usually send someone?

3. Technicians

- what are the kinds of jobs and responsibilities they would have?
- what level of formal qualifications are required?
    1. HNC/D expected?
    2. Is a lesser qualification accepted? What proportion?
    3. How frequently do companies take unqualified people and sponsor their training?
    4. Does the college giving the qualification matter?
        a. what are some of the better ones according to the industry?
        b. why would some be frowned upon?
    5. What informal qualifications are usually required?
        - How much work experience? what kind?
        - Is specialisation required? what kinds?
        - What age ranges does the industry usually hire within?
        - Are people without dependents preferred?
        - Are people from the immediate locality preferred? why?
        - What qualities in an applicant would recommend him/her well for a vacancy?
    6. Have you seen the importance of these factors change over the past 5 years?, or the last time that the companies expanded?
        - qualification level
        - specialisation level
        - age
        - work experience
        - locality/background

7. What's the industry's average starting pay?
   . how does that compare to 5 years ago?
8. Is this a skill category which is important only to large, expanding computer companies?
   . Are smaller/older electronics companies recruiting them too? for what kinds of jobs?
9. How would you estimate the p.a. growth of technicians in this region over the past 10 years? 5 years?
10. Do you recommend any forecasts for the next 5 years?
11. There are many public claims that there are a shortage of technicians yet there seems to be unemployed technicians. Is that true in this region?
    . how would you explain this surplus? what kinds of people with qualifications are not being hired? has technical change influenced qualities of employability?
    . what porportion of technician applicants are men? women?
    . what proportion of successful recruits are men? women?
      . how would you explain this?

Maintenance personnel

1. Does repair/maintenance work require different qualifications?
   . what are they?
   . do the companies require specialisation in machines or processes? work experience? how much?
2. What proportion of a company's labour force is likely to be maintenance workers?
   . has that changed over the past 5 years? 10 years?
3. How are they recruited? from what localities?
4. If they are short supply, what qualities would the company look for?
5. What turnover level can be expected in this category?
6. What is the starting pay?
7. What proportion of these people are men? women?
   . what has caused this proportion?

Operators/assemblers/testers

1. What kinds of qualifications are required?
   . passed in science subjects in school?
   . work experience in electronics industry?
   . work experience generally? how much?
2. How are the huge surpluses sifted through?
   . people who know someone already employed by the company?

- what age group is preferred? why?
- does the husband's occupation make any difference?

3. Do the companies prefer people without children? only young children? people with few financial responsibilities?
4. How local does the company expect these employees to be?
6. How do most applicants find out about vacancies? Jobcentre notices?
7. The work seems to require extreme care on the employee's part: how is this trait determined in the interview process?
   - are applicants tested?
8. What other qualities are companies looking for?
9. What qualities in an applicant would suggest their unsuitablility?
10. A few employers have mentioned that the job can be a lot of pressure: how can it be determined that the applicant will cope well?
11. Are physical examinations now required of all applicants? why?
12. Have the industries changed in the kind of person considered the most suitable for these jobs over the past 5 to 10 years?
    - with the level of employment that exists, has the industry recruited men for these jobs?
      1. if yes, to what extent?
      2. if no, why are women more suitable?
13. How would you forecast the change/growth in employment in these jobs over the next 5 years?
14. Does the availability of public transport limit who could work in these companies?
15. As the industry employs a lot of women have companies adapted on recruitment policies to account for this (ie hours of work, shifts, temporary contracts)?
16. With the increase in technology many of he jobs no longer require manual manipulations, have companies considered hiring men as operators?
17. What child-care facilities are available locally?
    - please describe them and the extent of their availability.
    - approximately how much per week do they cost? is there a shortage?

Engineers

1. In a market that is very tight by comparison with other occupational areas, what qualities/qualifications do the industries

consider important in cautiously hiring engineers?

  . age range
  . locality for recruitment

2. These companies seems to be recruiting throughout the UK for engineers: what advantages might Scottish engineers have in applying for these jobs?
3. Wwhat is the starting salary? How would you estimate the p.a. growth rate in engineers' salaries over the past 5 years?

GENERAL ISSUES

1. What are the industries doing to try to maintain the relative stability of their labour forces--to minimise their turnover of engineers, technicians, and operators?
   . what usually happens when a temporary contract expires?
2. Though there is a lot of growth and expansion in the industries now, both are subject to severe cyclical downturns. What are the industries doing to protect themselves if/when this should happen?
   . have they depended on subcontracting work? what work?
   . does hiring on temporary contracts help protect against overhiring? Who is employed this way usually? of what duration are the contracts usually?

QUESTIONNAIRE FOR PRODUCTION OPERATORS

Background

1. how old are you?
2. when did you start working for the company?
3. do you have children or other dependents?
   . how many? what age?
4. please tell me what you do at work:
   . what is your job title or label?
   . what department do you work in?
   . have you ever done any other jobs during your employment?
     . what other jobs? for how long?
5. what formal qualifications do you have?
6. what weas your previous work experience?
   . where? for how long?
7. how are those men/women working in jobs similar to yours like you or different from you?
8. how long did it take you to learn your job well?
   a. how long did the company formally train you?
   b. who trained you where?
   c. what was the content of that training?
9. how did you find out about the job vacancy?

10. what kind of employee did you think the company was looking for?

11. why did you think your chances were for getting the job? why?
    a. friends or relatives in the company?
    b. age group/guidelines
    c. experience in electronics?

12. what kinds of things were you asked at the interview?
    a. did the application ask what school you went to?
    b. did they ask you what family responsibilities you had, your spouses occupation or your financial situation?
    c. did they have you take any tests?
    d. did they ask you to take a medical examination before employing you?
        1. what did it include?
        2. a urine specimen? did you know why?
    e. did they ask you what you thought about trade unions?
    f. did they ask you any questions that you didn't expect? that surprised you?

13. when you were hired, was it a temporary or permanent contract? full or part-time?
    . did the company ask you for a specified time commitment?
    . when you took the job, how long did you expect to work there?
    . what circumstances might cause you to leave?

14. did the contract require your secrecy on company matters? what issues were of concern?

Work Situation

1. What are your hours of work?
2. How long were you trained? what did it include?
3. How do people get put on various shifts?
    . do women work night shifts as frequently as men?
    . how does one move from one shift to another?
4. How frequently and when does overtime arise?
    . how much is usually offered?
    . are you expected to work overtime? are you usually asked? why not?
5. Have any aspects of your job been automated in the past five years?
    . explain exactly what and how

6. Have there been any changes in what you do and how you do it?
    . please describe the changes, why they happened and why you think the changes were made.
7. Has there been any reorganisation of who you work with or how your work related to that of others?

8. Have you been moved from one job to another? how often?
. why?

9. Has the industry emphasis on improving product quality led to any changs in your work or the organisation of work in the plant?

Quality Circles

1. How long have you participated?
2. How do you feel about it as a way to include you in a 'participatory' way to give you some say over your work?
   . what else would you like to have?

Other Responsibilities

1. Have you been asked to learn to fix your machine?
   If yes, why?
   . what were you trained to do? how long did it take?
   . how many other operators/assemblers have been trained to do this?
   If no:
   . what do you think you'd have to know to fix your machine?
   . do you know how long it would take to learn?
   . why do you think you've not been trained to do it?

Testers

1. How is the job that the technician does differ from yours?
   a. could you do either of those jobs?
   b. what would you need to know?
   c. who are the technicians?
      1. age range; gender; marital/financial status

Organisation of Work

1. Who are the supervisors and foremen?
   . were they promoted from the line or recruited from the outside?
   . what age or time on the job is necessary for promotion to lead operator?
2. Have you seen any changes in the type of worker now hired as operator, technician or engineer?
3. When the company is recruiting, what kinds of things might stop you from recommending a friend for a job?
4. How does management increase productivity or meet rises in demand?
5. How does management adjust to downturns in the market?

Pay and Related Issues

1. What is your gross or take-home pay?
   . how does that compare with people doing similar work on shifts?
   . how and when are increases determined?
      . are increases the same for female and male employees?
2. Who else in your household earns money regularly?
3. Do you have child-care expenses or costs for dependents?
4. How do you get to work? approximately what are the weekly costs?
   . did you or any or your friends move house to be near work?
5. How does your pay and benefit package compare with the women you know:
   . working in other semi-conductor and computer companies in Scotland?
   . working in other Scottish electronics companies?
   . working in other traditional women's jobs?
6. How does managment deal with requests to take a child to a doctor's appointment, or to stay home with a sick child/relative?
   . who do you arrange it with?
   . does it cost you anything?

Other

1. Whom do you talk to when there are personal problems that are affecting your work?
   . is that satisfactory?
2. Have there been many problems at work--eg pacing, quality, that the management has to deal with?
   . what happened?
   . how are these disputes dealt with?
   . are the established procedures satisfactory?
3. How do you feel about not knowing where management is?
4. Do you think management treats women employees specially? different from men in any way?
5. Do you think the assemblers are involved as higher level people in the way the company operates? why/why not?
6. Do you have any concerns at work that you complain to friends about?
   . have you had any health problems during your period of work with this employer? What? When?
   . did it persist?
7. Have you been aware of any kinds of occupational hazards in your workplace?
   . the materials handled?
   . the work environment?
   . the level of stress?
   . people complaining about headaches, dizziness, rashes, etc.?

8. What are the important aspects of working at your firm that set it apart from other jobs that you have had or know about?
9. Do you think that joining a trade union would improve your conditions at work? why or why not?
10. If you had to do it all over again, what kind of training and job would you like to have had? would you consider pursuing that now? why not?

QUESTIONNAIRE FOR TECHNOLOGY ACADEMICS IN REGIONAL COLLEGES OF TECHNOLOGY

1. What are the technical areas that a qualification as an electronics technician now requires?
    . length of study of each; total course
    . how assessed?
    . to be qualified must all be passed?
2. What are the distinctions now between HNC/HND/other?
    . do they have a different weight in the job market?
3. What are the possible patterns for taking the course?
4. What qualifications does this section of the industry usually require?
    . level?
    . grades within certificate?
    . specialisation?
    . expectations?
5. What are the qualifications for enrolling in the course?
    . is it currently difficult to get a place?
    . what's the proportion of applicants to enrollees now? 5 years ago?
6. How many complete the qualifications per annum?
    . how does that compare with 5 years ago?
    . what are you forecasting for 5 years from now?
7. What precisely are the kinds of jobs they do?
    . what qualification for maintenence/fixing machines?
    . what are the chances of a completer getting a job here in the industry?
    . what improves their chances?
8. In what ways have technological changes in the industries affected the content of courses/qualifications?
9. Has the emphasis in the syllabus shifted? from what/how?
10. The tech offers a refresher/modernising course for V/E techs: what subjects/skills does this focus on?
11. Has the degree of specialisation or the types of specialisation changed?
    . what are the important areas?
    . what committment does the term specialisation signify/indicate?
12. The industry claims there is a shortage of electronics skills. As there's a surplus of techicians, what skills are actually in short supply?
13. By how much do you expect the need for these skills to grow over the next 5 years?
    . how is the industry coping with this?

. I've heard that many are taking untrained people and the firms are training them on the job. Do you think this is working satisfactorily?

14. When recommending students for jobs in the industry, what qualities do you consider the most important in their employability?

15. Are you aware of companies hiring degree engineers to do tech work?

16. Do many companies call employees technicians though they have no qualifications? Why are companies doing this?

. what would their tasks be?

. what would they be unable to do?

17. Would your staff consider offering a lower-level technician qualification?

. what functional abilities would it develop?

18. In terms of the jobs your students get, does the work challenge them sufficiently? have you seen signs of de-skilling?

19. How significant is the industry's attempt to skill up operators? what does it require? where is the training?

Quality Of Technology Expertise

1. How does the teaching faculty maintain contact with the industries?

. have these arrangments recently been made to help the industry meet its shortages?

2. How have the relationships changed over the past 10 years?

3. Some have expressed concern that the educational institutions can't possibly keep up with industry needs due to the expense and frequency of change of technical equipment. If that's the case, how should appropriate technicians be trained?

Other

1. The overwhelming number of employable technicians are young men. What is the proportion of male to female in last year's course?

2. Do you have students working in the industry who might be willing to talk with me about their work?

3. What is the beginning pay in the technician grade?

4. What proportion of yearly p.a. qualifications are earned by technicians?

5. Why are there so few women in this occupation?

APPENDIX 4. TRAINING AND QUALIFICATIONS IN ELECTRONICS TECHNOLOGY AVAILABLE IN THE SCOTTISH EDUCATION AND TRAINING SYSTEM

1983/84

FORMAL QUALIFICATIONS

The four formal qualifications outlined below are all considered "qualified technician" training.

City and Guilds (C&G)

Traditional four-year program of part-time classroom study sponsored by employers during apprenticeship in a firm. While common for many tradeand skilled jobs in mature industries, it was no longer a common path for training people in high tech.

Certificate (C)
(Formerly Ordinary Certificate)

The Certificate, like its predecessor, was planned asa two-year technologyu-sppecific academic program offered in colleges of technology. The Certificate and the Higher Certificate were traditionally part-time courses, two and three years, respectively. They were targeted to working class school-leavers who gained apprenticeship positions or less formal employee sponsorship to allow both work and study. The courses then were organised as day or block release to allow the student to be employed in the industry.

Higher Certificate (HC)
(Formerly Higher National Certificate or HNC)

The Certificate is necessary for enrollment in a HC course and this higher level qualification conventionally took another two years. Historically it was a common path for working class youth to a professional qualificaiton (eg membership in the Institute for Electrical and Electronics Engineers) and managerial possibilities. The difference between the HNC and the HC was primarily the structure of the course, specifically the required number and timing of principles and elective subjects. However because of the increasing demand for high tech qualifications in the 1980s, the technology courses were pressured by the Manpower Services Commission (MSC) to reorganise and run these courses as full-time rather than part-time programmes. As a result, middle class students increasingly filled these courses, along with those for the HD (see below), because they could afford not to work during their studies.

Higher Diploma (HD)
(Formerly Higher National Diploma - HND)

A three-year course, the HD was known as a more academically-rigourous course. It provider both a broader and deeper study of the technology. Students attended full-time. Industry experience was limited to possible summer or sandwich placements (which during the time of the field research was very difficult to arrange).

NB. The Diploma course, the one-year qualification for full-time students, was all but defunct by the time of the survey. The bidding up of qualifications made it an insufficient preparation in the technology for someone seeking employment for a "skilled" job in high tech.

INDUSTRY-SPECIFIC TRAINING WITHOUT A QUALIFICATION

SkillCentres

These Government-sponsored centres training/retrained enemployed people in short programmes. Run by the MSC, centres offered a range of vocational training varying with the centre and the region. Often traditional skills in construction, plumbing etc. wre included. Becuase of the importance of high tech to Scotland, at least one SkillCentre in Glasgow had been equipped with advanced test and related high tech equipment to train technicians for the industry. The centre's success in placing its trainees competing with those with approved qualifications was unknown as the centre was not fully operational during the survey period.

Also Information Technology Centres (ITECs) were similarly created and funded by the Government and run by the MSC. However their focus was training unemployed youth -predominantly in urban areas of high unemployment - for lower-level jobs using computers. Programmes were short - usually three months and usually trained youth as computer operators or low-level technology troubleshooters. [Individual centres reflected the strengths and weaknesses of their directors and the MSC regional officials.]

Open Tech

A major initiavtive of the Thatcher Government, Open Tech wasdesigned to serve industry by retraining and upgrading technical employees to use new technologies to the greatestadvantage. Modelled after Open University and the distance learning approach, the courses were planned to be open to individuals wanting further training in microelectronics applications and willing to finance themselves outside of work time. Courses were designed to be task-specific and to last for a few months. They offered no formal qualification.

Again because of the importance of training for high tech capabilities in Scotland, the regional laboratory for students had been outfitted at enormous expense toinclude extremely advanced equipment relevant for the region's computer and semiconductor industries. This programme also had not begun at the time of the field survey.

16 to 18 Action Plan

This was the Scottish Technical Education Council's (SCOTEC) effort to respond to industry pressure for preparing the region's school students for work in the high tech industry. While the curriculum included many vocational areas, the emphasis was on electronics technology subjects. Students were to select whatever offered modules (of only 40 hours of classroom teaching) they wanted. While some of the more advanced ones were to be offered only after prerequisites were completed, the choice and the number completed were primarily up to the individual student. The modules were to be ungraded, offered as pass/fail courses; in addition, study led to no formal qualification - simply a list of completed modules. This was to repace the highly structured courses leading to formal qualifications in the technology colleges: the motivation was to prepare more people for work in the industry quicker.

The first programmes were to begin in September 1984, so no assessment of participation or placement success was possible.