Microelectronics, Long Waves and World Structural Change: New Perspectives for Developing Countries

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World Development, Vol. 13, No. 3, pp. 441-463

Summary

This article assesses the way in which emerging new technologies could enhance development prospects. To do this, it first presents a long-term view of the relationship between the techno-economic sphere and the socio-institutional framework, defining the present period as one of transition and structural change. It then outlines the main characteristics of the technological revolution based on microelectronics. It finally argues that these characteristics will offer a completely new range of opportunities for reshaping development strategies.

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1. INTRODUCTION

At present, the prospects for developing countries seem bleaker than ever. As general stagnation continues, with short-lived spurts of growth in the industrialized world, export opportunities for the Third World are significantly reduced. This, combined with the rising cost of imports and a reduction la investment flows, is putting unbearable pressures on weak debt-ridden economies. At the same time, the electronics revolution seems to have widened the technological gap to unbreachable proportions.

This article will present an alternative view. It will argue that the world is experiencing a structural crisis, during which, in spite of the obvious difficulties, there would be greater — rather than lesser — scope for a major positive change in development prospects.

The argument is based on a somewhat Schumpeterian[1] interpretation of the so-called Kondratiev long waves.[2] The explanation proposed here for the recurrence of cycles of about 50 years' duration in economic growth, attributes a central role to the diffusion of successive technological revolutions, representing a quantum jump in potential productivity for all or most of the economy. The reason for the long wave pattern would be that, to yield its full growth potential, each of these "techno-economic paradigms" — as we shall call them — requires a fundamental restructuring of the socio-institutional framework, on the national and international levels. The resulting social and institutional transformations then determine the general shape of economic development, or the "mode of growth" of the next long wave. A Kondratiev wave is thus defined here as the rise and fall of a mode of growth and each crisis as the painful transition from one mode of growth to the next.

The present period is seen as one such transition. The mode of growth that led to the boom of the 1950s and 1960s has run its course. The world must now make the transition from a set of social and institutional arrangements, shaped by the characteristics — and fostering the full deployment — of a constellation of mass production technologies based on low-cost oil, to another capable of fruitful and appropriate interaction with a new system of flexible technologies, based on low-cost electronics.

This means that extrapolations from the past or from the turbulent present are misleading. If and when a new upswing is unleashed in the world economy, it is likely to be framed by a set of national and international institutions, which will differ as much from those of the l950s and 1960s as these differed from the prevailing conditions in the "Belle Epoque" at the turn of the century. It also means that the present is precisely the period of creation of those future conditions and that all social actors, including the developing countries, can and should take an active part in that complex — and obviously conflict ridden — trial-and-error process.

1 See Schumpeter (1939).

2 Kondratiev (1935).

To undertake this task successfully however, it is essential to identify the new range of the possible. The deeper the understanding of the potentialities and limitations of the new "techno-economic paradigm", the greater the scope for shaping it imaginatively and effectively through innovative action in the social and institutional spheres.

Section 2 of this paper will introduce the concept of "techno-economic paradigms" and present an outline of the long wave argument[3]. This theoretical framework is a necessary prerequisite for understanding the relevance of the discussions that follow. Section 3 undertakes the analysis of the defining features of the presently diffusing microelectronics paradigm, touching upon some of the questions it raises for development strategies. Section 4 is a brief exploration into the challenges and opportunities facing the developing countries in the present transition.

As a whole, the article is intended as food for thought. The reader will find no statistics; references will be sparse, though hundreds could be given; examples will be provided only when they seem indispensable to illustrate an idea rather than to prove it. This is fully intentional. The paper is conceived mainly as a contribution for opening new paths in development thinking. As the argument evolves, it will become increasingly clear that we are making a case for defining the present period as a time for informed speculation and bold experimentation.

2. TECHNOLOGY AND LONG WAVES

Conventional wisdom tends to see technology as a matter for scientists and engineers, and its evolution as a series of individual inventions resulting in continuous cumulative advance; furthermore, most people find it easier to think of technologies in the plural, in view of their tremendous variety. Yet, since technology is the "how" and the "what" of production, it is in fact very much a social and economic matter. The process of technological advance in terms of knowledge and inventions is a relatively autonomous process, but innovation — i.e. application and diffusion of specific techniques in the productive sphere — is very much determined by social conditions and economic profit decisions. Thus technical change can be accelerated or held hack by social and economic factors[4].

Even the autonomy of the research process is only relative, and economic criteria are implicitly present in the minds of scientists and engineers. The object has always been to turn base metals into gold and not the reverse. So, although a great proportion of basic science is endogenously guided, applications and development efforts, while still keeping a certain amount of autonomy, are much more directly engaged in the interplay of "supply push" and "demand pull" with the users of innovations in the economic sphere[5].

The readiness to absorb or demand new technology varies greatly under different economic conditions, even in the same firm; and the sorts of technical solutions sought in

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3 See also Perez (1983).

4 For an analysis of the various ways in which technological change occurs in interaction with economic and social factors, see Rosenberg, (1982).

5 Dosi (1982).

the economic sphere can change in nature depending on a variety of internal and external factors affecting productivity, profitability and markets. In recent decades, much social science research has focused on the nature of this techno-economic interaction. On a general level, innovations have been classified by their impact on productivity, as to whether they are mainly labor saving or capital saving[6]; by their relative importance, distinguishing radical from incremental innovations[7] and by their object, either process or product.[8] Other efforts have focused on the pattern of evolution of each particular innovation leading to the notion of technological trajectories.[9] This concept is used to describe the path from birth to maturity of any particular technology, from the generally awkward first introduction, followed by the identification of one bottleneck after another bringing forth complementary innovations, through successive incremental improvements, leading to the final optimization and relative standardization of the process or product, after which further efforts bring diminishing returns.[10]

Plotted against time, the level of productivity achieved by a particular technological process, as it is subjected to successive improvements through additional investment, would then present the "S" shape of many biological growth processes.

This growing body of literature has made it increasingly clear that technical change does not occur at an even rhythm, but neither is it merely a random process. Further still, the analysis of the patterns of propagation of new technologies across the economy tends to confirm Schumpeter's view about the bunching of innovations and their diffusion in bandwagon fashion. It has been found, for example, that during certain periods, process innovations tend to outstrip product innovations in most industries.[11] This suggests that innovations in equipment goods occur in clusters.

Here we are interested in the relationship between these waves of technical change and long cycles in economic growth. In this context, Christopher Freeman[12] has introduced the notion of "new technological systems," to describe clusters of interrelated product and process, technical and organizational innovations, affecting many branches of the economy. Taking the accent away from the first introduction of single innovations and focusing on their rate of diffusion as interconnected systems of technical change, Freeman points to patterns of structural change in the economy-which, through their widespread social consequences, could underlie the Kondratiev long waves.

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[6] See Heertje (1977), pp. 161-167.

[7] For a discussion of the concept of "radical" innovations (as well as a different interpretation of long wave phenomena), see Mensch (1979). For a discussion of "incremental" innovations as well as a good empirical example, see Hollander (1965). For a summary of the distinctions between incremental, radical and revolutionary innovations, see Freeman (1984).

[8] See J. J. Van Duijn (1981) and (1983).

[9] For a discussion of the concept of "natural trajectories" in technical innovation, see Nelson and Winter (1977). For "technological trajectories", see Dosi (1982).

[10] The process of identifying and overcoming bottlenecks as a focusing device in steering technological advance both within a technology and across interrelated families is discussed by Rosenberg (1976) esp. Part 2. The notion of diminishing returns to technical improvement is known as Wolff's Law. The original source is: *Die Vo1kswirtschaft der Gegenwart und Zukunft* (Leipzig: 1912).

[11] J. J. Van Duijn (1981. 1983): Abernathy and Utterback (1978).

[12] C. Freeman (1982); and Freeman et al. (1982), Chapter 4.

Here we would like to fuse the concepts of technological trajectories and technological systems and take them one step further. We suggest that these notions are applicable to the analysis of the whole body of technology during relatively long periods. We propose that it is possible to identify each successive Kondratiev wave with the deployment of a specific, all-pervasive, technological revolution. In other words, that behind the apparently infinite variety of technologies of each long-wave upswing, there is a distinct set of accepted "common-sense" principles, which define a broad technological trajectory towards a general "best practice" frontier. These principles are applied in the generation of innovations and in the organization of production in one firm after another, in one branch after another, within and across countries. As this process of propagation evolves, there is a prolonged period of economic growth, based on relatively high profits and increasing productivity. But, gradually, as the range of applications is more or less fully covered and when, through successive incremental improvements, the best practice frontier is actually approached, the forces underlying that wave of prosperity dwindle. As this occurs, limits to growth are encountered by more and more sectors of the economy, profits decrease, and productivity growth slows down.

Yet, well before the downswing is visible as a general phenomenon, diminishing returns are experienced by some of the most dynamic firms and sectors. Among them, there ensues a complex trial-and-error process spurred by the profit motive. It results in waves of mergers and acquisitions, various forms of speculation, efforts to "stretch" the technologies by containing labor costs or relocating. But it also involves a persistent search in the pool of the technologically feasible for what would potentially be economic ally profitable. This intensified feedback interaction between the technological and economic spheres, eventually leads — through discovery and rediscovery — to the gradual emergence and subsequent rapid development of new technical elements. As these prove capable of overcoming the specific bottlenecks encountered within the mature technologies, imitation and further innovation along those lines, gradually converge in synergistic fashion to define a general model to follow. Each new model is based on a different set of "common-sense" principles, indicating a higher best practice frontier, destined once again to transform the whole techno-economic system.

The downswing of each long wave sets in as the process of abandonment of the exhausted model and the initial propagation of the new.

(a) A techno-economic paradigm as a set of common sense guidelines for technological and investment decisions

Technological decisions are taken in a specific socio-economic context and in turn influence that context. Economic theory would have us believe that managers take into account the relative prices not just of labor and capital, in general, but of each possible combination of different types of labor, of different types of equipment and of different sorts of inputs, for a range of possible products. But, how does this work in practice?

We suggest that the behavior of the relative cost structure of all inputs to production follows more or less predictable trends for relatively long periods. This predictability becomes the basis for the construction of an "ideal type" of productive organization, which defines the contours of the most efficient and "least cost" combinations for a given period. It thus serves as a general "rule-of thumb" guide for investment and technological decisions. That general guiding model is the "techno-economic paradigm." As it generalizes, it introduces a strong bias in both technical and organizational innovation. Eventually, the range of choice in technique is itself contained within a relatively narrow spectrum, as the supply of capital equipment increasingly embodies the new principles. Furthermore, for each type of product, expected productivity levels, optimal scales and relative prices become gradually established, together with the forms of competition in each market.

The process can be seen as analogous to the appearance of a new genetic pool, which contains the blueprint for a great variety of organisms (products and processes) and their forms of interrelation. It diffuses through hybridization, cross-breeding, evolution and new entrants. Its increasingly obvious advantages inevitably destine it to transform most and substitute many of the old "species" and create a new "eco-system."

The focusing device or main organizing principle of this selective mechanism would be a particular input or set of inputs, capable of strongly influencing the behavior of the relative cost structure. Such an input, which we shall call the "key factor", is capable of playing a steering role because it fulfills the following conditions:

(1) clearly perceived low — and descending — relative cost,

(2) apparently unlimited supply (for ah practical purposes).

(3) obvious potential for all-pervasive influence in the productive sphere, and

(4) a generally recognized capacity, based on a set of interwoven technical and organizational innovations, to reduce the costs and change the quality of capital equipment, labor and products.

This conjunction of characteristics holds today for microelectronics. For this reason, it is increasingly steering both engineering and managerial common sense towards its intensive use and gradually shaping the new "best practice" frontier for old and new industries. It held until recently for oil, together with petrochemicals and other energy-intensive materials, which underlay the now exhausted mass production paradigm of the post-war upswing. In the previous long wave, at the turn of the century, the role of "key factor" was played by low-cost steel, shaping the growth of the heavy mechanical, electrical and chemical engineering industries. The Victorian boom in the mid-l9th century (the "railway age") had low-cost coal and steam-powered transportation at its core. And, it could be argued that in the Industrial Revolution the role of "key factor" fell upon low cost machine-tending and cotton growing labor.

Of course, none of these inputs are really "new" in a technical sense. Each had a previous history of development within the previous paradigm and even further into the past. The truly new aspect in each case is the drastic reduction in relative cost, which is generally associated with a technical or organizational breakthrough.[13] And, these breakthroughs are more likely to occur — or to be fully noticed, exploited and widely applied — when the set of technologies based on the prevailing key factor has exhausted its potential for further increasing productivity.

But, a full-fledged techno-economic paradigm grows in complexity and coherence, going far beyond technical change and affecting almost every aspect of the productive system. The full constellation — once crystallized — involves:

(1) New concepts of efficiency for the organization of production at the plant level.

(2) A new model for the management and organization of the firm.

(3) A distinctly lower labor input per unit of output, with a different skill profile of employment.[14]

(4) A strong bias in technological innovation, favoring key factor use.

(5) A new pattern of investment, favoring key factor related sectors, propelling and propelled by investment in a new infrastructural network.

(6) A consequent bias in the composition of production, with faster rates of growth in key factor related products.

(7) A redefinition of optimal scales leading to a redistribution of production between large and small firms.

(8) A new pattern in the geographic location of investment, based on the shift in comparative advantages (and disadvantages!).

(9) A restructuring of interbranch relationships, where those branches that produce or intensively use the key factor, become the new engines of growth and generate a new range of "induced" activities, which generally proliferate in bandwagon fashion, once the upswing begins.

To give a rough illustration of these various elements, let us look at the now exhausted techno-economic paradigm. It came together in the 1920s and 1930s and underlay the present mode of growth established after World War II. It was based on low-cost oil and energy-intensive materials, especially petrochemicals. The model for efficient productive organization at the plant level was the continuous flow process or assembly-line for the

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[13] Steel existed subservient to iron, until the Bessemer and Siemens Martin processes slashed its cost to a tenth. Oil had been used for limited purposes until the internal combustion engine made it central for all sorts of transportation. And this use, together with oil fueled generation of electricity, became cheap when low cost free-flowing oil, especially from the Middle East came on stream. Electronics began with tubes, then transistors and, for a long time developed within — and submitted to the "logic" of — the mass production, energy intensive paradigm. It only became an all pervasive key factor when its original control functions fused in synergetic fashion with data processing. Subsequently, "large scale integration" resulted in increasingly powerful, ever-cheaper microprocessors and other electronic "chips." Into the future, one could perhaps speculate that biotechnology might follow an analogous path as it grows and expands as an increasingly important industry, within the microelectronics-led paradigm. It may well make successive fundamental and incremental advances and gradually expand its sphere of influence beyond pharmaceutical and food production. It is already affecting such apparently unrelated areas as mining and pollution control and experiments are under way for the production of microelectronic "bio-chips." Yet much ground might have to be covered before radical cost-cutting breakthroughs with all-pervasive influence are made.

[14] This translates into new trends in the pattern of income distribution and in the evolution of consumer demand. For a brief discussion of these interactions, see Pérez (1983). pp. 366-368.

mass production of identical products. The ideal type of firm was the "corporation," run by a separate, professional, managerial and administrative hierarchy; it included in-house R&D and operated in oligopolistic markets. Growth was led by giant oil, chemicals, automobile and other mass producers of durable goods for the defense or consumer markets. The growth and interplay of these core branches, induced the proliferation of the service sector (from gasoline stations and supermarkets to the advertising industry and the diversified financial sector), as well as the growth of the construction industry. It demanded increasing amounts of middle range specialization in both blue- and white-collar skills. It benefited from economies of agglomeration and required an ever-expanding highway network, together with oil and electricity distribution systems for energy intensive production, transportation and life styles.

Today, with cheap microelectronics widely available (together with the consequent low-cost of information handling), a new techno-economic paradigm is coming together and diffusing. It is no longer "common sense" to continue along the now expensive! path of energy and materials intensity. The "ideal" productive organization, which has been evolving since the early seventies, brings together management, production and marketing into one single integrated system (a process we might call "systemation"), for turning out a flexible output of preferably information-intensive, rapidly changing, products and services. Growth would presumably be led by the electronics and information sectors, propelling and propelled by an all-encompassing telecommunications infrastructure, which would bring down to negligible levels the cost of access for producers and consumers alike. The skill profile tends to change from mainly middle range to increasingly high and low range qualifications and from narrow specialization to broader and multipurpose basic skills for information handling. Diversity and flexibility at all levels substitute uniformity and repetitiveness as "common-sense" best practice.

But why the crisis? Why can the productive system not make a smooth transition from one paradigm to the other?

(b) Long wave recessions as the manifestation of a "mismatch" between the socio-institutional framework and the techno-economic sphere

The transition to a new techno-economic regime cannot proceed smoothly, not only because it implies massive transformation and much destruction of existing plant, but mainly because the prevailing pattern of social behavior and the existing institutional structure were shaped around the requirements and possibilities created by the previous paradigm. That is why, as the potential of the old paradigm is exhausted, previously successful regulating or stimulating policies do not work. In turn, the relative inertia of the socio-institutional framework becomes an insurmountable obstacle for the full deployment of the new paradigm. Worse still, the very diffusion of the new technologies, as far as conditions allow, is itself an aggravating factor because the new investment pattern disrupts the social fabric and creates unexpected cross currents and counter-trends in all markets. Under these conditions, long wave recessions and depressions can be seen as the syndrome of a serious "mismatch" between the socio institutional framework and the new dynamics in the techno-economic sphere. The crisis is the emergency signal calling for a redefinition of the general mode of growth.

At the micro level, when numerical control or computer technology is introduced in a firm previously working with electromechanical technology, it is not possible to reap all the potential productivity increase without transforming the whole organization both at the plant and the office levels, including extensive retraining and redefinition of the forms of interaction. In a similar manner, when the full constellation of a new techno-economic paradigm tends to take over the bulk of production within a society, it will not yield its full growth potential until the socio-institutional framework is transformed to adapt to its requirements.

This would indicate that our "ecosystem" analogy has a fundamental limitation. While in nature, it is the external environment that forces the adaptation of the living species; in economic development, it would be the environment that is reshaped to suit the potential of the new genetic pool. Yet it must be emphasized that, in spite of appearances, we are not making an argument for mere technological determinism. The variety of suitable environments is quite large, and whatever specific form is arrived at, from the wide range of viable options, will in turn determine the preferred ways in which the latent techno-economic potential develops through strong "feedback" selective action and gradual mutual adjustment.

So, when the downswing of a long wave occurs, the new techno-economic paradigm to which institutions must respond is already diffusing. Ironically, it is precisely when the seeds of change are being sown around peak prosperity that institutions become more attached to practices that seem to have achieved the result of unrelenting growth. This is why it is particularly difficult to bring about the required profound transformations. Much more so in view of the fact that this inertia is also upheld by powerful vested interests.

Historically, when the required structural transformations have finally been brought about, creating the framework for a new mode of growth and unleashing the upswing, they have generally affected the following, among many other, aspects of society:

(1) The specific forms of operation and regulation of the various markets (product. labor, capital, money) on the national and international levels.

(2) The organization of the banking and credit systems.

(3) The relative proportions and character of public and private responsibility in generation, distribution and redistribution of in come, as well as the corresponding social arrangements.

(4) The forms of organization of workers and major interest groups, together with the legal framework within which they operate.

(5) The provision of education and training in its quality, volume and the type of institutions in charge of it.

(6) The conditions under which inventions are generated, protected and traded.

(7) The international division of production as well as the means for regulating inter-country trade and investment.

(8) The international relative power balance and the arrangements for maintaining it.

To unleash the previous upswing, a change as profound and unprecedented as massive state intervention in the economy, along Keynesian principles, was necessary to foster the full deployment of the oil-based mass production paradigm. A complex set of demand management mechanisms was established, from the most direct, such as central control of the money supply and of the level of government spending, to the more indirect such as the expanding system of consumer credit and the public provision of national statistics for marketing and production planning. Trade unions became institutionalized, the working week and working year were shortened and unemployment and retirement benefits were generalized. This was made possible by the income tax system, which also sustained the "public service" and "government spending" mechanisms for redistribution of income. On the international level, these national arrangements were complemented by the UN organization, the leading role of the United States, Bretton Woods, the IMF, the GATT, the provisional Marshall Plan and the increasingly accelerated demise of colonial empires. All these developments created an adequate framework for growth based on mass production, as well as the means for regulating and fostering the fluid expansion of international investment and trade.[15]

(c) The construction of a new model of growth as the outcome of an intensive process of social confrontation, creativity and compromise

Clearly, such widely ranging changes do not occur all at once. They emerge gradually, converging into a more or less coherent framework. Nor do they come about easily. They require an enormous amount of inventiveness and experimentation as well as compromise. And, since any particular set of arrangements favors some groups to the detriment of others, its establishment does not occur without social and international confrontation. So, the construction of a new mode of growth is paced by the level of understanding, the weight of inertia and the opposition of those who fear it for real or imagined reasons. The time it takes to create the new framework and the specific form of the ultimate outcome depend on the relative strength of the various social forces and on their capacity to develop and implement viable innovative responses. Nothing, of course, can guarantee success nor that collapse or devastating war can be avoided.

During the last structural crisis in the 1930s, the present Third World was not among the players. Most countries were under colonial rule; and those that were not were marginal participants in the world economy, with no international institutions in which to make their voice heard. This time, as a result of the previous mode of growth, there are real possibilities of influencing the course of events for the next upswing. Some of the reasons

[15] For a similar approach to the relationship between the socio-institutional structure and the underlying technology, based on the concept of "Regulation," as well as a very comprehensive analysis of what he terms "Fordist" modes of production and consumption, see Aglietta (1979).

for this relate to the world political scene, but others stem from the specific market expansion requirements of the new technologies.

However, the general direction of change required to accommodate a particular technological potential is more analogous to crossing an ocean than to following a railroad track. It is a wide space for innovation in social organization and national and international institutions. The proposed solutions can vary quite widely and very different political frameworks can achieve high rates of growth. That they can be as different as fascism and Keynesian democracy, was clearly seen in the last Kondratiev trough. Further still, as far as following a particular technological model for growth, the present socialist system can be seen as another of the alternatives that proved viable. We would suggest that, although with somewhat different manifestations, those countries have also encountered limits to growth and face the need to transform the socio-institutional framework. But this is not the place to discuss that issue.

The important idea to bear in mind is that what happens in the transition period has enormous hearing on the nature of the next upswing. Once an adequate mode of growth is established, it molds, regulates and determines the preferred ways in which the new technological potential is exploited. Because a quantum jump in productivity implies a quantum jump in wealth creating capacity, it contains, among the possible outcomes, widespread improvements in living standards.

Each transition, then, by implying a radical restructuring, reopens the question of the development perspectives of the various countries, as well as that of the better or worse distribution of the benefits of future growth, among social groups, regions and countries.

Thus, in spite of the crisis and because of the crisis, it is essential to open new spaces for development thinking in terms of the future. Yet, from what has been argued, social institutional and economic planning innovations are more likely to be viable if based on a deep understanding of both the demands and the potential, both the scope and the limitations of the new techno-economic paradigm. And this understanding is possible because, on the one hand, the paradigm has already diffused to a sufficient degree for recognition and, on the other, we now possess better analytical tools and more historical experience.

In this context, a basic task would be to detect the main features of the new pattern of techno-economic behavior based on the potential of the new technology, distinguishing what are merely survival tactics of those tied to the old paradigm from the more coherent initiatives pointing towards the future. It is upon these new trends that the appropriate institutional configuration must be constructed in this transition period.

In the following section, we attempt the analysis of the main features of the new paradigm which is gradually becoming more and more visible and more and more coherent, as organizational innovations within firms join the technical cluster growing around microelectronics.[16]

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[16] Although the impact on employment is probably the most important single issue in the process of paradigm change, it will not be discussed here. Due to its complexity, it will be analyzed in a separate article. The reader is invited to keep the issue in mind in the

3. THE CHARACTERISTICS OF THE TECHNO-ECONOMIC PARADIGM BASED ON MICROELECTRONICS

In considering the specific features of the techno-economic paradigm which is taking shape around microelectronics, we shall try to make as clear a contrast as possible with those which have characterized the mass-production. oil-based paradigm. For the sake of brevity, the analysis will be limited to some of the essential features, albeit with a substantial amount of oversimplification.

The first part will analyze how the trend towards "information intensity" would tend to modify input mix and investment patterns in terms of relative cost advantages. The second part will focus on the trend towards "flexibility" in plant, in product mix and in product change over time. The third and last part of this section, will explore the new trends in firm organization; on the one hand, the concept of "systemation," and on the other the potential for decentralization. In the course of the discussion, attention will be given to some of the issues raised for development strategies, always in a tentative spirit to stimulate thinking and experimentation.

(a) Information intensity vs. energy and materials intensity

The overriding feature of the new paradigm, and the one that is likely to have the most profound consequences, is the trend towards information intensity rather than energy and materials intensity in production. This stems directly from the very visible change in the general relative cost structure towards ever cheaper information handling potential through microelectronics and digital telecommunications.

It should be clear that this is a relative cost argument. It does not imply that energy or raw materials prices are expected to take an upward course in absolute terms, but that the decreasing cost and growing potential of microelectronics results in an increasing relative gap in the future.

In product engineering, there would be a tendency to redesign existing goods to make them smaller, less energy-consuming, with less moving parts, more electronics and more software. This has already been the case for a variety of products such as watches and clocks, calculators, cash registers, sewing machines and computers themselves, but the possibilities are far from being fully exploited. In addition, many needs that are today fulfilled with durable goods, due to the characteristics of the previous paradigm, might tend to be met with information intensive services instead.

In plant engineering, not only would energy saving techniques based on electronics be applied as a matter of good process design, but also materials saving techniques. The possibilities generated by both computer-aided design and computer-controlled manufacturing greatly increase precision and allow production to narrower tolerances. Furthermore, tighter inventory controls and on-line quality control would allow a reduction in waste and rejects. Both these trends, together with the reduction in size and parts already

course of the present discussion and to consult the growing bibliography on the subject. See, for example, Rada (1980); Lupton (1984); Freeman *el al.* (1984).

mentioned, would tend to reduce even further the amount of materials required per unit of product or, as Smith puts it, would greatly increase the "productivity of resources".[17]

New products and services: The most promising trend in sheer growth terms is the flourishing of innovations and entrepreneurial activity stemming directly from low cost electronics and data processing. This would be analogous to the flurry of consumer durables of the presently waning paradigm, which began to gather momentum in the 1920s with automobiles, radios and refrigerators, acquired full force through the 1950s, and peaked in the late 1960s with such products as electric can openers and electric carving knives. In that case, it was a question of identifying home activities that required the use of energy and designing a product to fulfill them and open a new market. In the present case, it would be a question of detecting home or, and especially, producer activities that require information handling or decision-making and designing an electronic product or a software package or setting up an information intensive service to open a new market. The important thing to note is that these new products or services are in fact relatively simple applications of already well-known principles so that there would be no doubt as to technical feasibility. Success would depend (as it did with consumer durables) on an adequate perception of market acceptance and the diminishing costs of inputs.

Old and new giants: This general advantage of information intensity is clearly revealed in the fact that, at present, in the midst of recession and strong inflationary pressures, the firms most closely related to the production or intensive use of microelectronics are showing generally high growth rates and their products are the only ones decreasing in price, even in absolute terms! As in previous paradigm shifts, this advantage, which translates into unusually high profit rates for some, selects the firms that, by growth or diversification, will become the largest and most dynamic of the next upswing. Consequently, some of the new firms in these sectors might join the ranks of the giants. But, also, some of the old giants in the mature industries are already showing — with more or less successful results — an increasing tendency, not just to transform their products and processes but also to diversify into the new and more dynamic, information-intensive areas of the new paradigm: micro electronic components, equipment for the "factory of the future" or the "office of the future;" data processing, financial, technological and other producer services: telecommunications, satellites, fiber optics and other aspects of data transmission; and obviously, the "starwars" military sector.[18]

Impact on raw material producers: The trends we have been discussing must be seen dynamically. The reduction in the energy and raw materials content of individual products, and the possibly faster growth of services, is a powerful force in reversing the Fourth Kondratiev trends that threatened to result in natural resource depletion. It does not, however, mean that producers of these basic inputs will face ever dwindling markets. The initial reductions are likely to be the most drastic; but once a higher productivity of resources becomes the norm, the sheer expansion of production, especially when — or

[17] Smith (1983).

[18] It should by now be clear that the general trend towards information intensity is not to be misconstrued as leading to a purely "service economy." Much to the contrary, most service applications of electronics are rendered by using manufactured equipment and the main market for many of the new services is the manufacturing industry.

rather, if — the upswing gets underway, would allow a resumption of raw materials market growth, with probably lower, but certainly not negative, elasticity in relation to output.[19]

Thus, the new technologies based on low cost electronics could lead to a new pattern in inter-branch relationships and in the evolution of the general product mix. Not only would most production technologies undergo important changes, but also the goods they produce would become information intensive. The same would occur in most existing service industries, while there would be increasing growth in services of a totally new character. Under these circumstances, national and world gross product and trade can be expected to contain an increasing proportion of information and service related value added.

(i) *New issues for developing countries*

Although this is only one of the features of the new paradigm, it can already serve as a guide for rethinking certain aspects of development strategies. In so far as trends in the developed world affect the various developing countries, significant changes can be expected in foreign investment patterns and in the composition of world trade. The first because there is a fundamental reshuffling of comparative advantages at the same time as there is an internal restructuring of transnational corporations. The second, because the faster rate of growth of information intensive services in international trade would affect the evolution of export markets for raw materials and other Third World goods, as well as the composition of imports.

Already, the transmission and sale of processed information itself is reaching considerable proportions in international markets. In recent years, trade in patents and "know-how" and other technological information has been growing faster than commodity trade. The increasingly transnational character of banking and financial services has been further expanded by computer technology and digital transmission. Consultancy firms both in traditional engineering and in the new "systems" engineering areas are coming to the fore. Software services, standard, semi-custom and custom, are set for rapid growth.[20] And telecommunications itself, which is the main means of "transportation" of most of the above services and many more, could grow at a much faster rate than the established means of physical transport.

These trends certainly require innovative responses. It is now essential to examine closely the service side of the balance of payments but, more than that, the concepts of "industrialization" and "import substitution" as well as "export promotion" have to be redefined. All are now profoundly transformed to include the elusive "software and information" areas which, in the form of technological policy, would have to be institutionally addressed and placed at the core, not at the side, of development thinking.

Depending upon how far advanced the country is along the previous path of industrialization, strategic decisions are in order regarding the telecommunications

[19] Nevertheless, attention should also be paid to the wave of change in materials themselves. The diffusion of recycling techniques, fiber optics, ceramics and similar developments could substantially change the prospects for specific materials and influence energy consumption indirectly.

[20] See *Business Week* (February 1984a), pp. 54-71

network, the electronics industry, the service sector, in its new much wider sense, and in particular the means to develop and protect local technical and consultancy capabilities. The latter will be crucial, not only to make a direct contribution, but also to help avoid a flood of misdirected technological services leading to a dram on economic resources.

The greatest challenge, however, lies in identifying the new opportunities. A more long term view could bring forth new types of advantages. For raw materials producers, for instance, the fact that in the long run there would be a clear advantage in transportation costs for "tele-transmitted" services or for small-sized goods with high information value added, might head to a rather unexpected development: it could generate a comparative advantage for local production of energy or materials intensive goods in resource-rich countries. That many OPEC countries have been investing heavily in such energy-intensive industries as aluminium, steel and petrochemicals could be interpreted as early manifestations of such a trend. The question is whether, in the case of certain products, further vertical integration will prove to be the most cost-effective arrangement to avoid the increasing share of multiple transportation costs in the final price.[21]

(b) Flexible vs mass production

After information intensity, "flexibility" is probably the most important key-word within the new paradigm. It challenges the old best practice concept of mass production in three central aspects. High-volume output of identical products is no longer the main route to high productivity, which can now be achieved for a diversified set of low-volume products. The "minimum change" strategy in product development might no longer be necessary for cost effectiveness, as rapid technical change becomes much less costly and less risky. Market growth on the basis of "homogenous" demand is no longer essential, as the new technologies permit high profitability in catering to segmented markets and provide ample space for adapting production systems and output to specific local conditions and needs. Let us briefly discuss each of these features.

(i) *Economies of scope or of specialization based on flexibility vs. economies of scale based on homogeneity*

As regards the new potential for diversity in production, the new paradigm affects the accepted concepts of optimal scale of plant and market. When production, as well as productivity, depended on the repetitive movements of motors and workers and every change of model or tooling was down-time, optimal production costs were closely related to achieving high volume production of identical units. With electronic controls and the relatively low cost of programming rapid changes in production schedules, such limitations disappear to a great extent.

It is, of course, still possible to apply the new technologies for mass production of certain components or products at a scale that could be a multiple of the previously established optimal size. However, the most significant change, rich in eventual

[21] In the past, somewhat analogous conditions, created a "natural" protective barrier for the growth of local construction materials and civil engineering industries.

combinations, is a quantum jump in potential productivity for small- and medium-batch production. It could be said that, with the new technologies, plant scale becomes relatively independent of market size. Thus, the question of "barriers to entry" is redefined for most industries.

Flexible manufacturing technologies allow plant size to relate to a changing mix of a range of products submitted to similar transformation processes. On the one hand, one very large plant can produce for several relatively small markets, applying what is now being referred to as "economies of scope"[22]. On the other hand, since individual pieces of equipment can be provided with "intelligence," they can display similar flexibility in performance. This opens a range of new opportunities for relatively small plants serving one or a set of small local markets or specific market "niches." These can achieve high productivity levels with "economies of specialization," not necessarily dependent on large scale.[23]

This potential for flexibility and adaptability has varying impact across industries and across activities within each industry. In general, the quantum jump in productivity allowed by microelectronics seems to be greatest precisely in those industries or activities that were least amenable to mass production techniques under the previous paradigm. Therefore, the activities most easily transformed are the most decision intensive, such as office work, product design, stock control, quality control and others that were peripheral to the production process proper and, in the past, often constituted cost and time bottlenecks.

Equally, it is in the industries previously characterized by high rates of product change, high craft intensity and small or medium production runs, that the impact is greatest. This has already been the case in printing, which might in the future go through a further revolution, beyond ink and paper, using an array of new computer-related means of recording and disseminating information.[24] Mechanical engineering (and therefore a substantial portion of the capital goods industry), while continuing to be multi-process, multi-product, is being transformed by computer-aided design and manufacturing (CAD-CAM), flexible manufacturing systems (FMS) and computer-integrated manufacturing (CIM) into a continuous flow industry[25]. To a certain degree, the potential exists for a similar transformation in such areas as clothing and furniture.[26] These are sectors in which there has traditionally been a great number of small firms. This might change in the future as large firms introduce computerized flexible systems and tend to cover greater portions of a diversified market. The smaller firms could be successful on the basis of locational advantages or in skillfully selected market niches.

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22 Bylinsky (1983), pp. 50-51.

23 In a sense, one could suggest that for certain types of products or services the flexibility of electronic equipment could eventually change the idea that "custom made" is equivalent to "luxury." The possibility of refined market segmentation in many areas together with an increase in the "on-line" linkages between markets and suppliers could gradually allow the "craft" potential of the new technologies to flourish. And this can occur both under factory type conditions and as a home craft. For an example discussing both types of conditions in the case of weaving, see: "Micro electronics in textile production: A family firm and cottage industry with AVL looms," in Bhalla et al. (1984).

24 Hills (1984).

25 Kaplinsky (1984); S. Jacobsson (1982); Bessant (1984). See also other articles in this issue.

26 Hoffman and Rush (1984); and Guy (1984).

By contrast, assembly, a high-productivity area in mass production techniques, might become the bottleneck of flexible production facilities. Robots are clearly advantageous for ultra-high precision tasks such as electronic chip production; for the assembly of certain electronics products where quality is central and for hazardous or unpleasant activities such as spraying or welding. Their economics are very doubtful and controversial as regards medium or small batch assembly, involving frequent changes in product range or in product design. The fact is that, whereas it is very easy for a computer to control the cutting of the most complex of shapes in a very small fraction of the time taken by a highly skilled operator, it is much more difficult for it and it requires much more sophisticated equipment and software to perform the apparently simple task of correctly picking up a part and inserting it in the right place. For this reason, in achieving economies of scope, the new low-cost flexibility available for design and the other transformation processes could stumble against the high cost of hatch assembly robotics.

Solutions are being sought in radical redesign of parts and products to make them more amenable to robot manipulation (in some cases even to the point of bypassing assembly altogether). Another route, which has already been put in practice, is subcontracting the assembly tasks with specialized local firms. Both trends will probably develop, depending on specific conditions. Overcoming the bottleneck, though, depends on whether the cost of robots and sensors as well as of their operation, can be substantially reduced. This might hinge on how quickly radical breakthroughs are made in "artificial intelligence," for low cost programming and reprogramming, as well as on the experience gained in the diffusion of robotics in certain manipulation tasks where they are bound to generalize, such as those involving high hazards, high skills, high precision or activities that could simply not be done by humans, such as deep sea mining or work in outer space.[27]

In the process industries, such as chemicals, paper, electricity, metallurgy, food processing, etc., the main impact might be in plant design. For continuous flow processes, which had applied electronic controls very early on, there might be a certain degree of reversal of the trend towards fixed output giant plants as a means for minimizing unit costs. The new potential for cost reduction by means of precise control of quantity and quality of inputs, throughputs and outputs as well as of process parameters might lead to smaller and/or more flexible design of plant, with greater adaptability to market and input variations, perhaps including closed-loop, no-waste systems.[28]

On the other hand, some batch processes, common in the pharmaceutical and food industries, might be transformed into continuous flow, while achieving economies of scope. Such new elements as flexible automatic feeding, electronic process controls, self-cleaning systems and automatic measuring and packaging, are being incorporated in "piecemeal" fashion, but they could tend to come together as a total system and become the norm for many groups of products.

In service area, for information intensive activities, the flexibility potential, regarding both size and capacity to adapt product mix to changing market patterns, seems particularly

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[27] For further discussion on the issue of robotics, Ayres and Miller; and Jacobsson (1982).

[28] For an example about the limits to economies of scale in the electrical industry and the trend towards flexible sourcing in the Limited States, see *Business Week* (1984b), pp. 68-71.

great. In the case of software and information services, however, it will take a long time before the rules of the game are laid down both on the supply and on the demand side, since they are in the process of creating new markets, whose size is unknown and often depends on the rate of diffusion of other equipment or of infrastructure networks. Even the activity classes themselves await definitions in practice, before optimal product mix or scales are established. This trial-and-error process of boundary definition seems typical of the new industries in each paradigm shift: the "model" Ford plant in the 1930s was vertically integrated even to include glass-making.

As regards the more traditional service activities, though, the change towards "economies of scope" for the giants and "economies of specialization" for the smaller firms seems to be under way. An article in the *Financial Times*[29] described the "fundamental restructuring" of financial services, identifying "three basic roles for successful participants:" (1) broad-based competitors, which would be the merged and reorganized giants with state-of-the-art information systems and very broad market coverage, product innovation, brand franchises and image advertising; (2) low-cost producers which would be smaller firms with an emphasis on minimum cost in "simple product lines targeted at the price-sensitive, commodity segment of the market;" and (3) speciality firms, also small, but geared at specific, highly demanding, semi-custom market niches.

This example of reorganization is a particularly clear illustration of what could tend to be the pattern of distribution of markets by firm sizes in many industries as they restructure. The largest firms would tend to widen their market coverage across a wide range of technologically dynamic products. This would leave spaces for small or medium firms, both in the more routine mass production areas of the market and in the exploitation of skillfully segmented, specialized market niches.

Outside industry and information intensive services, all other productive activities, from mining and agriculture[30] to distribution and most areas of the service sector are being more or less radically transformed by information technology in the direction of computer-controlled, input adaptable, market-adaptable flexible systems.

Beyond traditional industry divisions a paradigm shift, as it sweeps across the productive sphere, not only transforms existing industries and creates new ones; it can also change established industry boundaries. The present shift may blur the distinction between manufacturing and services and, within each industry, it can modify the traditional patterns of horizontal or vertical integration. This aspect of the transition makes it difficult to assess what is really happening, when analyzing industry using the established classification system.

For developing countries, the changes brought about by the new flexible technologies mean, as they do for developed countries, that, on the whole, the bulk of existing plant is obsolete by international standards. Every single sector needs to be re-examined afresh to

[29] Allen *et al.* (1984).

[30] Information intensity and flexibility in agriculture might be based not only on microelectronics, but also on biotechnology. Increasing research efforts are being made to develop natural pest-control systems and soil-enriching bacteria, which could in time, expand the agricultural frontier while reducing the need for petrochemical pesticides and fertilizers.

assess its prospects in national and international markets under the new conditions. The reasons that led firms or countries to concentrate resources in some industries, as opposed to others, might no longer be valid. Certain export-oriented sectors may face new difficulties; in others, previously adequate protection policies could prove incapable of stemming import competition.

Both national planning and individual project evaluation, by national or international agencies, would have to recognize a totally new set of conditions governing the choice of technique and scale. Assessing adequacy or competitiveness on the basis of past or even present average costs, without bearing in mind the dynamics of technical change, could be highly misleading and bring disastrous results. This would apply to any sector or project, for the changes tend to affect the whole spectrum. It is particularly crucial, however, in the case of the capital goods industry which, apart from its obvious impact in determining the productivity of the user industries, is in the midst of a profound transformation world wide in both products and processes.

(ii) *Rapid technical change vs. "minimum change" strategy*

The new flexibility potential stretches beyond changes in optimal scale and variable output mix. It expands the capacity to make successive changes in products, both in appearance and in technical performance without great loss in efficiency.

The coupling of computer-aided design with computer-aided manufacturing (CAD-CAM),[31] together with on-going developments in computer-aided software, can reduce the relative cost of innovation and the time span of learning curves. This feature opens the way for rapid product change in time; and, although its impact could vary widely depending on the industry, it is likely to have a profound impact on business behavior. It could reshape the forms of competition and hence of oligopolistic practices in many areas; it may change the distribution of production between large and small firms, and it is likely to give a key role to the in-house research and development departments.

Change in the forms of competition: From past experience, it could be said that it is generally in the interest of highly concentrated oligopolies to administer technical change, by pacing the rhythm of innovations to take best advantage of each product cycle in yielding optimum overall profitability. We would argue that such a "minimum change" strategy was indeed appropriate under the previous paradigm, based on mass production of identical units, within which product change implied high costs in dedicated equipment and tooling, as well as high risks. However, as the relatively low cost of flexibility and dynamism under the new conditions is realized, the struggle for market share could, in certain industries, increasingly take the form of fast innovation and imitation. This is already happening in the areas of software and electronics products where protection based on patenting seems extremely difficult to uphold.

Opportunities for small and medium firms: This capacity for quick technical change might have consequences in the long-run distribution of production between large and small or medium firms, because it is related to the question of "barriers to entry". Whereas

[31] For a thorough discussion of the implications of CAD, see Kaplinsky (1982).

the electronic components sector is already becoming concentrated and the level of investment at the present stage of development has reached prohibitive proportions,[32] wide areas of product applications and software are quite far from reaching that situation. It can be argued indeed that, with the powerful capabilities and low and decreasing cost of both components and development systems (i.e. equipment with which to design microprocessor based applications), there will, for a relatively long time, be ample space for new small firms with new products. And the same can be said about innovation in services, more so if telecommunications do become all-pervasive and cost-decreasing. Whether these firms become mere risk-takers, to be taken over by the giants if successful, or whether they will proliferate in bandwagon fashion and become typical of the next upswing, cannot be foreseen. Yet, the second course, which would guarantee continued market expansion for the components, the equipment, the services and the telecommunications produced by the giants, seems much more promising for overall growth.

The role of research and development departments: In the previous paradigm, the existence of an in-house R&D department was a “best practice” feature indispensable in most large corporations. Its role, however, and the tightness of its relationship with management, marketing or the production process, varied widely across branches, depending on how science-based the products were. Already though, and perhaps even more in the future, the R&D department, or departments, are becoming a core management tool in most large firms. Furthermore, dynamic R&D might increasingly be the key to the existence and survival of small and medium firms, especially in the electronics and information sectors.

In developing countries, most of the R&D is done in more or less academic institutes and (putting aside the question of the local relevance of some of the problems tackled) great difficulty is encountered in trying to transfer the results for application in the productive sphere. With the new paradigm, there would be greater need for in-house R&D efforts, directly linked to production, and for explicit technological strategies on the part of management, especially — though not only — in export oriented sectors.

(iii) *User-defined systems vs producer-defined products*

The conjunction of flexible production capabilities and greater information intensity of equipment and products generates another trend with far-reaching consequences: the diversity of applications available to the user.

The typical products of the previous Kondratiev were conceived to perform a single task or set of tasks that were more or less strictly defined by the manufacturer. Products based on microelectronics are, at least potentially, multi purpose. Not only are individual pieces of equipment increasingly versatile, but they can be linked together into diverse combinations, depending on user needs. This has become common in office equipment, where the market offers a range of basic core products and a range of optional peripheral elements. As the necessary drive towards standardization and compatibility advances in

[32] Dosi (1984).

both hardware and software, the generalization of the trend towards modularity on the supply side for manufacturing equipment is also likely to advance. Final systems in use are thus, potentially, user defined, and can grow in complexity at a rhythm also dependent on the user.

This organic type of system growth creates scope for adaptability in process design on the part of producers. It can mean, for developing countries, that efforts at matching technical choice to specific local conditions have a better chance of success. Moreover, this adaptability also applies to the products made with those techniques. Under the mass production paradigm, the drive towards uniformity in consumption patterns encompassed the privileged minorities of all developing countries. The question of adapting either capital or consumer goods to diversity in climate or culture was not on the agenda, as long as productivity and profitability depended mainly on growing mass markets for identical products. The new technologies open the path — though nothing can guarantee it will be trodden — for adapting to diversity in conditions.

Taking advantage of this new potential is no easy matter. It requires overcoming decades of imitation it implies a willingness to recognize local needs and building confidence in the real possibility of addressing them successfully. And, this applies both to the public and to the private sectors. The general point is that once the mass production constraint is eliminated as the only means of high productivity achievement, diversity in demand can become a source of investment opportunities. It can even create naturally protected markets and regional export advantages. Yet, fulfilling this potential requires vast amounts of individual, social and institutional creativity, based on adequate information and education, appropriate stimulating policies and, hopefully, a genuine interest in the welfare of the national population.

(c) New concepts for organizational efficiency

When speaking about information intensity and flexibility, we seemed to assume that engineers and managers would immediately respond to the new dynamics in the relative cost structure and to the potential offered by the new technologies. The process, of course, is neither simple nor automatic. Yet the changes in the optimal organization of the firm are even more difficult as they require overcoming deeply rooted behavior patterns. In fact, the diffusion of a new technological style is also a conflict ridden process of creation through trial and error of a new organizational model as regards the management of the firm. This process is extremely uneven and tends to spread through "sink or swim" imitation under competitive pressures. It is profoundly linked to the characteristics of the new technologies, especially to the features that contribute to the quantum jump in productivity in relation to previous practices. Here we shall discuss some of the elements already visible in the process of diffusion of the new organizational model.

Obviously, there is never one and only one form of organization of the firm at any one period. There are differences stemming from type of branch, national conditions, and particularly size and scope of firm. Yet, certain general principles can be widely accepted as constituting "best practice" guidelines and will, therefore, tend to shape the organizational goals of most firms (and in the longer run even of most institutions). It is in the sphere of these general principles that the following discussion will be placed.

Nevertheless, it should be kept in mind that the innovative process in this area is taking place now, and there is still much ground for creativity. Ford's first assembly line, which became the prototype for plant-level efficiency in the mass production paradigm, was established at the beginning of this century. However, Sloan's professional management model,[33] which became the "ideal type" of corporate organization, was actually developed in General Motors some fifteen years later. Furthermore, it was only during World War II that organic links between industry, science and government were established as a feature of the Keynesian mode of growth.

(i) *The internal organization of the firm: systemation vs automation*

The Fourth Kondratiev model of organization implied a sharp separation of plant management from economic management and, within each, a clear differentiation of activities to identify ah forms of repetitiveness for subsequent automation. It was mainly an analytical model. It demanded focusing attention on parts or elements of processes; it led to detailed definition of tasks, posts, departments, sections, responsibilities and to complex hierarchies. The new paradigm is intrinsically synthetic. It focuses on links and systems of interrelations for holistic techno economic coordination.

Although many applications of electronic equipment are generally referred to as "automation," we suggest the use of the term "systemation" to describe the new trend towards merging of activities — managerial and productive, white and blue collar, design and marketing, economic and technical — into one single interactive system[34]. This term has the advantage of de emphasizing mere "hardware," and emphasizing the systemic, feedback nature of the organizational "software." We believe this is an essential distinguishing feature between the new and the old model of firm organization.

In fact, many unsuccessful attempts at introducing electronic equipment may stem from thinking they are mere pieces of hardware, which can be incorporated into the previous plant or office with some retraining, for "business as usual but hopefully better." In reality, reaping the fruits of the new technology requires a profound transformation in the internal organization of the firm and in its interconnections with markets and suppliers.

In a sense, it could be said that information technology does for the firm what the assembly line did for the plant. The firm, as a whole, becomes a continuous flow system of activities, information, evaluations and decisions. But there is a crucial difference: whereas the assembly line was based on the 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.

We have already seen that, in plant organization, the new technology not only changes the core transformation processes, but also the erstwhile peripheral tasks such as design,

[33] See Drucker (1972).

[34] A detailed analysis of "intra-sphere and inter-sphere" automation and the concept of "systemo-facture," can be found in Kaplinsky (1984). See also article in this issue.

stock control, quality control, maintenance, etc. Thus, the potential exists for the complete fusion of all production activities into one single, flexible, optimized system from the input to the output end. A similar integration can occur in the office through computerization and communications systems both internal and external.

Yet, although such trends in plant and office could already be considered enormous transformations, they are not the crucial part of the story. It is the possibility of merging both into a single system that constitutes the truly radical change at the organizational level. This stems from the potential provided by the equipment itself, which, at the same time as it controls the physical volumes and qualities of inputs, throughputs and outputs, can yield both the technical data and the economic information for constant monitoring of techno-economic performance.

This does not mean, of course, that all firm activities would be physically on a unified space. Much to the contrary, telecommunications capabilities actually increase the degrees of freedom concerning location (including even that of individual people). In fact, they might lead to a much wider geographical dispersion, as urban agglomerations lose their capacity to provide external economies. Nor does it imply that they would constitute a single unit. If the old corporate structure managed multi-plant, multi-country operations, the new technological infrastructure would allow the efficient management of world wide, giant, complex and rapidly changing conglomerate structures. (And this is indeed the direction in which transnational corporations have been moving since the late 1960s).

(ii) *Relationship between production and markets: dynamic "on-line" monitoring vs periodic planning*

But systemation goes beyond the internal organization of the firm and allows the establishment of relatively low-cost feedback loops with the market, for acquiring information in real time. This interconnection gives full meaning to the potential for flexibility in output previously discussed. The quickest way to convey the idea is probably through an example. Let us then look at a case in the highly volatile area of fashion.

Benneton, an Italian family firm described as "one of the most successful clothing companies in Europe,"[35] is organized in a flexible network of production and distribution. At the market end it has 2500 national and international outlets, furnished with specially designed electronic cash registers that transmit on-line full data about which articles are being sold, their sizes and color. This information is centrally received and processed for decision-making at the design and production end. There, the output mix flexibility of the main production facilities is complemented by a network of 200 small firms in a sort of "putting out" system that provides additional flexibility regarding volume, although possibly at the expense of these indirect workers. Allegedly the response time to market changes is reduced to 10 days.

This potential for reliable feedback hoops with the market could have a profound impact on management practices. It can transform production planning from a periodic hit-or-miss activity into a more reliable day-to-day adaptive system, coupled with flexible

[35] Buxton (1983).

production facilities. Previously, production planning relied on the flow of orders, tempered by past experience, intuition and the availability of national statistics indicators; but this introduces an inevitable time lag resulting in wide inventory fluctuations. With electronic equipment and systemation, given the appropriate software, every aspect of the business can be monitored in detail and in "real time." Not only can the possible (model-simulated) or actual effects of any decision be known much faster than before, but also fine tuning and decision changing are much more rapidly per formed. Short-term profit maximizing or profit flow optimizing through adjustments in costs, prices and volumes, as well as very tight inventory controls and dynamic production scheduling, can now be information-based.[36]

It is, of course, probable that the larger firms will be the ones to adopt the systemation model more fully. Nevertheless, the general concepts also apply to smaller firms.[37] In particular, the on-line market information systems could diffuse quite widely, as both producers and distributors adopt computerized equipment and telecommunications become truly all-pervasive and low cost.

(iii) *A new management style: information-based vs. intuition-based skills*

These developments also tend to change the required management skills. Much of the experience of successful managers involved having the type of intuition that would lead to the right decisions in the face of scant information. That might be why the first reaction of traditional managers to the masses of data that could now be available is a certain sense of intoxication. In the future, coordination and information management skills are likely to become essential for daily operations. Creative, intuitive skills might be increasingly required for human relations and for the more strategic questions, such as investment or technological decisions as well as for the design of the information systems themselves.

As a matter of fact, since firm growth might often depend on market scope and technological dynamism, it could prove very ineffective for top management to ignore or delegate the technical questions. Both strategic and short-term decisions are likely to involve a tightly woven techno-economic package. Thus, the new conditions imply a substantial transformation in the required management skills, right through to the topmost levels.

(iv) *A new system of control: decentralized networks vs hierarchical bureaucracies*

Thus far, the analysis of the new organizational model, might have led the reader to believe that all forces within the new technology favored giant firms and centralized

[36] The generalization of on-line market monitoring implies the likelihood of dampening the short business cycles due to inventory fluctuations. An analogy can be made with the role played during the Fourth Kondratiev upswing (late 1940s to late 1960s) by the elaborate system of statistics established by national governments. This constituted a significant step upwards in the amount of information available for business planning and contributed, together with other measures, to reduce the intensity of short cycles, when compared with previous Kondratievs.

[37] In Japan, no-inventory systems, called "just-in time" have been developed, which are less based on up-to-date equipment than on new management practices and greater worker involvement and participation. See Schonberger (1982).

control. Nevertheless, there are very essential complementary characteristics that greatly widen the space for local autonomy and decentralization.

To begin with, the typical pyramidal organization is radically questioned. Until recently, the more complex the organization the greater the proliferation of intermediate control levels. The various layers of "middle" management served as a sort of relay system collecting and processing information from below, taking minor decisions or suggesting major ones to top management or top government officials and then transmitting the final decisions downwards. Today, provided the adequate software, those relay and processing tasks can be done by computers, and the present function of middle managers made redundant.

This, in itself, already flattens the control system bringing decisions and actions closer together. But, if this were to lead to hyper centralization of decision-making, the main flexibility potential of the new system would be hopelessly lost. The core feature of low cost microprocessors is the capacity for providing "distributed intelligence," which, in organizational terms, means distributed decision making. An illustration from a hardware system, might clarify the implications. Let us look, for example, at the evolution of traffic control systems.

In electromechanical times, traffic light relay mechanisms were individually hand-set to change at prescribed intervals according to control plans drawn up at the central office, on the basis of sample "counts" taken by hand or instrument. By the end of the first stage of computerized traffic control, all the information was being fed into a giant computer with very complex and expensive software, provided with a giant display of the city's traffic control system, where the hyper-centralized decisions were made. Today, infinitely more flexible systems have been developed with microprocessor intelligence at each traffic light. Information on traffic flows at each intersection is collected on-line, on the spot, so each set of lights can react to demand. Further intercommunications links are provided among intersections in an area or along a main route for collective coordination, and even wider systems of information sharing between areas can be established for further interactive optimization. In this new context, the central control unit acquires a monitoring and coordinating role in charge of designing and evaluating the distributed intelligence network. This type of system, apart from being infinitely less costly and amen able to modular installation, is far more effective and reliable than the totally centralized one.[38]

Bearing in mind the obvious limits to the analogy, it serves to make the organizational point quite clearly. A centralized decision making system would have to be able to simulate every single possible combination of events with every single possible combination of elements, and this is indeed a cumbersome and nearly impossible task. If organizations are to be diversified and flexible, to take full advantage of the new potential, they will probably tend to be based on flexible, interactive, relatively autonomous units, linked in adaptive on-line systems of coordination under dynamic strategic management.

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[38] I owe this example to Dr. R. Suarez, President of EYT CA., an electronics company in Caracas, Venezuela, where one such system was developed.

But, the analogy can be taken further. Because “intelligence” can be provided for single pieces of equipment, central coordination is not indispensable for efficiency in every case, and many local and niche markets, for products or services, can be covered by independent small firms or cooperative networks. And, going still further, greater worker participation, already experimented with more widely in Japan but also in some Western firms, could give better results in both human and productivity terms. Ah the more so, because of the need for teamwork, multi-task posts and multi-purpose skills. This aspect, much to our regret, can not be discussed here.

Thus, in organizational terms, the new paradigm combines trends towards centralization and decentralization, towards more control and more autonomy, so the variety of combinations is likely to be quite wide, not only in the present transitional period, but probably into the future upswing.

Moreover, this applies not only to firms. The new organizational model, as in previous Kondratievs, overflows into all sorts of other social activities from the educational system to the functioning of government. “Bureaucracy” in Weber’s time was an innovation that led to the division of labor in the control sphere, increasing the efficiency of organizations during the Third Kondratiev. In the Fourth, it was taken to its utmost limits and has now become a cumbersome and costly bottleneck. Yet, both those who cry against government bureaucracies and those who defend them seem to be trapped in the same mental block: confusing the form of the organization with its purpose. The same social goals could now be achieved with a different and more efficient organization; and, rather than reduce the number of people at work, the object could often be to expand and enrich the goals.

(v) *Decentralization: a key feature for developing countries*

It would seem that an emphasis on taking advantage of the decentralizing potential of the new paradigm could open fruitful paths for the Third World. To begin with, the planning system itself might warrant radical rethinking. Central coordination of regional, local or sectorial units with a high degree of autonomy, especially economic, could prove more effective than either true centralized control or so-called “indicative planning.” It should also be remembered that a model of organization is mainly a set of principles. It can, therefore, be applied with the “least hardware” solution. There is indeed a danger of massive overinvestment and wrong technological choice. So, original solutions to real local needs, taking into account local conditions and limitations, are possible.[39]

But these solutions should be sought now, before technical choice becomes more rigid. If groups of developing countries are able to set and put into practice standards more appropriate to their specific conditions and a more adequate mode of growth, it is not unlikely that these could become powerful indicators for developed country producers seeking export opportunities in the Third World.

[39] Peter Dempsey, managing director of Ingersoll Engineers, the firm responsible for the installation of over 50% of UK FMS systems, estimates that close to 70% of the benefits are achieved from organizational changes without any hardware; see Proceedings of FMS-2 (1984).

It seems that the first locomotive was designed with horse-like legs; but, if it had been conceived in a world without horses, it might never have gone through that "hybrid" stage. It is true that technology is not socially neutral, but perhaps its scope is greater than the limits imposed by those who have molded it.

To take just one current example: the typical pattern for electricity generation and distribution was established, in the Third Kondratiev, as a centralized network based on the use of low-cost steel for large engineering equipment. It was further pushed in this direction by mass production concepts and the availability of how cost oil, which closed-off the route of most other possible sources. Today, this same centralizing model sees nuclear power as the only real alternative. Existing infrastructure makes it difficult to conceive a truly diversified semi-decentralized system. Even in the introduction of solar technology, experimental stations have covered acres of land with solar collectors for central redistribution. This rather awkward form of application has been used in spite of the widespread agreement that it is more natural for a technology that collects an all-pervasive source of energy to install the generating equipment at the points of use.

Individual, national or regional initiatives, involving non-imitative behavior in these types of issues, could develop and gear the new potential towards more appropriate solutions for Third World conditions.[40]

In the following section, we shall explore the more general perspectives in the context of the changes in the international framework that can occur in long wave transitions.

4. CHALLENGES AND PERSPECTIVES FOR DEVELOPING COUNTRIES IN THE PRESENT LONG WAVE TRANSITION

If our long wave hypotheses are correct, the uppermost idea that should guide development strategy today is that planning must address the problems and opportunities of tomorrow and not those of yesterday. As we suggested at the beginning, this is a time for speculation and innovation. Although the future is built upon the past, in transition periods mere extrapolation from the past is useless and even counter productive.

Obviously, the problem of arriving at successful responses in developing countries is tremendously complex. It requires not only an understanding of the new techno-economic paradigm, but also foreseeing the possible responses of the core industrialized countries, to prefigure the general climate of the future international framework; and, this has to be done in most cases in the face of scant financial resources and tremendous human hardship. Nevertheless, an adequate response is more likely with higher information and understanding. As we have seen, certain features of the new paradigm and of this specific transition could be used to advantage in opening new avenues for development.

[40] For a set of case studies involving imaginative applications of new technologies to Third World conditions, see Bhalla *et al.* (1984).

(a) A new space for development thinking

From what has been argued, the first point to keep in mind is that the transformation in the relative cost structure changes both comparative advantages and comparative disadvantages. For each country, this implies a fundamental rethinking of its relative advantage position within the new techno-economic paradigm to identify the new possibilities. This should not be misunderstood as going back on the discussion of static and dynamic comparative advantages, nor as a negation of the role of the state in creating or enhancing such advantages or using protective measures to overcome disadvantages. It merely means that the world of the past is dying and, with it, the opportunities it opened or closed. Only a reassessment of real possibilities can lead to adequate and innovative development policies.

This basic rethinking involves the question of specific resource endowment, location, size, cultural or environmental factors and previous areas of relative development. However, it also involves a reassessment of the technology gap. Since the new overarching technology is now at its relatively early stages, it is possible to attempt a direct entry without going through the technological stages it leaves behind. As Luc Soete[41] has pointed out in his analysis of the international diffusion of technology, each crisis in a long wave results in a restructuring of the relative positions of countries. This is partly because the new technologies allow "leapfrogging" for some of the countries that do not carry the inertia of the previous industrial structure. In the particular area of microelectronics applications and software, Morris Teubal[42] has noted that technical knowledge of the type acquired in universities is the essential initial skill required. This is in contrast to the need for productive experience in traditional mechanical engineering or investment experience needed for success in the process industries. (Of course, this situation is temporary; as the new areas develop and standardize their practices, experience will once again become necessary for success).

These general comments apart, the route to development does not hinge on whether countries can or cannot enter the microelectronics or information race. Even industrialized countries might be wrong in believing that, with enough government funds to support the growth of information technology, they can unleash the recovery. We have already seen that the process of diffusion of the new technology, without changes in the socio-institutional framework, actually aggravates the crisis. The real question for developed countries is how to manage the transition. This does involve an effort to reorient economic activity by enhancing the conditions that stimulate a successful restructuring but also to avoid a collapse; and, this requires both temporary innovations to deal with the major ills brought about by the transition — especially unemployment — as well as more permanent ones to shape the future.

For developing countries, it is a question of taking advantage of the transitional phase to leap forward. This also requires socio-institutional transformations. However, since this is not the place to address the wider social issues, the discussion will be limited to an

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41 Soete (1983); see also article in this issue.

42 Teubal(1982)

overview of the new degrees of freedom for achieving economic growth. Although increasing wealth can be unevenly distributed, better distribution and greater welfare are more likely with increasing wealth.

Because electronics and information technology, and especially its flexible organizational paradigm, can transform any activity, from mining and agriculture through health care and education to biotechnology and satellites, the real question is which activities to emphasize as the core of a development policy. The how, as was discussed in Section 3, seems to involve a much more integrated systems approach, requiring the development of design capacity for process, products, general organization and marketing systems. Thus, there might be higher chances of success by focusing on one or very few integrated complexes or flexible decentralized clusters of activities, centered around local resources or local conditions.

This approach could imply a revision of the traditional concept of "industrialization," substituting it with a much wider concept of integrated development. A more adequate approach to planning would reevaluate all wealth-creating activities, from agriculture and mining to information services, and all the elements of each process, from design through organization to national and world marketing. This means that no particular sector is intrinsically "better" for development but that creating adaptive integrated systems and interactive links is better for the development of any sector.

(b) Some old obstacles reduced

Traditionally, underdeveloped countries have suffered from the insufficient size of local markets, lack of an experienced and skilled work force and a shortage of managers. Under the new conditions, these might no longer be such acute obstacles.

As we have seen, with good process and organizational design (and provided the goal is well chosen), it should now be possible to achieve high productivity levels on the basis of a small market for one product or a combination of them. These opportunities are further enhanced by the new potential for catering to specific local needs and conditions. So, developing countries could now play a more active role in segmented demand and product creation, for local markets as well as for international niches.

As regards the typical skill profile, the new technology can be applied with a combination of technical and professional personnel and relatively low-skilled, rapidly trained labor. Thus while the more industrialized countries must face the challenge of recycling the bulk of the redundant skills, developing countries could by-pass that previous bottleneck when entering new sectors of production.

As far as managers are concerned, the problem remains, but it now has a different character. Again, the need for the old skills can be more or less by-passed and the new skills, based on a capacity to design and coordinate information intensive systems, can be acquired and developed. In this area, the innovation process is taking place now ah over the world, so there is likely to be time for educational and trial-and-error learning. In this context, it might be worthwhile to reassess present efforts in professional education or training (including those to be acquired abroad). Also, since many previously trained engineers are often under utilized in the passive operation of the old technologies, they can be turned into a valuable asset if they are well directed and given a more creative role.

(c) Transnationals and autonomous development

It could be argued that the relatively autonomous industrialization of Third World countries is generally not in the interest of transnational corporations. For a long time, these countries have been said to be a source of cheap raw materials and labor, as well as a profitable market for mass-produced goods, either finished or assembled in local subsidiaries. However, if our long wave model is sound, this need no longer is the case.

In the first place, an energy and materials saving technology does not hinge upon the decreasing relative cost of oil or raw materials for increasing productivity, profitability and growth. In the particular case of oil, the transnationals in the field have accepted, and sometimes fostered, fully compensated nationalization and now derive profit from selling technological and marketing services to their erstwhile subsidiaries. A similar phenomenon is occurring in some of the metallurgical industries, where rather than setting up subsidiaries, transnationals have often entered either minority share agreements or design, construction and technology service con tracts with developing countries. These events could be seen as analogous to the mixed blessing of political independence without economic autonomy. Yet, it is shortsighted to deny that they create better conditions for increased autonomy.

Secondly, there is reason to believe that transnationals may no longer seek the "final assembly subsidiary" route. This practice origin ally served market expansion objectives and later, at the peak of the prosperity phase, became a stretching solution to the limits on productivity growth under the old paradigm, by reducing labor costs. While the new technologies are at their early stages, initial market expansion comes from product change and cost reductions, and there is much scope for cost reduction in process and organizational change in the main plants. Thus, although the question of robotized assembly is not yet clear, the trend towards off-shore migration might be over, at least for some time.

By contrast, it can be argued that under the new conditions, a certain level of autonomous development in the Third World could be very important for the new transnationals as they restructure. High local investment levels would actually increase the world market for the core products of the new paradigm; electronic components, computerized office or production equipment and telecommunications, as well as engineering consultancy, plant design and construction and all other information intensive services, from financial to technological.

A certain historical parallel can be drawn with the Third Kondratiev "Belle Epoque" upswing. Then, the giant firms concentrated in steel (which we have suggested was the low cost "key factor" of the period), electrical equipment, heavy chemicals, shipbuilding, engines and machinery, great engineering works and, in general, products destined for producers or governments. At that time, the spread of electricity led to a proliferation of small and medium firms serving local consumer markets (much of the food processing, ready-made clothing and of the early consumer durables industries were born under these conditions). It was a wave of small-scale industrialization with a vast geographical range following the electrical net work, as opposed to the previous model of highly concentrated steam-powered industrial complexes in railroad centres and ports. Yet, without this wave of small industry and commerce, purchasing equipment and electricity and transforming the agricultural world, the giants would not have found the appropriate market growth.

Because this need for market expansion of the appropriate sort seems to have appeared at each transition, we would go as far as to argue that it is very unlikely that a new upswing can be unleashed without the development of at least a considerable group of Third World countries. To allow the achievement of the quantum jump in productivity promised by this new technology, the present internal markets of the developed countries plus the fringe high income groups of the Third World are clearly insufficient.

However, achieving this is no simple matter. In view of the present shortage of investment funds and the enormous levels of debt, moves to facilitate market expansion based on Third World development might require new transitional or permanent institutional arrangements for international income redistribution. Some of these might take the form of agreements on better prices for raw materials (which is what OPEC achieved in a unilateral way), but others might be oriented towards some form of inter national Keynesianism as was suggested in the Brandt Report.

Before all this is dismissed as utopian, we would like to invite the reader to imagine how it, might have sounded in the early 1930s to say that, to bring forth the necessary market growth for economic revival, developed countries would have to raise the wages of the majority of manufacturing workers, organized in officially recognized labor unions, to a level where they could own a car and a house full of electrical appliances; that governments would have to directly employ a significant and growing proportion of the population, as well as to generalize social security benefits, and that much of the labor shed by higher productivity manufacturing and mechanized agriculture would be taken up by a fast growing service sector, while the working week would be reduced to forty hours for all. Further still, let us try to imagine how the world looked to those living in the "Belle Epoque" prosperity, when almost every industrialized country had or aspired to a colonial empire. It surely must have been very difficult to foresee the generalization of political independence in Africa and Asia. Neither of these series of developments occurred without conflict, of course, but both became central features of the general mode of growth.

(d) The risk of "missing the boat"

Of course, the so-called Third World does not exist as such. It is a concept based on real, and doubtless essential similarities, but it necessarily overlooks significant differences between countries. United Nations literature already distinguishes the "newly industrializing countries" (NICs), at the upper end, and the poorest "less developed countries," at the lower. Other groups based on cultural or regional similarities or on resource endowment are also singled out for various purposes. In the transition, however, the recognition of the specific conditions of each country or group of countries is crucial.

Yet, whatever their origins, these conditions must now be seen as starting points for the future, rather than as static obstacles.

Historically, long wave transitions have involved radical changes in the rules of the game. And, in spite of the obvious weight of relative power factors, the new rules are created by all the players. Thus, in the present transition, developing countries, both individually and through international organizations, can and should work constructively towards understanding the new conditions and in creating the new appropriate socio-institutional framework, on national and world levels.

Just as government institutions in developed countries can fruitlessly apply old policies because of the inertia created by past successes, developing country governments might miss the opportunities opened by the transition under the weight of inertia resulting from past frustration. Even the social and political groups who did benefit under recent conditions might find them selves on the losing end if they rely on the continuation of past practices.

In a sense, one could visualize long wave transitions as a sort of thawing out of the system, allowing fluidity of movement and a more or less wide spectrum of choice. Once the upswing gets underway, though, industries, social groups and countries are caught, as it were, in a certain growth path within the generally established new mode of growth. The opportunities and development perspectives of each are then high or limited, depending on the relative positions attained in the system. Leapfrogging then becomes very difficult indeed until the system reaches limits to growth again at the next peak of the long wave.

Even in the transition, there are tremendous restrictions, and there is a certain limit to just how far any particular country can advance. But, whatever the possibilities, the chances are much higher of taking advantage of them through a bold and fundamental rethinking of the development process, than if thwarted by the obstacles of the recent past.

Granted, this is particularly difficult for developing countries while the industrialized world persists in trying to overcome the crisis with the old practices. This, as was the case in the previous downswing, has resulted in fierce inter national competition, which in turn has led to a stiffening of nationalistic policies. Worse still, some see signs of a gradual growth in militaristic tendencies vaguely reminiscent of what happened in the thirties. Yet, this time, a world war would simply be the end.

Assuming the gravity of that danger precludes the war route, it might be that, as the various attempts at recovery result in short spurts of growth and the underlying crisis continues or even deepens, more creative and constructive solutions on a wider level will be sought. Under those circumstances, it is likely to become increasingly clear that to achieve a sustained recovery, industrialized countries, for their own sake, have to find solutions to the debt crisis and, in fact, have a stake in the development of the Third World.

The question remains whether the developing countries are preparing themselves to face the challenge and take best advantage of the new opportunities. There are, of course, no recipes.

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