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Electronics-based Automation Technologies and the Onset of Systemofacture: Implications for Third World Industrialization

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Summary. — This paper considers the implications of emergent best-practice techniques for Third World industrial strategies. These new techniques are described in historical context, and are considered to consist of two major developments. These are the adoption of systemic, electronics-based automation technologies, and the adoption of Japanese-style just-in-time production techniques. The implications for Third World industrialization are considered in four major areas, namely: policies concerning technological diffusion; networking and infrastructure; skill acquisition; and the role of design in comparative advantage.

1. INTRODUCTION

Many aspects of development studies are affected, in one way or another, by the maturation and diffusion of microelectronics technology. The one which we will primarily address concerns the link between the technology and the insertion of less-developed countries (LDCs) in the international division of labor in manufacturing. This is not to deny the potential for using the technology to meet domestic needs within the context of import-substituting industrialization or basic-needs strategies. However, given the frequently observed bias in technological development towards the interests of private appropriation, developed country factor–price ratios and high-income consumers, it is in the area of traded goods and production processes that the technology is currently most widely diffused.

In one important respect, this analysis differs from earlier works in the field.[1] In these it was common to discuss the 'impact of microelectronics' on trade, or comparative advantage or social organization, or some other category of analysis. However this approach is, in our view, misdirected for two reasons.

First, and fundamentally, we reject the perspective that technology determines social relations, for technology is, itself, *a product of social relations*. Individual production techniques utilizing microelectronics need not necessarily de-emphasize skills; nor need they be primarily developed to meet the needs of the military sector; and nor need they be applied to meet the 'needs' of high-income consumers. That they do predominantly assume these, and other, particular characteristics is a function of the social relations in which the technology was developed and is diffusing, rather than an inherent feature of the technology itself.

Second, the emergence of crisis in the global economy is accompanied by a number of important developments, of which the diffusion of microelectronics technology is only one aspect. Thus, the restructuring of the international division of labor in manufacturing, which we believe is imminent, will be associated with a series of important changes. These include not only the adoption of radical technical change, but also an altered role for transnational corporations, the re-emergence of protectionism and trade blocs, and the partial resolution of the debt crisis (see Kaplinsky 1984b and 1984c for further discussion). Thus, an exclusive focus on microelectronics is too restrictive to allow for a full understanding of contemporary developments in the international division of labor. It is for this reason that our discussion covers not only the characteristics of emerging automation technology, but also the organizational framework within which the technology is being innovated in best-practice plants.

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As a consequence, we shall avoid referring to the 'impact of microelectronics on the international division of labor in manufacturing.' Rather, our concern is to highlight a particular facet of current technological developments, given the context in which it is diffusing through the technologically advanced economies. Specifically, we shall focus on its *systemic* characteristics, for these illuminate some of the most important policy implications for social and private decision-making alike. It will be readily seen from this discussion that while microelectronics technology has a key role to play in the emergence of what we have called systemofacture, it is only part of ongoing and major changes in the pattern of industrial organization. It is to the totality of these changes which we respond, and not to microelectronics technologies *per se*.

To understand best the implications of the new electronics based automation technologies for Third World industrialization, it is necessary to concentrate most of the analysis which follows on what is happening in the industrially advanced economies. Two developments are particularly important here; namely, the emergence of intra-enterprise systemic technology (Section 2); and the re-organization of production and inter-enterprise links in best-practice enterprises (Section 3). Together, these two developments make up what we term systemofacture; and to assess their true significance, the analysis is extended somewhat to place these factors in historical perspective. Then, in Sections 4 and 5, we draw out a number of key implications for Third World industrial strategies. Therefore, while much of the analysis is undertaken in relation to industrially advanced economies, the conclusions are focussed on the implications for Third World industrialization.

2. MICROELECTRONICS AND THE EVOLUTION OF AUTOMATION: INTRA-ENTERPRISE SYSTEMIC TECHNOLOGY

Historically, there has been some dispute as to the meaning of the concept of automation. At issue is the specificity of the term. Thomas (1969) for example argues that:

> . . . 'automation' is a technology quite distinct from mechanization and it is concerned with replacing or aiding human *mental* effort as distinct from aiding man's physical effort.'[2]

The virtue of Thomas's perspective is that it emphasizes the *control* characteristics of automation technology (cybernetics), a field in which microelectronics devices have a particularly crucial role. However, despite its attractions, it is more common to view automation in its more general sense, defined by Einzig (1957) as

> a technological method that tends to reduce current production costs in terms of man hours per unit of output. . . . Its loose use practically as a synonym for advanced mechanization may shock the technologist, but serves the purpose of economists.'[3]

Despite the logic of viewing automation technologies in the broadest sense, distinguishing control from other subsets of automation technology is important. Bell (1972) offered some clarity in a muddy debate when he suggested that there are, in fact, three different elements to automation technology in manufacture: namely control, transformation of inputs, and transfer between workpoints. In each of these areas, degrees of automation exist but a high level of automation in one area need not be associated with a high level in the other two.

This was an important insight, since for the first time it provided for a difference in the types of automation as well as a difference in its degree. Bell (and more recently Coombs, 1982) went on to argue that advances in these types of automation technologies occurred at different periods of history. The automation of transformation began first, in the 18th century (with the introduction of water power), developing further in the 19th century (with steam power) and the 20th century (with the introduction of electricity and the internal combustion engine). In each case, complementary advances in materials technology (for example, high-speed steel) further enhanced the degree to which transformation machinery became more productive. Then, towards the end of the 19th century, these advances in transformation technologies came up against the bottleneck of transfer, and the need to speed up the whole operation rather than merely that of transforming particular inputs. This involved not merely automation of transfer itself (for example, the use of conveyor belts) but, perhaps more significantly, a reorganization in the way in which production occurred. 'Scientific management' and the assembly line were perhaps the key organizational outcomes in the 1875–1925 period. Finally, it is in the most recent period that the automation of control has become most marked, both because of the need to make increasingly productive transfer lines more flexible, and because of the extent to which emerging technologies (especially electronics) facilitated this flexibility. It is not surprising, therefore, that it was in this period that Wiener (1947) and others, through their emphasis on feedback control, sought to institute this as the 'true' characteristic of automation in general.

This, then, is the current state of the art with regard to the characterization of automation. It comprises, three dimensions. First, automation should be considered in its widest sense; second, there are degrees of automation; and third, automation consists of three components — transformation, transfer and control. In the contemporary period, the automation of control has become a particular concern, facilitated by the development of low-cost, small and reliable microelectronic circuitry. But is this adequate? Does it give us a sufficient hold on the concept to explain the nature and significance of developments now unfolding that will give us the 'factory of the future', as promised by American TNCs such as General Electric, IBM and Westinghouse, their Japanese counterparts such as Fujitsu Fanuc, Kawasaki and other international competitors? We believe not, and the reason is that this literature only covers one — albeit a key — sphere of production: the physical transfer of inputs into outputs. But what of the other important technological developments that are now unfolding, such as those in the office, and those in the conception and design of new and improved products? These, too, are important elements in the organization of production and lend themselves to analysis in a similar way. To understand the significance of this critique of the state-of-the-art studies on automation, it is necessary to offer first a brief description of the organization of production in the modern enterprise.

In the modern industrial firm, as we can see from Figure 1, there are essentially three spheres of production. The first of these is design where the nature of the firm's output (e.g. automobiles, buildings, sweets) is defined and new production processes are explored. The key actors in this sphere are skilled engineers, scientists and technicians; but to work effectively, they require the back-up help of a staff of 'information processing' assistants, such as secretaries and librarians. The actual transformation of these designs into a physical product occurs in a second sphere of production in which the raw materials and intermediate inputs are stored, processed into final products and ultimately delivered to the consumer. (This is often another affiliate of the same firm.) Those two spheres of production, which are the kernel of an enterprise's activities, could not operate effectively without some form of coordination, and this comprises the third sphere of production.

Naturally, the extent to which these spheres of production exist in any particular enterprise depends upon the nature of the activity involved. Firms producing simple products with relatively low technology will have a poorly developed design department, whereas small, high-technology electronics firms may have a very

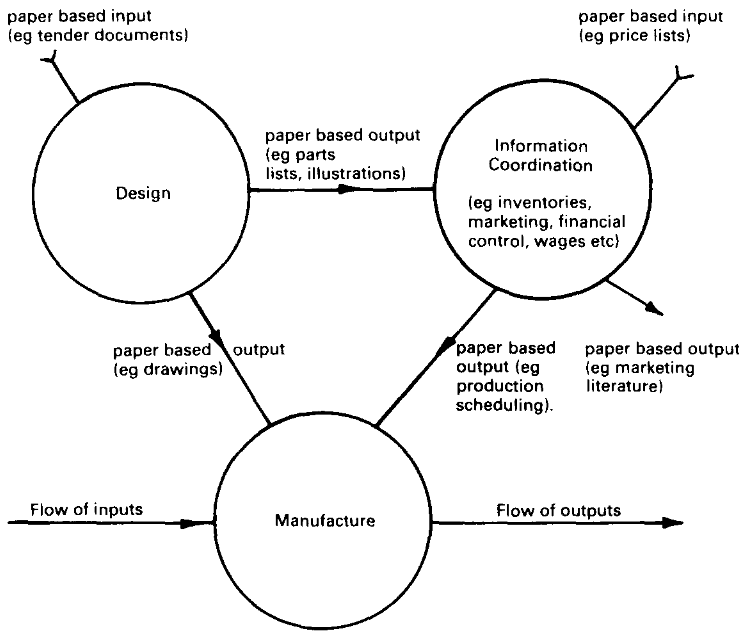


Figure 1. *Pre-electronic organization of factory production.*

well-developed design capability that requires little formal coordination. Nevertheless, in almost all modern enterprises, whatever their sector or size, these three spheres of production will tend to be separated into different units (often in different towns, cities and even countries): the R&D block, the factory and the administration. Clearly this separation of function has not always been the predominant form of organization; a point to which we will return later.

Now within each of these three spheres of production are a variety of separate activities. For example, within the design sphere, design itself is usually an activity distinct from drawing, copying and tracing; within the manufacturing sphere important differences exist between handling, forming, assembling, control, storage and distribution; and within the coordination sphere, information must be gathered, processed, stored, and transmitted. Some activities are common to all enterprises — for example, handling in the manufacturing sphere — but there will inevitably be a variation in the number and type of other activities. This variation is particularly marked in the manufacturing sphere, where it will be affected by factors such as the nature of the process (flow or batch) and scale (small or large batch).

By the last quarter of the 19th century, therefore, the larger enterprises in Western Europe and North America had seen the evolution of the three spheres of production. The sphere of design was increasingly based upon the application of scientific principles; coordination saw the emergence of tiers of management; and manufacture was characterized by the application of ever more complex machinery, involving a steady growth in the division of tasks. The last three-quarters of a century has seen the extension of this differentiated enterprise from the local to national markets, and thereafter from national to international markets (Chandler, 1977). The three spheres of production continued to extend over this period until, today, we can observe their functioning across the globe. As the extensive literature on the transnational corporation (TNC) shows, design, coordination and manufacture in a single firm often extend over national boundaries; design and senior management in the home country with manufacture and elements of coordination spread over a great number of countries.

Armed with the recognition that there are these three spheres of production, each with its particular sets of activities, it is possible to categorize three different types of automation. As we shall see, the predominance of each of these three types of automation has changed over the years.

(a) *Intra-activity automation* refers to automation that occurs within a particular activity. Clearly, in line with our earlier definition of automation, this intra-activity automation may take a variety of forms ranging from the simple substitution of machine power for human power (as in the use of computer-aided drafting systems) to the more complex incorporation of machine 'intelligence' and control (as in computer-aided design systems). The determining characteristics of this type of automation, however, are that it is limited to a particular activity and that it is consequently isolated from other activities within or beyond the particular sphere of production.

(b) *Intra-sphere automation* refers to automation technologies that have links with other activities within the same sphere. Indeed, the origins of the term 'automation' in the Ford assembly plant of the 1920s illustrate this type of automation well: the new transfer line mechanized the flow of materials between different activities such as lathes, drilling and boring machines. In its more complex form — as in the newly flexible manufacturing systems — intra-sphere automation involves the monitoring of the progress of production with an ability to adjust components of individual activities, if this becomes necessary.

(c) *Inter-sphere automation* is the third and most complete form of automation and involves coordination between activities in different spheres of production. In view of the number of activities within each of the different spheres, there is a wide variety of potential inter-sphere combinations. These may be relatively limited and simple; for example, using design parameters to set machine settings automatically; or they may be wide-ranging and complex, such as in the linking of changes in the specification of productions to parameters generated in redesign, and thus in continual adjustments made in machine settings.

The essential difference between these three different types of automation is shown in Figure 2. In Figure 2 (a), we illustrate the introduction of automation technologies into individual activities within each of the three spheres. As we can see, there is no link between these individual intra-activity automation technologies and other activities, even within the same sphere. In Figure 2 (b), we illustrate how an automation technology is introduced into a particular sphere with some form of interlinking (involving feedback in the case of the manufacturing sphere) between different activities. Finally, in Figure 2 (c), we give an example of the merging of the three-sphere industrial enterprise back towards the single-sphere type of organization which, as we

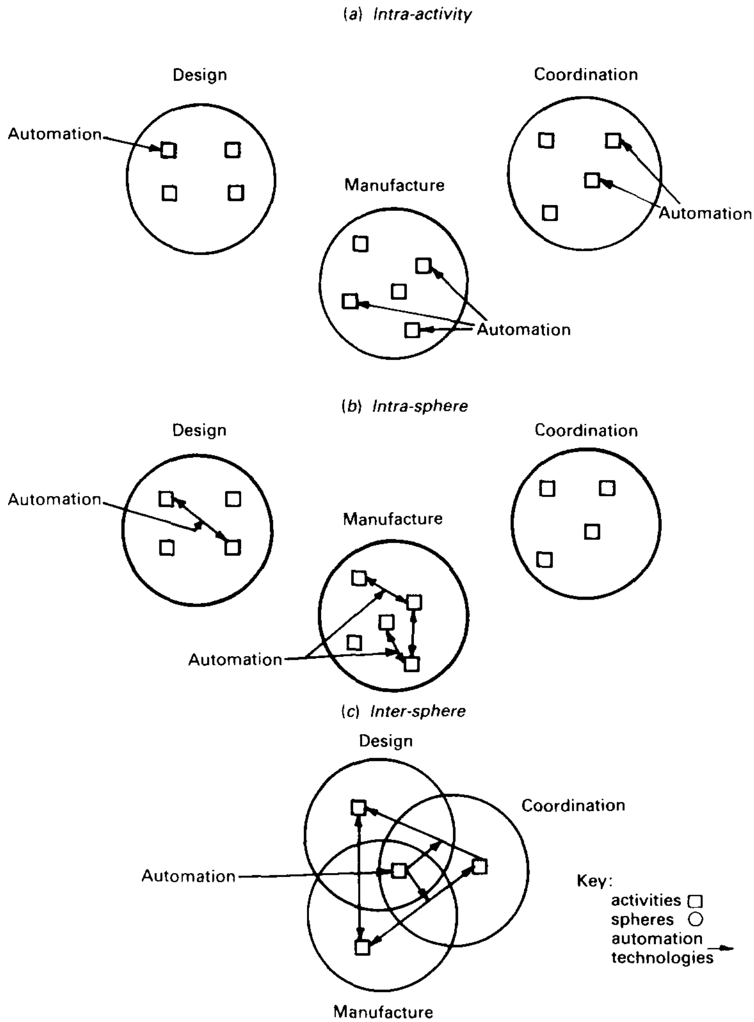


Figure 2. *The three different types of automation.*

shall see, characterized pre-industrial revolution enterprises. In this case, automation technology links different activities between different spheres of production.

Before we proceed to examine the impact of electronics on automation technologies and best-practice organization of production, it is important to recognize that the gradual separation of the enterprise into these distinct spheres of production had two diverse sets of origins.

First, it was underpinned by the emerging technological logic of machinofacture. Production processes became increasingly mechanized, and design (including research) became increasingly knowledge-based. Their separation as tasks was thus predicated by their inherent specialization; their separation into separate *spheres* was predicted by the dominant, paper-based mode of communication, which provided little scope for the synergies of integration now being made possible by informatics technologies.

But there was also a second process underlying the separation of the enterprise into three distinct spheres of production, associated with the control of the labor process in the capitalist mode of production within which the industrial revolution took place. This perspective is provided by Marglin (1976),[4] although there must be some doubt concerning the absolutist (and partly polemical?) vein in which he presents the issues.

What is at issue now is the transition to the automated enterprise. Whereas the last three centuries have seen the gradual evolution and specialization of the three spheres of production, what we are now beginning to witness is the re-emergence of the unitary, undifferentiated firm. The development of the automated enterprise, embodying the extension of inter-sphere automation throughout the firm, is leading once again to the unity of spheres, as illustrated in Figure 3. This is the significance of drawing out the three types of intra-activity, intra-sphere and inter-sphere automation. Merely focusing on its components — that is transformation, transfer and control — ignores the central importance of these emerging developments in firm structure and organization.

It is in this transition to the integrated enterprises that the historical significance of microelectronics technology is to be found. There are two reasons for this — the emergence of a pervasive digital (often called 'binary') logic, and the dramatic reduction in the costs/capability curve.

well as the speed, with which microelectronics is diffusing in the manufacturing sector.

Hence in referring to the three types of automation outlined above, microelectronics in intra-activity automation has tended to be associated with the optimization of control and the storage of information. Indeed, this was the major area of the technology's diffusion in the period between 1960 and the late 1970s. In the manufacturing sphere, we saw the maturation of numerical control, beginning with simple machine tools and currently extending to assembly robots;[5] in the design sphere, microelectronics systems began with batch-oriented mainframe design computers and have progressed to interactive computer-aided design (CAD) and computer-aided drafting systems; in the sphere of coordination, applications began with computers being used for stock-and-wage control, and then extended to word processing and, most recently, to electronic printing.

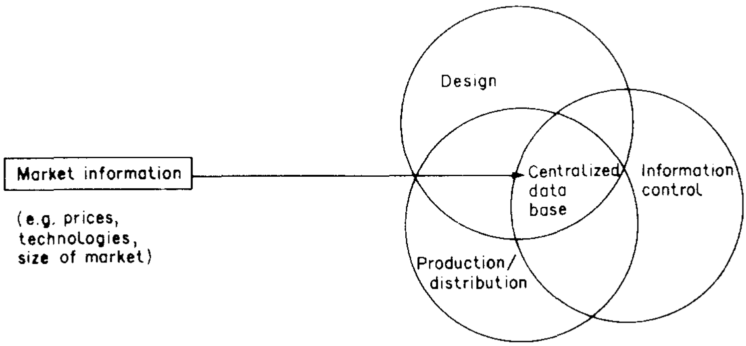


Figure 3. *The move to the single system automated factory.*

Binary systems operate as the basis of either/or logic in which counting and logical systems can be decomposed into a variety of stages, each of which can be answered with binary logic. Thus, a common way of *processing* ideas or information can be utilized in a wide variety of activities, across the full range of spheres of production within the enterprise, as well as with external firms and institutions. Because digital logic can easily be *transmitted* via the interrupted flow of electricity (or light, as is proposed for the future generation of computers), there is a ready interconnection between different digital logic systems. It is this convergence between processing and transmitting information ('informatics') that provides the key facilitating technology for intra-sphere and inter-sphere automation discussed above.

There is no need to detail the extended decline in the cost/capability curve since the integrated circuit was introduced in 1959; the figures are well known and available in a variety of other sources (see Soete and Dosi, 1983, Table 4). However, the significance of this decline is paramount in explaining the pervasiveness, as

Then towards the mid-1970s, fledgling attempts were made at intra-sphere automation based upon microelectronics systems.[6] This trend towards intra-sphere automation is currently the major objective of most major machinery suppliers providing equipment for each of three spheres of production. In the design sphere, computer-aided design and drafting systems are widely available and have until recently been the province of new American firms such as Computervision, Calma and Intergraph. In the manufacturing sphere, we are seeing the transition to flexible manufacturing systems, hitherto the speciality of Japanese and Swedish firms with a few exceptions from the United States and Europe. Finally, in the sphere of coordination, a number of predominantly American firms are developing intergrated, multi-function workstations covering the full range of activities.

These efforts at intra-sphere automation, based on digitized electronics technology represent the cutting edge of technical progress in the mid-1980s. But already the focus of innovative attention in the industrially advanced economies is moving to wider horizons, namely inter-sphere automation. The attraction is to combine digitized islands of intra-activity automation as well as sets of intra-sphere automation across the three spheres of production. Initially, the tasks are narrowly defined, as when CAD systems (in the design sphere) automatically set numerically controlled machine tools in the manufacturing sphere. But the potential is far greater, as many major corporations are beginning to realize. General Electric (GE) of the United States, the world's largest engineering firms,[7] is restructuring its operations to take advantage of the potential offered by microelectronics to implement inter-sphere automation by both providing and using this type of automation technology. In the former case, GE has during the last four years spent over $700 million to acquire and expand electronics-based machinery supplying-firms in the three spheres of production.[8] With respect to using the new technology, GE has, in the same period, invested over $2 billion in re-equipping plants. This amount includes $316 million in a new, inter-sphere automation plant to manufacture locomotives, a good illustration of the potential for systems-gains offered by the new electronics-based technology.

> Starting at the beginning, the design output of the engineering department will be passed on to the manufacturing engineers in electronic form, rather than as drawings, and will then move through materials control, which will automatically schedule and order materials and keep track of stock and production. All this information will come together in the factory in the host computer, which will contain in its memory details about how, when and what to produce. This, in turn, will send instructions to the computer-controlled equipment, such as numerically controlled machines and robots, which will actually do the job. Quality controls, financial data, and customer service records will also be plugged into the same systems (Lambert, 1983).

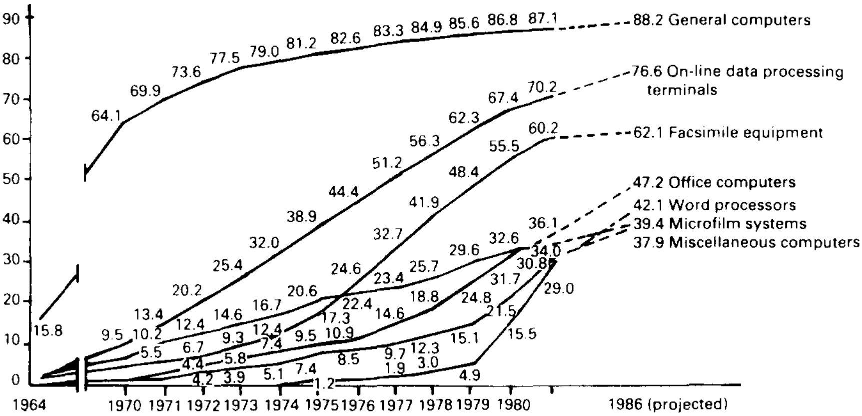
Increasingly, therefore, the direction of technical change in the industrially advanced countries is assuming a *systemic* character, involving the merging of disparate islands of automation. The organizing thread of this new era of automation is the control of information, the rapid processing and communication of which is vastly facilitated by using electronically controlled equipment.[9] The significance of the systemic nature of these technological developments should not be underestimated, since it has important consequences for the pattern of innovation. Unlike previous eras of automation where the productivity gains were identifiably related to the introduction of discrete machines, in this new epoch the major productivity gains are being realized when individual sets of equipment in many different parts of the enterprise are linked. This linkage involves two requirements. First is the widespread dispersion of electronics-based equipment throughout the enterprise, and second is the ability to coordinate their workings. (We return to the policy relevance of this discussion in Section 4.)

In the former case, evidence is increasing of widespread diffusion in the industrially advanced economies and in all three spheres of production. Figure 4, for example, charts the rapid spread of electronics-based information-processing automation in the coordination sphere in Japan; Table 1 provides evidence of the spread of NC lathes in the sphere of manufacture; and Figure 5 charts the rapid spread of interactive CAD in the design sphere. In each of these cases, innovation was justified in terms of the short-run productivity gains provided in each of separate activities. Yet, in historical perspective, the true significance is likely to emerge when the individual electronics-based sets of equipment are linked as is evident from the description of the new locomotive plant cited above.

More problematically, the linkage of these items of equipment is constrained not only by technological factors,[10] but also by managerial perspectives which, historically, have been based on the decentralization of control and responsibility. Evidence is increasing that electronics-based automated production, built around centralized data bases, permits a greater level of control by senior management, but that this requires changes in pattern of managerial organization (see Kaplinsky, 1984a, Chapter 7).[11] In these circumstances, management is required to implement a wide, enterprise-level of organization, restructuring coordination to exploit the potential for systemic productivity gains.

3. THE REORGANIZATION OF PRODUCTION AND INTER-ENTERPRISE LINKS IN BEST-PRACTICE ENTERPRISES

The structure of the modern enterprise as we have come to know it was forged in the 19th and early 20th centuries in America. Chandler in his two classic studies (1962 and 1977) charts the transition from the rural and agrarian to the urban and industrial economy over the period from 1840 to World War II. The key development in the 1840–1920 period was the development of management (our coordination sphere



Note: The figures in this chart represent the proportions of firms among 100 enterprises surveyed installing respective types of equipment in the years indicated.

Source: Japan, Foreign Press Center 1982

Figure 4. *Percentage of Japanese enterprises using automation technology in the coordination sphere.* The figures in this graph represent the proportions of firms among 100 enterprises surveyed installing respective types of equipment in the years indicated. Source: Japan, Foreign Press Center (1982).

Table 1. *Investment in NC lathes as percentage of investment in all lathes in major producing countries*

Year	United States	Japan	United Kingdom	France	Sweden	Germany Fed. Rep. of	Italy
1974	n.a.	n.a.	n.a.	n.a.	34.4	n.a.	n.a.
1975	n.a.	23.4	n.a.	n.a.	42.6	16.5	n.a.
1976	n.a.	28.2	18.6	26.4	41.6	n.a.	15.2
1977	n.a.	40.8	21.3	46.7	52.6	n.a.	n.a.
1978	n.a.	40.1	n.a.	n.a.	69.9	n.a.	n.a.
1979	n.a.	50.8	38.4	73.8	69.5	n.a.	n.a.
1980	56.5	n.a.	47.3	n.a.	n.a.	47.1	50.0

Source: UNCTAD (1982).

discussed above) as a specialized function. Thus, the

> . . . modern business enterprise took the place of market mechanisms in coordinating the activities of the economy and allocating its resources. In many sectors of the economy the visible hand of management replaced what Adam Smith referred to as the invisible hand of market forces.[12]

Before 1840 enterprises had expanded production by employing more apprentices and craftpersons, or putting-out work, or by innovating simple machinery.[13] Then central management controlling marketing, production, finance and purchasing gradually came to dominate, particularly as the development of railroads had led to the emergence of a national market. This laid the basis for mass production and the development of the multidivisional, national firm after the 1920s, modelled on the patterns of Du Pont, General Motors, Standard Oil of New Jersey and Sears Roebuck.[14]

After the 1920s, these national firms became increasingly transnational, developing production in many foreign markets, partly following the pattern of Vernon's product-cycle theory (Vernon, 1966). However, until the 1960s, there was little structural difference between these international subsidiaries and the national firms from which they evolved. Then, following the sustained technological advances in transport technology (low-cost air travel, containerized

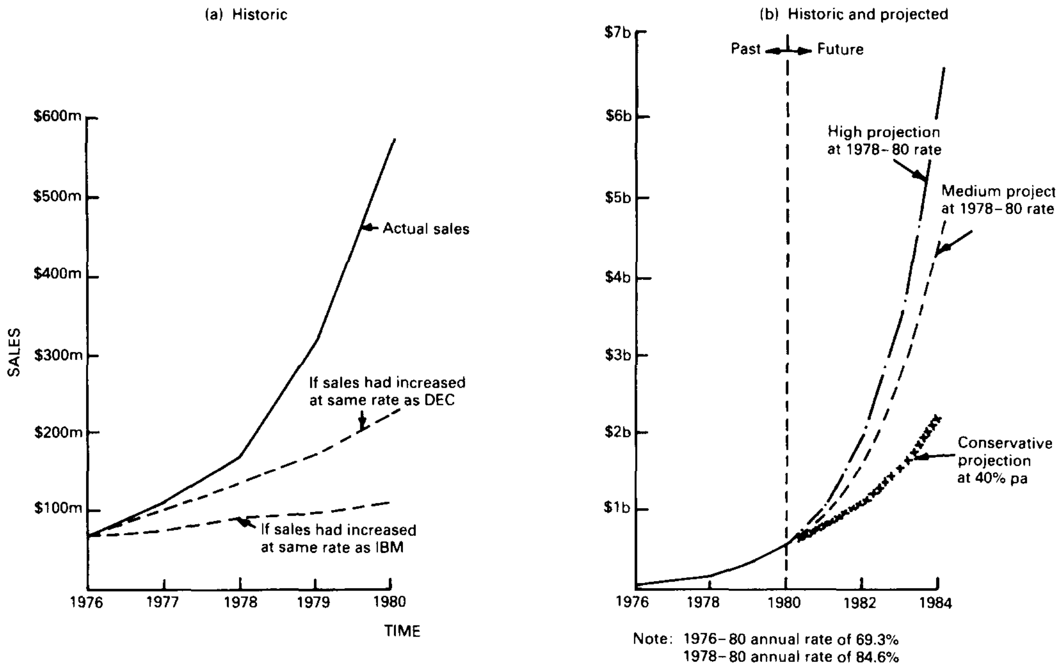


Figure 5. *Sales of interactive CAD systems — past and projected.* Note: 1976–80 annual rate of 69.3%; 1978–80 annual rate of 84.6%. Source: Kaplinsky (1982b).

shipping and bulk-handling facilities), and in a light of an increasingly competitive trading environment, some of the major transnational firms began to reshape their international activities. Instead of operating a series of similar enterprises spread around the globe, a New International Division of Labor was fashioned involving integrated and complementary production between various affiliates in different countries and regions. In the words of Frobel *et al.*

> the development and refinement of technology and job organization makes it possible to decompose complex production processes into elementary units such that even unskilled labor can be easily trained in quite a short period of time to carry out these rudimentary operations.[15] [Consequently,] . . . Usually vertically integrated into transnational enterprises world market factories produce, assemble or finish components, intermediate products or final products in processes which allow for the profitable utilization of the labor-force available at the respective sites . . . to produce for the world market.[16]

Beginning with American firms, especially in the electronics sector, this changing international division of labor became increasingly widespread across sectors and countries (Frobel *et al.*, 1980; Peet, 1982). Indeed, many observers have predicted that this pattern will increasingly become the norm.

There are a number of reasons why we believe that the continuation of these trends in the International Division of Labor is unlikely, particularly in relation to the behavior of the TNC (see Kaplinsky, 1984c). However, the future orientation of the TNC is not our primary concern here; and in the following discussion, we shall focus our analysis on only one element of this scenario, notably the tendency towards Japanese-style just-in-time (JIT) production techniques. We consider this issue because it involves particular types of systemic integration between enterprises, thereby maintaining our concern with the systemic implications of the new, microelectronics-based automation technologies.

The best way to understand the significance of these JIT production techniques, is to consider the pattern of production technology in the automobile industry. Although the mass production line was not pioneered in the automobile sector,[17] it was Henry Ford's magneto plant that first provided graphic evidence of the advantages of mass production in assembly. Ford reorganized the labor process such that what had previously taken a single person 20 min, was split into 29 operations with 14 persons assembling 1335 magneto in 8 hours. This represented a fourfold increase in labor productivity. The same principle was then extended to the chassis assembly line, reducing the labor content progressively from 12½ hours in August 1913 to 1½ hours by April 1914.

This procedure, involving the decomposition and specialization of work tasks, the installation of conveyor belts and the primacy of keeping production lines moving, became established throughout the automobile and other mass-production sectors, and not just in the United States. For the purposes of this discussion, there were four important elements to this scheme. First, because of the need to keep production lines moving, substantial inventories of parts were maintained to guard against defects and interruptions of supply. This latter aspect became especially important when firms came to specialize in relation to the New International Division of Labor and supply lines became stretched across continents.[18] Second, many of the independent component suppliers became similarly organized, also stretching production across continents. Third, individual job tasks were segmented, and work became increasingly specialized and monotonous. And, finally, for the production line to work continuously, its control became the responsibility of line foremen and middle management, rather than the province of individual production workers, or senior management.[19]

This system of organization, extensively diffused in most parts of the world automobile industry, has suddenly been challenged. The visible sign is that Japanese automobile firms are able to land small cars in the United States, duty- and transport-paid, for around 30–40% less than their American counterparts can manufacture them (Jones and Anderson, 1983). On investigation, the basis for this low-cost production is twofold: first, the widespread diffusion of the systemic, electronics-based automation technologies described in Section 2; and, second, the development of a unique method of organizing production, JIT production.

Just-in-time production, for which the best available description is to be found in Schonberger (1982), has a number of elements that clearly distinguish it from the mass-production line described above. First, as its name implies, it is built around the zero-inventory principle; in many cases, assembly plants have components delivered two or three times a day;[20] compare this to General Motors strategy of three plants shipping engines around the world. A second key element is the adoption of a zero-defect policy, rather than existing forms of quality control that sample and generate 'acceptable' levels of defects. This is important, since one of the primary factors necessitating inventories is to safeguard continuous production from stoppages due to sub-quality components. (Although this is the primary reason for the zero-defect policy, it is clearly an important competitive factor in selling final products; hence, the renowned reliability of Japanese cars, televisions, and other consumer durables). Third, flexibility is built into the system in two ways: (1) Workers are expected to undertake different tasks, rather than specializing in the existing pattern; and (2) machinery and plant layout are altered to facilitate rapid changeover. In five years, Toyota cut the set-up time for an 800 ton press from one hour to twelve min; in 1982, the average time in the United States was six hours. Thus, Toyota changes product lines at least once per day, whereas the American car manufacturer does it at ten-day or more intervals (Schonberger, 1982). And, finally, whereas control over the movement of production lines has hitherto been the exclusive province of line management, in the JIT system, it is the responsibility of each worker. This is a requirement of the zero-defect policy.[21]

The key point related to our discussion is the implications that this procedure have for inter-firm relationships. Obviously, for the zero-inventory principle to have any significance, supply lines have to be shortened. For example, General Motors has recently made a policy decision that 83% of all component suppliers will be within 100 miles of its new final assembly plan in Flint, Michigan. Inventory levels in the first three years were reduced by 50%, with the expectation that this will increase further as the JIT system matures (*Iron Age*, 1983). One study of IBM's adoption of JIT techniques observes that

> . . . currently IBM plants procure 45 percent of their inputs from vendors within a one-day trucking radius. They plan to increase that amount as much as possible, given the constraint of limited sources of such specialized inputs as semi-conductors. Thus, to maintain business with IBM, a vendor will have to be located near the plant.[22]

A second major implication for inter-firm relationships is a change in the nature of the links between assemblers and users. This involves a sharp reduction in the number of suppliers; in the case of one large IBM plant in the United States, from 550 to 150; in General Motors Michigan complex, by 50%; in Volvo, from 1000 to 600. It also requires a much closer design relationship between the two sets of firms (see Schonberger, 1982 and Jones and Anderson, 1983) with component suppliers actively collaborating with assemblers from the earliest stages of design. This restructuring of the design relationship is the major underlying factor in the above-noted desire of assembling firms to reduce the number of component suppliers.

Thus, the combined effect of these changes in inter-firm relations is that they involve the adoption of more organic, and system-like relationships. The production unit comes to resemble a cluster of integrated, yet separate, plants operating in close proximity and with a detailed coordination of product development, production schedules and delivery. Together with the adoption of electronics-based automation technologies[23] (which are crucial to increasing machine flexibility and information control to handle rapid changes in product mix), these developments move production towards a new pattern of *systemofacture*. This is likely to have profound implications for LDC industrial policy, and it is to these issues which we now explore.

4. SYSTEMOFACTURE: IMPLICATIONS FOR LDC INDUSTRIAL POLICY

In any discussion of this sort — which not only addresses a broad survey of general issues, but also speculates on the nature and diffusion of future patterns of industrial technology and organization — there is a great danger of squeezing marginal cases into tight categories. Thus, while we may be able to make reasonably determinate judgments with respect to the future pattern of Japanese innovation, and to contrast this coherently with likely developments in sub-Saharan Africa, there are many countries that do not easily lend themselves to this sort of typology. For example, what is to be the future of the United Kingdom or Italy, both relatively laggard in the adoption of the New Technology? Conversely, to what extent will the neo-NICs, such as Malaysia, Sri Lanka and Thailand (whose future is optimistically forecast by Havrylyshyn and Alikhani, 1982), be able to make the transition to the new systemic technologies and patterns of industrial organization discussed in previous sections of this paper? Because it is precisely to these marginal cases that policy prescription is most relevant, it is appropriate to be wary of making sweeping generalizations. Nevertheless, because we believe that the broad patterns of future industrial technology and organization are now evident and that certain general policy issues will be relevant for most economies, we will consider a number of major policy implications that emerge from the prior analysis.

Before doing so, however, it is useful to summarize the major issues that have arisen so far. We have argued that best-practice production will evolve into a pattern which we have termed systemofacture. This comprises two related sets of developments. First is the adoption of intra-firm systemic technologies. These involve a series of electronics-based automation technologies, facilitating internal economies through the linking of digital logic control systems with appropriate technologies for intercommunication. Although significant productivity and product enhancing gains are realized by the adoption of single, or a limited number, of such technologies, the major competitive gains arise out of the systemic networking of separate automation technologies throughout the enterprise, including design, production and information coordination. Second, we are witnessing the transition to a new structure of inter-plant relationships. The existing pattern of globally widespread, vertically integrated enterprises[24] is likely to be supplanted by geographically proximate plants, with closely coordinated product development, production and delivery-schedules. Thus, in terms of broad historical generalization, whereas the first industrial revolution involved the substitution of machines for labor (from 'manufacture' to 'machinofacture' in Marx's terminology), the current period may well be witnessing the transition from 'machinofacture' to 'systemofacture.'

What then is to be the appropriate policy response to these momentous developments? Clearly, for each individual country and each particular sector the detailed policy response will vary. Here we confine ourselves to four major sets of policy formulation.

(a) *Policies on technological diffusion*

There has been a common pattern in the development and diffusion of electronics-based automation technologies, particularly in the spheres of design and manufacture, in that the spur to initial technological development was not the reduction of costs but an increase in product quality.[25] Only once the technology matured and its costs began to decrease has it become an optimal choice of technique, and this has only occurred since the later 1970s. In the case of some automation technologies (for example, assembly robots and electronic printing) the available technologies are still too far up the cost curve to make them a cost-competitive choice of technique. Nevertheless, for a wide range of intra-activity automation technologies, the new technology represents an optimal choice of technique at developed country factor-price ratios. For example in Japan, the ratio of playback robot acquisition costs to annual labor costs fell from 11.9 in 1970 to 4.8 in 1975, and to 3.7 by 1978; in 1981 US prices CAD systems became the preferred technique when gross design-labor costs exceeded $10,000 pa. As a general observation, electronics-based automation technologies developed earliest in the design and manufacturing spheres, yet are diffusing most rapidly in the coordination sphere, since it is here that the choice of technique decisions have become most clear-cut.

Hitherto this pattern of diffusion has largely been concentrated in high-wage developed economies, where existing factor-price ratios are such that many of these intra-activity and intra-sphere automation technologies are now the optimal choice. However, in low-wage LDCs, the primary motive for their adoption is unlikely to be a response to relative market prices but rather the need to meet specific product standards particularly (and most unfortunately) in the case of production for the military sector. In this case, left to market forces alone, electronics-based automation technologies are likely to diffuse especially unevenly in LDCs, largely responding to the needs of product enhancement.

This may prove a viable strategy in the short-run, but as the systems-based automation technologies — which depend upon the *widespread* interlinking of digital logic automation technologies throughout the enterprise — spread in competitor countries, these partial responses to the imperatives of innovation are likely to prove inadequate. Instead, a comprehensive approach to technology acquisition is necessary, requiring the state (or its proxies) to intervene to correct the signals provided by the market. It may, therefore, not be sufficient to merely facilitate the purchase of obviously necessary electronics-based technologies such as CNC machine-tools or CAD, because for these technologies to realize their ultimate productivity gains they may necessarily have to be linked to less obviously attractive technologies such as word-processors, electronic printers and personal computers. Inevitably such policies will stimulate resistance, since it is not easy to justify high-cost automation technologies (such as word processors) when labor costs (e.g., for clerks and typists) are so low.[26]

(b) *Networking*[27] *and infrastructure*

As we have seen, the emergent best-practise forms of industrial organization involve a restructured relationship between industrial plants. This has two dimensions, namely, a transition to closer proximity, and the development of closer design and planning links. The important resource in these closer relationships is the ability to process and communicate information. Though electronics technologies in themselves only offer the ability to process information cheaply, accurately and rapidly, because of their digital-logic, they also offer the potential to reduce the costs of transmitting information. Particularly when allied to emergent communication technologies, the reduction in costs can become dramatic (see Table 2).

Thus, in addition to policy being focussed on the need to capture intra-enterprise systems gains through the widespread diffusion of electronics-based automation technologies, it will also be necessary to acquire complementary communication technologies to enable enterprises to capture inter-enterprise systems gains. In particular, this involves the adoption of new telecommunication technologies such as fibre-optic cables (the so-called 'Highways of the Information Economy') and satellite receivers/transmitters. In some senses, LDCs are at an advantage here in that they do not have an accumulated stock of outmoded communication technologies, and can

Table 2. *Capacities of different transmission technologies*

Technology	Speed (millions of binary signals per second)	Number of phone circuits	Cost per phone circuit ($1978)
Conventional cable	5	500	200
Coaxial cable	300	30,000	30
Terrestial-microwave	1,000,000,000	100,000	15
Satellite	1,000,000,000	100,000	30
Fibre optics	1,000,000,000,000	100,000,000	Unknown but very low

Source: Drawn from Cawkell (1978, reprinted in Forester, 1980).

thus start afresh. Nevertheless, once again it is unlikely that market forces alone will stimulate the necessary innovation, and direct policy intervention will be unavoidable if appropriate rates of diffusion are to be maintained.

(c) *Skill acquisition*

The discussion of skill acquisition in the development literature has largely been pursued in the context of policies designed to promote basic literacy and numeracy, artisanship and specific professional skills (such as doctors, engineers and even, for rather obscure reasons, economists). To some extent, this accumulated body of analysis and policy prescription is relevant to the technological developments that we have been addressing. More electrical engineers are required, as are more technicians for repairing electronically controlled equipment.[28]

Yet the skills required to make effective use of the new technologies go beyond those already recognized in many educational structures. Two additional capabilities are necessary. The first involves a change in the nature of existing training schedules and the need to develop the capability of recognizing systems-level productivity gains. This sounds like a relatively simple task, but in fact it requires a major adjustment to existing training programs. It no longer is adequate to merely train mechanical and electrical engineers as separate individuals, for the implementation of systemic gains requires a combination of both established disciplines. Similarly, existing training programs for management need to develop broader horizons so that the wider systemic gains are recognized. Thus, for example, General Electric in the United States is now insisting that all middle and senior management personnel attend training courses to familiarize themselves with the systemic nature of the new electronic-based automation technologies. The point we make here is that the recognition of the systemic nature of the technology is not something that can be left to common sense. It requires a specific recognition in the structure of training programs, right across the skill spectrum.

The second new type of capability required in the transition to systemofacture, is the ability to innovate. Perhaps this sounds suspiciously like the exhortations of previous decades, in which LDCs have been diagnosed as having 'weak entrepreneurship.' Yet the demands of the new technology, which are not only systemic in nature but also heavily knowledge-based, seem to make very special demands with respect to innovation. The evidence suggests that, certainly for the United States and the United Kingdom, it is new, small firms that seem to be more flexible and thus able to adapt more rapidly to the significant changes in work practices involved; moreover, these firms more often than not were started by science-based entrepreneurs. However, as Dore (1983) notes, the association between small firms and innovators in the United States and the United Kingdom may, in the face of increasingly complex technology, be a competitive drawback. The initiative may thus increasingly pass to large Japanese-type organizations (which Dore claims reach decisions by consensus, rather than conflict) or other newly industrial countries in which the social structure of accumulation is more conducive to innovation. Thus categorizing this ability to innovate as a 'skill' is perhaps too restrictive since clearly sets of specific social relations underlay the emergence of any set of innovators, be they within capitalist or socialist social formations. This may be so, but the level of discourse cannot be confined to the realm of political economy, for these are important educational issues involved, particularly in the training of scientists and technologists.

(d) *Design and comparative advantage*[29]

The transition to inter-sphere, systems-based automation discussed in Section 2 is premised on the capability of the new technology to process and communicate information rapidly, accurately and cheaply. In so doing, it has major implications for comparative advantage in industry, since in many sectors it is the existence of specific sets of knowledge that allows firms to compete effectively in world markets.

To make this point more clearly, it is necessary to discuss briefly the relationship between skills and knowledge, which are related but not identical concepts. Knowledge comprises an understanding of a process or information at an abstract level, such that it can be transmitted to another individual in a similarly abstract manner. As such, knowledge must be explicitly rationalized in abstract terms that can be readily understood — a process that we have come to know as science and technology. On the other hand, skill comprises of a set of practiced experience, which may involve not only the acquisition of knowledge, but also a greater or lesser degree of natural aptitude and implicit rules of operation. Skills are individually acquired and involve a combination of abstract learning, aptitude and experience, but the same is not true of knowledge, which is essentially abstract and less individual-specific. Perhaps most significantly, the lesson of the last three hundred years of technical progress has been that knowledge (generally embodied in machinery) has systematically become a substitute for skills. Hence the oft-observed tendency towards the deskilling of work by the substitution of increasingly complex machinery.

If we focus on the pattern of comparative advantage in manufacturing in the period since World War II, we can see a distinct pattern of specialization between the industrially advanced economies, especially in the discrete products industries. In general, the industrially advanced countries have had a marked comparative advantage in the skill-intensive, crafts-based industries, especially in the metal-working and capital goods sectors. Though this comparative advantage has also arisen from the knowledge inherent in the production processes and product technologies, the long history of artisanal skills has been a major factor in the competitive strength of these industrialized economies.

The new, electronics-based automation technologies are having a major impact on this existing pattern of comparative advantage, since they represent a continuation (albeit at a significantly faster pace) of the trend in which knowledge is being substituted for skill. Indeed, the conception of full inter-sphere automation, in which individual matching-settings are all derived from a single centralized data base graphically represents this trend for knowledge to be substituted for skills. Consider, for example, the skill of metal-working: in the mould industry, this takes 10–12 years of learning before a craftperson 'matures.' Yet the introduction of CNC machine tools currently taking place is sweeping away the need for these skills. As such the barriers to entry to new entrants — hitherto excluded by their lack of craft skills — is significantly eroded (see Jacobsson in this volume).

However, the introduction of CNC machine tools in itself cannot allow production to take place because these machines must be programmed with knowledge: and, this knowledge can be created in a variety of different places in the enterprise. The two major locii for creating this knowledge base are on the shop floor, and in the design office. Which one yields the greatest productivity benefits depends upon whether discrete, intra-activity automation is taking place, or whether the target is wider, intra-sphere or inter-sphere automation.

If individual machine tools are being introduced in a highly selective pattern of automation, then it is probably most appropriate for the machine tool-paths to be calculated at the point of production. In this case, there are no particular implications for the role of design in production. However, if a wider horizon of automation is involved, then logic argues that the design sphere has a key role — if not *the* key role to play in enabling the firm to innovate productively. This is because, as we have seen, digital logic allows for the productive, systemic networking of different electronics-based automation technologies. Since the information base established at the design-stage is the one that will subsequently form the core of coordination activities (e.g. parts lists, stock control) and manufacturing activities (notably in machine-settings), it is clearly crucial that the initial design be undertaken in a digital, electronic-format. Moreover, the experience of introducing such design procedures is that the content of the design phase necessarily becomes more science based (that is, knowledge-, rather than skill-intensive).

Again as in previous discussion, it is possible to respond by questioning whether this represents a new imperative. After all, design has long been recognized as an important industrial activity. At one level, this is a valid comment. Yet to make this observation and at the same time fail to respond with a significant increase in the effort devoted to design is to miss the point. The transition to systemofacture involves not just the automation of separate activities within each of the spheres of production. It also involves their interlinking, and without a science-based and systematic policy to design, the unified data base[30] that allows for systemic, inter-sphere automation will be unobtainable.

5. CONCLUSION

Consideration of the implications for the Third World industrialization of new best-practice production techniques (which, as we have seen, include the widespread use of microelectronics-based automation technologies) cannot be undertaken *in vacuo*. Particularly since the 1950s, there are few economies in which industrial-strategy decisions can be made in isolation from the world market. Since a growing share of world industrial output is traded, best-practice production techniques in the industrially advanced economies have important implications for industrialization in the Third World, whether it be primarily directed towards production for the home or export markets.

There are two particularly important lessons for the Third World which we believe are supported by previous discussion. First, best-practice production techniques are increasingly systemic in nature, but this tendency only partly reflects the introduction of electronics-based automation technologies; related changes are also implied in the proximity and relationship between different enterprises. And, second, if adopting the new electronics-based automation technologies, these can either be introduced in an incremental process of automating discrete sub-processes (intra-activity automation) or they can involve the innovation of more widespread, synergestic technologies (intra-sphere or inter-sphere automation). Unless the latter path is pursued, then, it is unlikely that the Third World will be able to arrest the likely trend towards comparative advantage reversal (see Kaplinsky, 1984a, Chapter 9).

Stated in such stark terms, the choice seems easy. Yet it is profoundly more complex, since not only are there detailed difficulties in introducing the new technology (for example the availability of particular skills), but there are important issues of social concern. Two such issues stand out in importance, and not just for the Third World. First, there can be little doubt that the new technology is labor displacing; how will the Third World, already characterized with high levels of structural unemployment, be able to work through this problem? Does it necessitate the divorce between income and work (which has gradually evolved in the welfare states of many industrially advanced economies), and can this be undertaken without fundamental changes in social relations? And, second, if the Japanese-type method of organizing production is to become the norm, this may involve substantial changes in the existing forms of labor process. Not only may this be difficult to implement, but it also raises normative questions concerning the very nature of development. As Bluestone and Harrison (1982) conclude:

> The Japanese system is therefore a two-edged sword. It offers economic prosperity and material progress. But it exacts a price in terms of regimentation, autocracy and institutionalized inequality. Such a form of social organization is surely not what we want.[31]

NOTES

1. Including some of my earlier work. See for example Kaplinsky (1981).

2. Thomas (1969), p. 6.

3. Einzig (1957), p. 2.

4. Note that Marglin is actually writing about the origin of the hierarchical labor process which characterizes the capitalist mode of production, and not the separation of the enterprise into three spheres of production. However, the emergence of the coordination sphere is directly related to the development of hierarchical control over production as is readily evident from any of the major studies of industrial management. See Chandler (1962); Chandler (1977); Taylor (1911).

5. Some observers, for example Perez in this volume, doubt that assembly robots will ever become viable in general manufacturing.

6. We specifically distinguish these types of intra-sphere automation from the earlier, pre-electronic technologies incorporated in moving production lines.

7. Another example, from the garment industry, is that of Gerber Scientific. See Hoffman and Rush (1984).

8. This includes Calma (a leading supplier of CAD equipment), GEISCO (the worlds largest software house), Intersil (manufacturing integrated circuits), SDRC (an engineering services company that assists user firms in introducing automation technologies) and a variety of licenses from Japanese and German firms to manufacture industrial robots.

9. One of the more significant consequences of this trend is the emergence of formerly specialized computer-hardware firms as comprehensive suppliers of automation technology. IBM, for example, is now the world's largest supplier of CAD equipment and is rapidly moving into the production of industrial robots. Building around its COPICS (communication-oriented-production-information-and-control-system) strategy, they aim to organize production around a unified data base.

10. Notably the underdevelopment of software products and the immaturity of local area network (LANS) technologies which enable the interlinking of different items of electronics-based equipment.

11. One of the more interesting implications of this restructuring is the relative undermining of the position of middle management. See *Business Week* (25 April 1983), and Perez in this volume.

12. Chandler (1977), p. 1.

13. The exceptions to this, Chandler goes on, were the textile industry using water-power and the armaments industry, which had guaranteed markets.

14. Chandler (1962).

15. Frobel *et al.* (1980), p. 35.

16. Frobel *et al.* (1980), pp. 302–303.

17. But rather in the production of cigarettes, matches, soap and canning — see Chandler (1977).

18. For example in the early 1970s General Motors decided to establish three engine-plants around the world (in Australia, Austria and Brazil) to serve all of its subsidiaries needs for a new, small engine.

19. These issues are treated in relation to the discussion on long-wave theories in a most interesting manner in Perez (1983).

20. Of course component suppliers also operate JIT procedures, otherwise there would be no point in a system which merely pushed inventories downstream.

21. All this is not to suggest that these Japanese production lines involve the 'humanization of work'. Schonberger, who by no stretch of the imagination can be characterized as a representative of labor's interests, remarks 'I have been astounded by statements I have heard from some Automation "authorities" to the effect that the Japanese reject Taylorism, supposedly in favour of a more humanistic approach . . . but the Japanese out-Taylor us all' (1982, p. 193).

22. Susman and Schultz (1983), p. 174.

23. However as Schonberger points out, the adoption of electronics-based automation technologies is in itself not an adequate way of ensuring JIT manufacture. Computer-intensive Materials Requirement Planning (MRP) techniques generally have far longer inventories than card-based ('Kanban') JIT procedures, a consequence of the organization of production in Western plants using MRP, rather than inherent in the system itself.

24. Sometimes these operate on an arms'-length basis as in the case of component suppliers and assemblers; but in other cases they are linked within large, transnational enterprises.

25. Numerical control of machinery, for example, was an expensive development required to machine complex shapes for aircraft wings; CAD evolved in the aerospace industry primarily to optimize designs rather than to save design costs.

26. This problem is not, of course, unique to LDCs, and is one of the major areas of public policy debate in industrially advanced economies.

27. In this discussion we do not refer to the development of local-area-networks (LANs), allowing intercommunication between digital techniques within a particular enterprise, but rather to the links between enterprises.

28. Yet the emergence of 'self-diagnosing' systems (which identify the malfunctioning component, allowing for simple replacement) and 'self-healing' systems (with redundant, additional components which automatically come into operation when something fails) reduces somewhat this need for artisanal skills.

29. These issues are treated further in Kaplinsky (1984d). See also Jacobsson (1982).

30. Which can be handled in either a centralized or a distributed form.

31. Bluestone and Harrison (1982), p. 220.

REFERENCES

Bell, R. M., *Changing Technology and Manpower Requirements in the Engineering Industry*, (London: Sussex University Press, 1972).

Bluestone, B. and B. Harrison, *The Deindustrialization of America: Plant Closings, Community Abandonment and the Dismantling of Basic Industry* (New York: Basic Books, 1982).

Business Week, 'How computers remake the manager's job' (20 April 1983).

Bright, J. R., *Automation and Management* (Boston: Harvard University Press, 1958).

Chandler, A. D., *Strategy and Structure: Chapters in the History of the American Industrial Enterprise* (Cambridge, Mass.: MIT Press, 1962).

Chandler, A. D., *The Visible Hand: The Managerial Revolution in American Business* (Cambridge, Mass.: Harvard University Press, 1977).

Coombs, R. W., 'Automation and long wave theories,' Ph.D. thesis, (University of Manchester, UK, 1982).

Dore, R., 'The social sources of the will to innovate,' (London: Technical Change Centre, 1983) (mimeo).

Einzig, P., *The Economic Consequences of Automation*, (London: Secker and Warburg, 1957).

Forester, T. (ed.), *The Microelectronics Revolution* (Oxford: Basic Blackwell, 1980).

Frobel, F., J. Heinrichs and O. Kreye, *The New International Division of Labour* (Cambridge: Cambridge University Press, 1980).

Havrylshyn, O. and L. Alikhani, 'Is there cause for export optimism? An enquiry into the existence of a second generation of successful exporters,' *Weltwirschaftliches Archive*, Vol. 118, No. 4, (1980), pp. 651–663.

Hoffman, K. and H. Rush, *Microelectronics and Clothing: The Impact of Technical Change on a Global Industry* (Geneva: ILO, 1984).

Iron Age, 'U.S. automakers want to curb costs and defects' (21 October 1983), pp. 90-93.

Jacobsson, S., 'Electronics and the technology gap — the case of numerically controlled machine tools,' in R. Kaplinsky (1982a), pp. 42–46.

Japan Foreign Press Centre, *Fiscal 1981 Survey on Labour Force by Occupation (Summary): Effect of*

Office Automation on Employment at Headquarters of Large Enterprises, R-82-10 (Tokyo: 1982).

Jones, D. and M. Anderson, 'Competition in the world auto industry: implications for production location,' (Science Policy Research Unit, University of Sussex, Brighton, UK, 1983) (mimeo).

Kaplinsky, R. 1981, 'Radical technical change and export-oriented industrialization: the impact of microelectronics,' *Vierteljahresberichte* No. 83, (1981) pp. 81–100.

Kaplinsky, R. 1982a, 'Comparative advantage in an automating world,' *Bulletin of the Institute of Development Studies*, Vol. 13, No. 2 (1984) (Institute of Development Studies, University of Sussex, Brighton, UK).

Kaplinsky, R., 1982b, *Computer Aided Design: Electronics, Comparative Advantage and Development*, (London: Frances Pinter, 1982).

Kaplinsky, R., 1984a, *Automation: The Technology and Society* (London: Longmans, 1984).

Kaplinsky, R., 1984b, 'The international context for industrialization in the coming decade,' *Journal of Development Studies* Vol. 21, No. 1 (1984) pp. 75–96.

Kaplinsky, R. 1984c, 'The New International Division of Labour in manufacturing', (Brighton UK: Institute of Development Studies, 1984) (mimeo).

Kaplinsky, R. 1984d, 'Comparative advantage by design,' paper presented at International Seminar, Design and Innovation Policy, London, Royal College of Art (1984).

Lambert, R., 'Geared for a rail revival: General Electric in the US goes for major investment,' *Financial Times* (14 April 1983).

Marx, K., *Capital*, Vol. I (Introduced by E. Mandel) (London: Penguin, 1976).

Peet, J. R., 'International capital, international culture,' in M. Taylor and N. Thrift (Eds.), *The Geography of Multinationals* (London: Croom Helm, 1982).

Perez, C. 'Structural change and assimilation of new technologies in the economic and social systems,' *Futures*, Vol. 15, No. 5 (October 1983).

Schonberger, R. J., *Japanese Manufacturing Techniques: Nine Hidden Lessons in Simplicity*, (London: Macmillan, 1982).

Smith, A., *The Wealth of Nations*, (London: Everyman's Library, 1950).

Soete, L. and G. Dosi, *Technology and Employment Opportunities in the UK Electrical and Electronic Industries*, (London: Frances Pinter, 1983).

Susman, P. and E. Schultz, 'Monopoly and competitive firm relations and regional development in global capitalism,' *Economic Geography*, Vol. 59, No. 2, (April 1983), pp. 161–176.

Taylor, F. W., *The Principles of Scientific Management* (New York: 1911), reprinted in F. W. Taylor, *Scientific Management*, (New York: Harper and Bros., 1947).

Thomas, H. A., *Automation for Management*, (London: Gower Press, 1969).

UNCTAD, *The Impact of Electronics Technology on the Capital Goods and Industrial Machinery Sector: Implications for Developing Countries*, TDF/B/C.6/Ac.7/3. (Geneva: United Nations, 1982).

Vernon, R., 'International investment and international trade in the product cycle,' *Quarterly Journal of Economics*, Vol. 80, No. 2 (May 1966), pp. 190–207.

Wiener, N. *Cybernetics, or Control and Communications in the Animal and the Machine*, (New York: John Wiley, 1948).