

# ***STRUCTURAL CHANGE AND ASSIMILATION OF NEW TECHNOLOGIES IN THE ECONOMIC AND SOCIAL SYSTEMS***

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Through generating a set of hypotheses about the interrelationship between diffusion of new technologies and economic development, the author seeks to identify the causal mechanisms of the depressions in the trough of the Kondratiev long wave. A model of the capitalist economy and an analysis of its structural patterns and processes are proposed, and from an examination of the technoeconomic and socioinstitutional characteristics of the fourth Kondratiev, some institutional requirements for the next upswing are elaborated.

A SET OF HYPOTHESES about the interrelationship between the diffusion of new technologies and economic development is presented in this article. With it we attempt to approach the causal mechanisms of the widespread depressions experienced every five or six decades by the economic system, corresponding to the troughs of the long waves, statistically identified by Nikolai Kondratiev<sup>1</sup> in the 1920s. In so doing, we hope to provide a framework with which to meet Nathan Rosenberg's challenge to specify "the conditions which would need to be fulfilled in order for technological innovation to generate long cycles in economic growth . . ." <sup>2</sup>. We also hope to open new lines of research leading to possible counter-long-cyclical policies.

We start from a somewhat Schumpeterian view of the role of innovation in provoking the cyclical behaviour of the capitalist economy. But, departing at least partially from his view, we postulate that Kondratiev's long waves are not a strictly economic phenomenon, but rather the manifestation, measurable in economic terms, of the harmonious or disharmonious behaviour of the total socioeconomic and institutional system (on the national and international levels).

A structural crisis (ie the depression in a long wave), as distinct from an economic recession, would be the visible syndrome of a breakdown in the complementarity between the dynamics of the economic subsystem and the related dynamics of the socio- institutional framework. It is, in the same movement, the painful and conflict-ridden process through which a dynamic harmony is reestablished among the different spheres of the total system.

The resulting complementary trends represent what we might call a 'mode of development' understood as a general pattern of growth, based on a set of accepted social and institutional mechanisms, national and international, influencing the operation and evolution of factor and other markets.

What provides the direction and shape of the movement are successive technological styles-or, if you prefer, successive quantum jumps in the general best-practice frontier-based on a constellation of interrelated innovations both strictly technical and organizational, the diffusion of which is propelled by the profit motive.

So for us the long waves represent distinct successive modes of development, responding to distinct successive technological styles. However, although we identify modes of development as stretching from trough to trough of each Kondratiev, we propose that technological styles evolve roughly from the peak of one long wave to the peak of the next. This is the crucial point on which medium- and long-term forecasting could be based. We claim that the crisis is brought about by the

Introduction of a new technological style when-and because-the previous one approaches the limits of its potentialities. Its initial diffusion, up to a certain critical level, both provokes the crisis of the old mode and sets the guidelines for the next mode of development, during which the new style will display its full potential.

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<sup>1</sup> N. D. Kondratiev, "The long waves in economic life", *Review of Economic Statistics*, 17, Nov 1935, pages 105-115.

<sup>2</sup> N. Rosenberg and C. R. Frischtak, *Technological Innovation and Long Waves* (Stanford University, Mimeo, January 1983), page 3.

Kondratiev<sup>3</sup> had certainly mentioned that during the downswing, together with other characteristic phenomena, there was "an especially large number of important discoveries and inventions in the technique of production . . . which, however, are usually applied on a large scale only at the beginning of the next long upswing".

However, Kondratiev emphasized that this and other recurring relationships did nothing more than further confirm the existence of the long waves. He strongly emphasized that he did not "by any means hold that they contain the explanation".

Thus, as far as the causation mechanism is concerned, Kondratiev does not make any explicit commitment to the role of innovation (at least, not in the article we are analysing). He attempts to demonstrate the existence of long waves, he denies the possibility that they may be due to random factors, and advances his opinion that their causes are "Inherent in the essence of the capitalistic economy".

For Schumpeter<sup>4</sup>, who does set out to build a theory of the causation mechanism, innovation is the single root cause of the cyclical behaviour of the capitalist economy. For him there is no essential difference between short, medium and long cycles, except the relative importance and weight of the specific innovation or cluster of innovations provoking them. Notably, the Kondratiev long waves would be carried by a series of interrelated innovations. Each of them would consist of an 'industrial revolution' and the absorption of its effects.

In spite of the complexity of Schumpeter's total model and of his constant reference to the historical context, for him the systemic process unfolds *within* the economic sphere conceived as a self-regulating organism which provokes its own disturbances (innovations) and absorbs its impacts by constantly striving towards new higher equilibria. As for the rest of society, it suffers and profits from this recurrent process of 'creative destruction', it is slowly and profoundly transformed; it is sometimes an obstacle, at other times a stimulus, but it is mainly an environment. Social conditions and the institutional framework are conditioning and conditioned by economic evolution, but they do not form a total structure with the economic system. They are therefore excluded from the causation mechanism for cyclical behaviour.

This is, in our opinion, the reason why even though Schumpeter's theory is generally associated with the explanation of crises or great depressions, he in fact gives a much better account of the shorter cycles and recessions than of the deeper long-cycle depressions.

Even his language is revealing of this uneasy spot in his model. He speaks of prosperity and recession when referring to the juglar intermediate cycles, but he uses the term 'abnormal liquidation' to name the path from recession towards the trough of a long wave and 'recovery' or 'revival' for the beginning of a long upswing. In fact, his model does not really provide a 'natural' exit from a depression-so much so that, despite his strongly inimical attitude towards outside intervention in the self-regulating economic system, he reluctantly admits that "the case for government action in depression, especially of government action of certain types, remains, independently of humanitarian considerations, incomparably stronger than it is in recession".<sup>5</sup>

Strictly speaking, if the system worked as Schumpeter says, deep depressions would be abnormal phenomena and their historical regularity indeed puzzling. Bypassing the problem by invoking the idea of an 'industrial revolution' is in conflict with the identification of the market as the absorption mechanism. Presumably, although the innovations do come in clusters, they are not absolutely synchronic in their introduction, and the market should be able to gradually absorb them through short or medium wave-like movements.

Thus Schumpeter does lay the foundations for a theory of the cyclical nature of the capitalist economy but *not* of long waves.

## Model of the capitalist system

We propose that the capitalist system be seen as a single very complex structure, the subsystems of which have different rates of change. For the sake of simplicity we can assume two main subsystems: on the one hand a technoeconomic, and on the other a social and institutional, the first having a much faster rate of response than the second. The long waves would be successive phases in the evolution of the total system or, as we have termed them, successive modes of development. The root cause of the dynamics

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<sup>3</sup> Kondratiev, *op cit*, ref 1.

<sup>4</sup> J. S. Schumpeter, *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process*, Vol I (McGraw-Hill, New York, 1939), page 223

<sup>5</sup> *Ibid*, page 155.

of the system would be the profit motive as generator of innovations in the productive sphere, understood in the broadest sense as a way of increasing productivity and expected profits from new investment.

Each mode of development would be shaped in response to a specific technological style understood as a kind of paradigm for the most efficient organization of production, ie the main form and direction along which productivity growth takes place within and across firms, industries and countries. The particular historical form of such a paradigm would evolve out of certain key technological developments, which result in a substantial change in the relative cost structure facing industry and which, at the same time, open a wide range of new opportunities for taking advantage of this particular evolution. In essence we assume a strong feedback interaction between the economic, social and institutional spheres which generates a dynamic complementarity centred around a technological style as roughly defined above. The upswing of the Kondratiev wave would be sustained and stimulated by the harmonious evolution of such complementarity up to the point where the underlying technological style approaches the limits of its potential for increasing productivity and profits.

To surmount this barrier, through trial and error, a new technological style emerges in the productive sphere to which the prevailing social and institutional framework is no longer suited. The new dynamics introduced in the system produce greater and greater disruption in the previously expected evolution of most markets, gradually transforming the social fabric and rendering the institutional mechanisms -which have a high degree of natural inertia, strengthened by the confidence of previous successes-more and more obsolete and counterproductive. This process would be visible as the downswing of the Kondratiev wave, eventually leading to a crisis of the whole system.

The structural crisis thus brought about is, then, not only a process of 'creative destruction' or 'abnormal liquidation' in the economic sphere, but also in the socio- institutional. In fact, the crisis forces the restructuring of the socio- institutional framework with innovations along lines that are complementary to the newly attained technological style or best-practice frontier. The final form the structure will take, from the wide range of the possible, and the timespan within which the transformation is effected to permit a new expansionary phase will, however, ultimately depend on the interests, actions, lucidity and relative strength of the social forces at play.

This rough summary of the form in which we see the evolution of the system should serve to hint at the way in which we envisage predictability to be possible at a time when the usual extrapolations seem powerless. If the characteristics of the new technological style (which is already in place) can be identified, and the trends created by its diffusion-both in the economic and extraeconomic spheres-can be disentangled from those belonging to the waning style, then the general lines of transformation can be prefigured and serve as criteria for purposive action. We return briefly to this point in the concluding section of this paper. Let us now proceed to give a more precise definition of the elements of the model we have sketched.

## Model elements

### *"Technological styles"*

We have been speaking of 'technological styles'. Others may prefer to call them 'technoeconomic paradigms' or 'patterns'. It is not easy to find the ideal term with which to convey the features of the phenomenon we are trying to describe. By 'technological style' we mean a kind of 'ideal type' of productive organization or best technological 'common sense' which develops as a response to what are perceived as the stable dynamics of the relative cost structure for a given period of capitalist development.

As long as the expected pattern of evolution of the relative costs of various types of material inputs, various types of equipment and different segments of labour skills follows the expected trends, managers and engineers will apply what becomes the 'technical common sense' to make incremental improvements along the natural trajectories of the technologies in place, or radical technological changes in those branches of production of goods or services which have not yet achieved the 'ideal type' of productive organization.

Thus, for a given period, with a given set of expected trends in the relative cost structure, more and more branches of the economy will tend to apply the prevailing technological style, understood as the most rational and efficient way of taking advantage of the general cost structure. The establishment of such a style or paradigm is grounded on the introduction of a cluster or constellation of interrelated innovations, both technical and managerial, which lead to the attainment of a general level of total factor or physical productivity clearly superior to what was 'normal' with the previous technological style.

This quantum jump in productivity can be seen as a technological revolution, which is made possible by the appearance in the general cost structure of a particular input that we could call the 'key factor', fulfilling the following conditions:

- Clearly perceived low-and descending- relative cost;
- Unlimited supply for all practical purposes;
- Potential all-pervasiveness;
- A capacity to reduce the costs of capital, labour and products as well as to change them qualitatively.

The conjunction of all these characteristics in a particular type of input, which, from a technical point of view, was probably available long before, occurs as a response to a persistent demand for technologies capable of surmounting the limits of the technological trajectories based on the use of the prevailing (or previous) 'key factor'.<sup>6</sup> However, once this conjunction of characteristics crystallizes and the evolution of the relative cost structure is modified in a manner generally perceived as long-term, engineering and investment behaviour tends to shift towards new technological paths. We then witness not only the establishment of a new 'best productive common sense' which strives to get maximum advantage of the new key factor, across wide families of related or apparently unrelated technologies, but also a sustained bias in favour of its intensive use, both in radical and in subsequent incremental innovations.

As we mentioned above, the appearance of the new 'key factor' and the technological style that takes shape around its characteristics are phenomena that occur near the peak and during the downswing of the *previous* Kondratiev. The transformations they generate in the productive sphere through their gradual diffusion will demand complementary innovations in the social and institutional spheres in order to give way to a new long wave upswing.

We suggest the role of key factor was played by low-cost and steam-powered transportation in the second Kondratiev; by low-cost steel for the third; lowcost energy, in the form of oil and energy- intensive materials, for the fourth; and is now being played by low-cost microelectronics on the way towards the fifth upswing.

As examples of what constitutes a technological style one might turn to the most recent and best known, which would be those shaped by low-cost energy between the third and fourth Kondratiev and, as we propose, by low-cost microelectronics between the fourth and fifth. The first would be the extension of the continuous flow concept of the chemical industry to the mass production of discrete identical units made with energy- intensive materials (the prototype of which was Henry Ford's assembly line), complemented on the organizational level by a sharp separation of management and administration from production, bringing Taylor's ideas of 'scientific management' to their ultimate consequences. The second, taking advantage of the characteristics of microelectronics, could perhaps be the flexible batch production network where all activities (managerial, administrative, productive, etc) are integrated in a total information- intensive system to turn out information intensive products or services.

## Investment patterns

This brings us to another element of the model, namely the contention that the emergence of a new technological style is accompanied by a general shift in investment patterns from the areas that were best adapted to the old style towards those most amenable to the new paradigm. This shift would result in a change in the relative importance of the different branches and in the specific intersectoral relationships. In concrete terms we think that it is possible to distinguish for each technological style-and therefore for each Kondratiev upswing-a specific network of interbranch relationships which describes the main characteristics of the distribution of production between branches and between large and small firms in relation to their weight in the gross product.

Essentially there would be three main types of branches determining the shape and rhythm of economic growth for the period.

A . The *carrier branches* which are those that make intensive use of the key factor, are the best adapted to the 'ideal' organization of production, induce a great variety of investment

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<sup>6</sup> The actual combination of 'accidental' and 'purposive' events leading to this particular development are not discussed here. Suffice it to note that the relative autonomy of science leads to a universe of the technologically feasible which is, at any time, much greater than the economically profitable.

opportunities up- and downstream (among them, and most important, great infrastructural investment of specific kinds) and, therefore, become the vectors of the technological style, having great influence in the general rhythm of economic growth.

B. *The 'motive branches'*, which are responsible for the production of the key factors and other inputs directly associated with them and have, therefore, the role of maintaining and deepening their relative cost advantage. Thus, while the motive branches create the conditions for the development of the technological style, the growth of their own market depends on the rhythm of generalization of the style across industries.

C. *The 'induced branches'*, whose development is both a consequence of and complementary to the growth of the carrier branches, only multiply in bandwagon fashion once the necessary social and institutional innovations, together with the appropriate infrastructural investment, have opened the way for the upswing and the generalization of the new technological style. They often use precisely the types of labour displaced by the carrier branches, which is why the initial technical unemployment effect provoked by diffusion in the downswing can be countered during the upswing.

Of course, there are many other branches which produce necessary goods under older, less productive, technological styles or with 'odd' highly specific technologies which are never generalizable -or at least not yet. Some of the first are able to get on the bandwagon of the prevailing style through technological innovations, the general tendency indeed being to try to achieve as much as possible in that direction. But the main argument is that the complementary growth of the carrier and motive branches is the engine that moves the economy and that those branches will tend to be increasingly concentrated in the hands of the largest firms for the period.

## Upswing characteristics

In summary, we suggest that the upswing of a Kondratiev long wave begins when a harmonic complementarity has been achieved, through adequate social and institutional innovations, between the 'technoeconomic paradigm', which emerged and developed in the previous Kondratiev peak and downswing, and the socio- institutional climate. This unleashes the swarming process and generates the wave of infrastructural investment that induces the attainment of full growth potential, through accelerated diffusion and ultimate generalization of the paradigm. It is a period of bandwagon effects, when one after another all productive units-and even social activities of all kinds-tend to apply what is then generally considered as the 'optimal or ideal form of productive organization'. A particular form of growth stabilizes; a particular way of life takes shape for the different segments of the population; a set of international investment production and trade patterns evolves; (utterly) refined statistical models of the economy can be made-and *can work*; economic science can develop with relative confidence with *ceteris paribus* assumptions; the trajectories of a large cluster of technologies become 'common sense' and seem to belong to the 'nature of things'; state policies, be they *laissez faire* or Keynesian or whatever, are seen more as objects of refinement than of radical change because their effectiveness seems to have been 'demonstrated'.

Now, if we remember that the technological style that is then in the process of generalization throughout the system had been introduced during the previous wave, shifting investment of large firms into those branches that have now become the 'carrier' and 'motive' branches, or allowing the appearance of new firms that quickly reach high growth, we can reasonably assume that it is in these branches that the first symptoms of exhaustion of the technological trajectories will be felt.

Presumably then, these would be the most likely to start searching within the large universe of the technologically feasible, though perhaps not yet the economically profitable, for new products and new processes that are either labour- or materials- or capital-saving, or seem to offer potential growth prospects. Some of these may result in outright fiascos, others would be the early prototypes of a possible future technological style, placing a strong demand and possibly high investment in developing the cost-cutting possibilities of the possible future key factor.

Presumably also, since the limits to a particular technological trajectory tend to translate for the firm into a reduction of the rate of profit or-a similar phenomenon-in a decrease in the expected rate of return from further investment along the same lines, the search for new profit opportunities might not be directed at investment in risky technological innovations but rather towards mergers and acquisitions or less orthodox speculative activities in whatever is found suitable in the particular period. From the mid- 1960s to the early 1970s there were waves of mergers as well as of speculation with money and raw materials;

there was persistent recourse to refined manipulation such as 'transfer pricing' and 'leads and lags' in international payments, as well as to developments such as 'tax havens' and other non-productive disruptive practices.

Here a brief reference to Mensch's<sup>7</sup> approach to the theory of long waves should be made. For him investments in alternative types of capital goods are made as a result of "systematic downgrading in operative value" of existing fixed capital in plant and equipment. We fully agree with this contention but part company with him, following Freeman, Clark and Soete<sup>8</sup>, when it comes to the difference between process innovations and product innovation. Whereas Mensch holds that basic innovations are made in the depths of a downturn, we would contend that the main process innovations (together, we would add, with those associated with the key factor and the main new organizational paradigm) could well have been made during the later part of the upswing and the beginning of the downswing. So, by the time depression arrives, the new generation of equipment and the organizational pattern that accompanies it, is already in the market, and what occurs is the application of this equipment mainly to product innovations. It is then vital to distinguish between the initial diffusion of a technological style which is made with 'idle' capital in a period of prosperity (and can be as primitive and costly and risky as Rosenberg<sup>9</sup> suggests) and the further diffusion of a tested technological style which is the most natural investment choice in a period of depression, if and when new investment is to be made in those conditions.

Thus our contention is that once the initial successful crystallization of the main elements of the new set of technologies has taken place, the peak of the Kondratiev is produced, as the conjunction of the attainment of the old best productive frontier by most of the economy (including the laggards) and a certain degree of diffusion of the new paradigm-within the old mould.

Thus, the peak of the long cycle is a kind of economic frenzy of a relatively short duration, but appearing as the promise of everlasting upward progress, while the old branches are still joining the bandwagon and new products and processes associated with the emerging technological style produce one big success story after another. This situation creates unwarranted expectations as to the health of the system and its unlimited opportunities, and it also tends to give undue confidence in the institutional mechanisms, reinforcing their rigidity and inertia. It is in the midst of such high growth that the seeds of the contraction are sown.

## Downswing characteristics

The descent of the Kondratiev wave sees the exhaustion of the new product and process investment opportunities associated with the prevailing technological style at the same time as the exhaustion of the technological trajectory of the carrier branches (even as their output may continue to grow with inflationary trends). These events affect the motive branches, whose capacity to continue maintaining the relative cost advantage of the key factors is reduced, not only for similar technical reasons but also by the very fact that their main sources of market growth are contracting.

At the same time, those segments of business whose growth potential had seemed unhampered and those of labour, whose job and earnings prospects had been more or less 'guaranteed' during the upswing, are the hardest hit (a shift which might, by the way, hint at why they tend to support 'strong' solutions to return to 'order').

As the various disequilibria manifest themselves in the various markets (labour, inputs, money, equipment) as a result both of the contraction in the old dynamics and of the unexpected market trends generated by the new investment patterns, more and more pressure is put on the state to find new means of stimulating and 'managing' the economy. The Keynes and the Schumpeters offer radically new theories and the Roosevelts and the Hiders establish radically new economic and political management mechanisms, while many others just offer to apply sternly more of the same old successful recipes.

The downswing is then a period of experimentation at all organizational levels of society, characterized by the proliferation of reassessments, proposed solutions and trial-and-error behaviour stimulated by the increasing gravity of the crisis. All this occurs in the face of the weight of tradition, of established ideas, of vested interests and other inertial forces which actively oppose the required transformations.

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<sup>7</sup> G. Mensch, Ch. Continho, K. Kaasch, "Changing capital values and the propensity to innovate", *Futures*, 13 (4), August 1981, page 283.

<sup>8</sup> C. Freeman, J. Clark, L. Soete, *Unemployment and Technical Innovation: A Study of Long Waves and Economic Development* (Frances Pinter, London, 1982).

<sup>9</sup> Rosenberg and Frischtak, *op cit*, ref 2, pages 10- 11.

For the working population it is generally a period of great suffering, as it is they, together with the weaker countries on the international level, who tend to carry the burden of the reaccommodation of the system. Meanwhile, on the economic level, the firms that are able relatively to escape the crisis are those linked to the production or use of the new key factor, which becomes more and more visible in the relative cost structure. It is towards these areas that new investment tends to go, intensifying the disruptive effects of the new technological style and sending signals in all directions for the adequate social and institutional changes required.

## Patterns and processes of transformation

We have defined a technological style as a kind of paradigm for the most effective organization of production, and have also suggested that this generates a particular pattern of interbranch relationships related also to the distribution of production between large and smaller firms. We now want to add that each technological style generates a typical pattern of transformation in the occupational structure, and a set of distinct trends in the spatial distribution of production on the international and national scales<sup>10</sup>.

We concentrate below on the way the occupational structure is affected by the paradigm shift and its diffusion. For ease of presentation we make use of the specific example of the 'assembly line' technological style which in our view shaped the fourth Kondratiev upswing.

The chain of relationships important for our purposes is represented in Figure 1. First, we briefly discuss what is meant by each of the elements and relationships indicated.

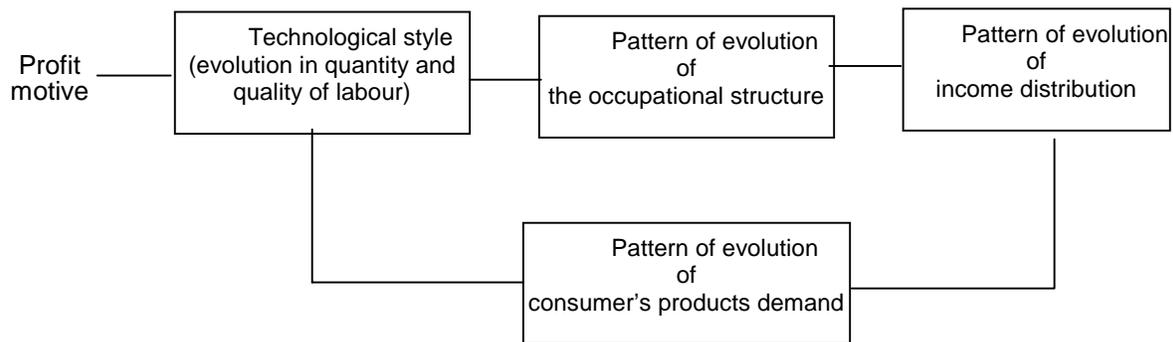


Figure 1. Chain of relationships

The profit motive should encounter no difficulty when presented as the propelling force and the organizing principle of the capitalist system. In this particular chain of events, however, it has been singled out as the criterion for choosing a particular type of equipment and a specific form of organization of production taking into account the existing pattern of available technology, opportunities, and especially of relative factor costs, including the evolution of the key factor we defined before and of the various skill segments of the labour force.

While the profit motive is the propeller, the technological style is the steering mechanism. In the chain of relationships now under analysis, we focus on its optimal paradigm for the usage of labour both in quantity and quality, ie on the 'ideal skill mix' in relation to the total mass of wages and salaries.

## Taylorism-seeds of the Fourth Kondratiev

As an illustration, we look at the historical moment at which the seeds of the recently prevailing paradigm were sown-when Frederick Winslow Taylor transformed the productive organization at the Bethlehem Steel yards at the turn of the 20th century. This event can be considered as the invention and first introduction of that particular social *and* institutional innovation *within* the productive sphere.

<sup>10</sup> We believe that each new technological style, being based on a shift in the general relative cost structure, provokes a corresponding change in the pattern of international relative cost advantages. However, this point is not pursued further in this paper.

## Occupational structure

According to Taylor's description<sup>11</sup>, over 500 labourers worked at different tasks in the yard, in gangs of anywhere up to about 75 men, each group under a foreman. Management merely indicated to the foremen what was to be done and trusted the experience of both foremen and workers (who often used their own tools) to do the job in their own way. Three years later there were only 140 labourers in the yard, each accomplishing the work previously done by three or four men but now with standardized, carefully designed company tools, and following strict standardized procedures determined by time and motion studies<sup>12</sup>. A planning room carefully prepared the following day's work for each individual worker and coordinated all movements in the yard. It was staffed with engineers, time and motion men, draughtsmen, a clerical staff, a telephone and messenger system, etc. The single group-foremen had been substituted by a set of functional overseers who coordinated, trained, timed and measured work and in general acted as the agents of the planning department.

The new organization, despite the new planning and toolroom expenses, despite the much higher salaries of the new white-collar staff, and even though the wages of the remaining labourers had been increased by 60 %, more than halved the cost of handling a ton of metal, from 7.2 cents/ton to 3.3 cents/ton<sup>13</sup>. And the new scientific management techniques yielded equivalent cost-cutting results when applied to everything from bricklaying to ball-bearing quality inspection and to machine-shop work.

Although Taylorism is only the seed out of which continuous massproduction evolved as a fully fledged technological style, even in its earliest form, it serves the purpose of our present analysis. It is not difficult to imagine how, with such results, the profit motive would propel the application of scientific management techniques. Then, as one firm after another reduces the usual size of its work force in relation to output and transforms its composition, new trends can be expected to become gradually visible in the total occupational structure. The truly magnified effect historically occurred of course with the diffusion of Ford's assembly-line style, combined with the internal combustion engine and low-cost oil. But let us follow the logic of Taylor's innovation for the sake of simplicity.

The diffusion and generalization of a technological style implies a transformation in the occupational profile of the working population along certain main trends. It is a dynamic and not a static pattern. It can best be understood as a set of different growth rates for different categories, resulting from the prevailing direction of changes in the organization of production. This type of transformation has, of course, many important social and labour market implications, which are not pursued in this paper.

Following our illustration through, the growth of a new layer of white-collar workers between managers and foremen, and the reduction of the number of manual labourers required for a given output, introduce a new pattern of evolution in the occupational structure. Initially, the old trends are not eliminated, for much of the growth in the aggregate takes place along traditional lines. The new trends appear simply as counter-trends, curb in g and transforming the lines of the old pattern. Yet each business cycle serves to filter out the old and strengthen and accelerate the application of the new style and the visibility of its consequences on the occupational structure of employment (and of unemployment!).

## Income distribution

But this change in occupational structure is accompanied by corresponding trends in income distribution. In Taylor's first experiment the salary mass was more than halved while the workforce was cut to less than a third. However, the main change was in the distribution of the globally reduced labour costs. From a three-layer structure of managers, clerks and foremen, and labourers, translating into about one high and one medium salary for every 70 to 80 lowwage labourers, the new organization implied a complex hierarchy of salaries. The ranks of the 'middle-income' groups began to swell. just as the salary mass was being cut and being redistributed within the enterprises, the income mass in the form of wages and salaries was being redistributed in society at large (and many were getting nothing at all).

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<sup>11</sup> F. W. Taylor, *The Principles of Scientific Management* (Norton, NY, 1967).

<sup>12</sup> We might note in passing that 'standardization' was a key concept in the prevailing paradigm of the third Kondratiev within which this very influential organizational innovation was born.

<sup>13</sup> Again, we might note that we had suggested low-cost steel as the key factor in the third Kondratiev, so any cost-cutting improvements in the motive branch producing it contributed to the upswing.

## Product demand

Again, the evolution in the income distribution translates into changes in the pattern of product demand. In our illustration, the new income distribution makes headway in a market sharply divided into luxury and staple goods (food, clothing and rent). The traditional middle class—the small proprietors and the educated few—consume from (and often cater to) both markets. Now gradually the staple markets begin to shrink relatively and a new middle-range demand pattern emerges and tends to grow.

But how does this affect the diffusion of the technological style as indicated in the diagram? At first, we can assume that the new middle layer of salaried workers grows slowly and joins the ranks of the traditional middle class in market behaviour. After all, people choose what to buy from what is available. But the particular evolution of market potential and market stagnation does not go unnoticed by producers. However faulty the information at hand may be, under the conditions we have been following, it is unlikely that an entrepreneur would launch a new investment to cater to a dwindling market such as cotton textiles, for instance. Instead, he might apply the new potential for productivity increase to turning a luxury good into one accessible to the growing middle layer, which is what Ford set out to do with his Model-T, and many others after him.

## Transformation process

Thus, the diffusion of a new form of organization of production requiring a new skill profile, translates into changes in income distribution which, in turn, affect the pattern of demand, signalling to producers the general characteristics of the new types of products which would both cater to the growing markets and be capable of being produced with the new technological style through which the process becomes a gradually accelerating feedback loop. This constant propagation increases the disruptive effects in the downswing and the harmony in the upswing.

Thus, the introduction of the assembly line as the optimum extension of 'scientific management' contained the crystallization of a change of paradigm for the manufacturing of discrete products along the continuous-flow concept of the chemical industries. It also implied a change in occupational structure, which tended to make blue-collar labour more homogeneous and ultimately led to a restructuring of the skill-based trade unions to the branch-based labour unions, while it created a pattern of growth of white-collar labour in an increasing hierarchy. It eventually led to a transformation in the product structure, where mass-produced energy-consuming durable consumer goods made with energy-intensive materials would be gradually introduced into the sprawling suburban homes, which the automobile itself and the expansion of the road network, together with the increase in 'middle-range' incomes made possible.

As Landes<sup>14</sup> so well expressed it, "The motor car industry was beginning to play . . . (by the end of the interwar period) a role analogous to that of the railroad in the mid-nineteenth century: it was a huge consumer of semifinished and finished intermediate products . . . and components . . . ; it had an insatiable appetite for fuel and other petroleum products; it required a small army of mechanics and service men to keep it going; and it gave a powerful impetus to investments in social and overhead capital (roads, bridges, tunnels). At the same time, it posed new technical problems in metallurgy, organic chemicals, and electrical engineering, eliciting solutions that had important consequences for other industries as well".

Thus, there was an accelerated process of diffusion in the main carrier branch, spurred by and spurring the oil industry, already run by a few giants, and rapidly finding lower-cost sources in Mexico, then Venezuela and South-East Asia (although the radical cost-cutting was to be made possible by the 'freeflowing' light oil from the Arabian Peninsula in the 1930s). From a peak average of \$2.00/bbl in the war and afterwar period (1915-20), the price of oil decreased to an average \$1.35/bbl in the 1926-30 period and to \$0.83/bbl in the postcrash years (1931-35). The average price of electricity in the USA, on the other hand, had fallen 41% by 1928 with respect to 1902 (or 31% in constant terms).

## Mass production technological style

We thus suggest that in the 1910s and 1920s, the technological style that shaped the fourth Kondratiev mode of development with its carrier and motive branches and its typical skill profile was already emerging and diffusing.

Both massive oil production and assembly-line technology were US-based, and the fastest rates of growth in electricity production and in radio and car sales took place in the USA. The greater weight of the

<sup>14</sup> D. S. Landes, *The Unbound Prometheus* (Cambridge University Press, 1972), page 442.

old style and the divided markets of Europe seemed to inhibit the achievement of the full potential for mass production of identical units inherent in the new style. The USA had all the conditions for proceeding unhampered to become the world centre of the new mode of development<sup>15</sup>.

But to make the transition from a system based on the growth of steel, capital goods, heavy electrical equipment, great engineering works (canals, bridges, dams, tunnels) and heavy chemistry, mainly geared towards big spenders, such as other capitalists or governments, into a mass production system catering to consumers and the massive defence markets, radical demand management and income redistribution innovations had to be made of which the directly economic role of the state is perhaps the most important.

The big upswing of the world economy after the second world war was then a period in which there was a good 'match' between the requirements of a mass production technological style, based on the almost universal availability of cheap oil, and the social and institutional framework within which this technological style could flourish. But this good 'match' was only achieved after a period of deep depression and social turmoil in the 1930s and after a major world war. During the 1930s, it was by no means clear how to achieve a set of appropriate institutional and social responses. As already indicated, the solutions which were then advocated and applied varied across a wide range from fascism to the New Deal and Communism<sup>16</sup>. It was only after the second world war that gradually a mode of development crystallized in the leading industrial countries, which did create the necessary harmonization of institutional framework with technological style.

## Socio-institutional structures

Among the main institutional changes which promoted this good 'match' were, on the national level, the major expansion of the role of the state in economic life. The Keynesian policies which, in one form or another, were adopted by most countries led to various demand management mechanisms both directly through infrastructural, defence and public service spending, and indirectly through income redistribution by means of taxation, interest rate management and massive government employment. More indirect but equally essential for demand management was the elaborate public statistics apparatus, which served both public policy and private investment and market forecasting.

Another important socio- institutional change was the rapid expansion of massive secondary and higher education to provide the enormous increase in requirements of 'white-collar', technical and clerical employees, together with the expansion of the various national forms of public health systems. Both were also great sources of employment and hence of income redistribution.

On the more directly economic level innovations such as large-scale consumer credit methods, and the expansion of publicity, the mass communications industry and the various forms of planned obsolescence, further increased the means of orienting the use of disposable income into intensive consumption of the various goods typical of the mass-production style (and later also of those which became the forerunners of the style to come).

The institutional acceptance of the labour unions as legal representatives of the workers (especially in the carrier branches) both fostered the growth of disposable income and stimulated the application of labour-saving incremental innovations, within old plants or in new investment, along the trajectory of the technological style. In general, the evolution of non-union labour wages tended somewhat to follow the trends set by union labour. Thus, one could consider it as an indirect form of demand management.

At the level of the firm, a new 'ideal type' of organization for giant firms emerged with horizontal integration and a complex managerial system which allowed reaching optimum plant size under a much larger optimum size of firm. Its workings were thoroughly described by Peter Drucker<sup>17</sup> in *The Concept of the Corporation*, based on his study of General Motors. Accompanying this organization was the in-house R and D laboratory, which earlier had only developed as a necessary feature of such science-based industries as chemistry and electricity, but could now serve the controlled and sophisticated forms of competition which came to characterize oligopolies.

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<sup>15</sup> This heavy early commitment and the consequent full adaptation to that particular technological style might help explain why today a country like Japan finds it easier to embrace the new style and make the institutional changes required, than the USA.

<sup>16</sup> As far as the mass production technological style that subtends these widely differing institutional and social arrangements there are no discernible differences, which serves to illustrate the vastly diverging range of alternatives opening before society at each critical phase.

<sup>17</sup> P. F. Drucker, *Concept of the Corporation* (Mentor, NY, 1972).

This particular development was a crucial element of the 'military-industrial complex' which, following the prototype of the Manhattan Project which produced the A-bomb, brought state, scientific, technological and industrial efforts to focus on pre-defined goals, eliciting a flurry of innovation requirements for new materials and processes which could later spin-off from military to civilian uses, once their primitive more costly stages of development had been borne by defence contracts.

On the international level, the Bretton Woods Agreement established a solid basis for the regulation of intercountry trade and investment (recognizing the hegemony of the USA in the new arrangement) and the Marshall Plan stimulated general international growth of investment and markets. Decolonization broke the empire-based barriers on investment and trade and allowed the energy- and materials-producing motive branches from different developed countries to establish more flexible competition arrangements to use the low-cost sources available in the developing countries. At the same time, the massive market growth needs of the technological style provoked an increasing number of 'common market' type agreements, as well as the 'local subsidiary' response of the carrier branches to the developing countries' tariff barrier policies. However, most international institutions and especially the UN organization were more of a facilitating nature than actually 'managing' economic growth, when compared to the main national institutions.

This impressionistic and incomplete list of the social and institutional innovations of the fourth Kondratiev mode of development, can be also considered-if our hypothesis about long waves is an acceptable approximation to the way the process evolves-as a list of obsolete mechanisms as regards the effective institutions required to unleash the upswing of the fifth Kondratiev based on microelectronics.

## Institutional requirements for the next upswing

According to the foregoing hypotheses, the social sciences would today have a tremendous job of disentangling the new trends generated by the already established technological style, with its family of interrelated technologies and more or less visible trajectories, from what are in fact either waning trends, due to the exhaustion of the old paradigm, or temporary responses, which will disappear once the transition is effected. In a sense, during the upswing we are dealing with statistical distributions where the 'mode' tends to coincide with the 'mean', but in downswings and crises we deal with bimodal distributions where the 'mean' aggregate *means* very little. Again, during the upswing qualitative factors can be relatively ignored in quantitative measurement, whereas interdisciplinarity and qualitative case study type research is indispensable during downswings.

In particular the precise detection of the characteristics of the new paradigm is essential to point to the institutional solutions which, at the same time as they open the way for the generalization of the new paradigm, find the appropriate solutions to make the lot of those who would have been its inevitable victims less painful or even better.

This is not to say there is a one-to-one correspondence between the general characteristics of the technological style and those of the adequate socio-institutional framework. We have already emphasized that there can be a wide range of scenarios, all valid as far as making high rates of growth possible, but vastly different as to their social consequences, as indeed was visible in the previous trough in the 1930s. Furthermore, the direction in which the technological trajectory of the new style will be exploited is not predetermined either, except in the general range of its possibilities. With these warnings in mind, one can nevertheless point out some basic elements, stemming from the essential features of the new technological potential and which are likely to characterize whatever valid alternatives are applied.

One of these elements stems from the fact that the new style seems to have a strong transnational dimension, based on the provision of the unprecedented data-management capabilities and telecommunications infrastructure for the efficient management of giant, complex, flexible, transnational conglomerates, which allow maximizing long-term profits and optimizing factor use on a planetary scale. So, national 'solutions' of the kind we grew accustomed to in the waning Kondratiev, seem ill adapted to manage an economy based on the new paradigm.

Another element pointing towards the need for a supranational framework is the enormous potential increase in plant scale for certain types of products. The radical productivity increases possible with computer-aided design and manufacturing, numerical control and distributed intelligence in the erstwhile less productive 'craft' technologies for the batch manufacture of capital goods, allow enormous increases in plant scale, where size of plant is not necessarily equivalent to size of market for one product but for a large, changing family of products. And these possible increases can, in that and other branches, involve the integration into one continuous process of various intermediate products, together with the final flexible

output, increasing the scaling-up potential. In the production of services, especially information and telecommunications, it is even more evident that the larger the market and the wider the coverage, the lower the unit cost and the larger the stimulus for the flourishing of the multiple investment opportunities that take advantage of the availability of these decreasing cost services.

The particular potential for flexible product mix and relatively quick changes in product design would allow the application of rapid obsolescence practices in capital goods (and software) for the office and for the production of goods and services. So, whereas mass production markets grew on the basis of personal income and defence expenditures, flexible capital goods production with constant upgrading of technology and software, would thrive with the proliferation of small- and medium-sized producers in developed and developing countries.

Again, since the technological style favours information- intensive products and services for both producers and consumers, the opening of an everincreasing range of 'bandwagon' application opportunities might depend on the growth of a massive world telecommunications infrastructure<sup>18</sup>.

Thus, the new potential for giant firms and very large-scale production in certain key areas, coupled with the opportunities for 'induced' decentralized production in other branches, indicate that national markets are a hindrance to full deployment. Thus, in one form or another, supranational management mechanisms seem necessary, among which some kind of international income redistribution system would appear as the basis for the appropriate, sustained market growth.

In recent years proposals have been heard for international Keynesianism, worldwide 'Marshall Plans', a new international economic order, industrial redeployment and other sorts of supranational arrangements. Yet most governments, especially in developed countries, still seem to place hope on nationally bound mechanisms.

As far as social organizations are concerned, there are two particularly worthy of note: the ecological movement and OPEC. The new technological style is fundamentally materials- saving. We consider only a few of its characteristics. It allows unprecedented downsizing of most products, reduces waste, permits production to closer tolerances, controls energy use, eliminates many moving parts, opens the possibility of closed-loop no-waste systems, etc. At the same time, in an indirect way, its full deployment would tend to fulfil many needs with services rather than products, and substitute much physical transportation with telecommunications while drastically diminishing paper consumption. Hence many demands of the ecological movement, which are in fact a rejection of the materials -intensive, energy- intensive waning style, can be met with a further diffusion of the applications of microelectronics. At the same time, the high cost of energy and materials should do nothing but stimulate investment in such applications. Thus the ecological movement can, at least in part, be seen as one of the forces contributing to the replacement of the 'old' style. Equally, OPEC, far from being the culprit of the crisis, might in fact be the prototype for a social organization of raw materials producers which, in a double role analogous to that of labour unions in the fourth Kondratiev, would serve as a stimulus for furthering the new technology along its trajectory and as an indirect income redistribution mechanism.

Concerning the occupational structure, the new technology seems to produce a centrifugal distribution with rapid growth of the highly qualified top of the scale and of the rapidly trained material or information feeders, panel watchers, button pushers, etc. This is in strong contrast with the rapid growth of the middle range in the previously prevalent technological style. Consequently, if states are efficiently to solve the technical unemployment problem, the focus would have to be placed on the middle strata, both for recycling and for creating conditions for the growth of the appropriate small and medium firms (organized perhaps by the displaced middle managers), capable of generating employment for qualified workers and markets for the office and production equipment producers.

Overall though, a very salient characteristic of the new technological system is its capacity to cope with variety, diversity and dispersion at all levels, as opposed to the prevailing need for 'massification', homogenization, and agglomeration typical of the paradigm about to be replaced. This might mean that the range of valid scenarios is particularly wide and furthermore, that these might be capable of accommodating an even wider range of social choice and institutional arrangements at the micro level.

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<sup>18</sup> This sort of two-tier arrangement can be seen as somewhat analogous to the third Kondratiev, when large producers hardly ever catered directly to consumers but rather, using the low-cost steel of the motive branches, concentrated their growth in large infrastructural works, heavy chemistry and equipment goods in the civil, mechanical and electrical engineering carrier branches, while electricity, small motors and power tools allowed deconcentrated production for consumer and other smaller-scale markets.

Whether these are some of the correct conclusions or not, only further research and practical experimentation can tell. Under present conditions, optimism is on very shaky grounds but, if our hypotheses seem plausible, then it can only be grounded on the capacity to accept change and to innovate boldly on the social and institutional spheres and, we contend, on a planetary scale.