INNOVATION AND LONG CYCLES OF ECONOMIC DEVELOPMENT

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1. LONG CYCLES AND TECHNOLOGICAL CHANGE

It would be astonishing if the experience of the 1970s and 1980s had not given rise to a revival of interest in theories of long cycles and long waves in economic and social development and indeed this has occurred. Economists generally refer to these long-cycle theories as Kondratiev cycles or Kondratiev long waves after the Russian economist who perished with many others in Siberia in the 1930s. Before his premature death, Kondratiev did more than anyone else to analyse and popularise the Idea of long cycles. However, it is true that he was not the originator of the Idea. There were many others who even before the First World War pointed to na apparent tendency for long-term series of prices, interest rates and trade to follow a cyclical half century pattern. Among them were Pareto, Parvus, and the Dutch Marxist, van Geldern (Barr, 1979).

Any explanation of the underlying process structuring the current economic crisis must, in particular, take into account the theory of long cycles advanced by Joseph Schumpeter (1939), who more than any other 20th century economist attempted to explain growth largely in terms of technical innovation. He suggested that the first long cycle of economic development was based on the diffusion of the steam engine and textile innovations in the latter part of the 18th century; the second, largely on the railways and the associates changes in the mechanical engineering and iron and steel industries; and the third on electric power, the internal combustion engine and the chemical industry. Interestingly, a personal comment on the relevance of Schumpeter´s ideas came recently from Paul Samuelson (1981), certainly the economist best known to undergraduate students in the post-war period. Appropriately enough, in the Japan Economic Journal last year he wrote:

“no-one can predict the future with confidence. Still it is my considered guess that the final quarter of the 20th century will fall far short of the third quarter in its achieved rate of economic progress. The dark horoscope of my old teacher Joseph Schumpeter may have particular relevance here. When I was a precocious student I didn´t think much of Joseph Schumpeter ´s futurology. But, like Mark Twain, who said that when he was 14 he thought his father was awful dumb, but by the time he reached 21 was surprised at how much the old had smartened up, when I re-read Schumpeter´s Capitalism Socialism and Democracy I find new meanings in it.”

In Schumpeter’s theory, the ability and initiative of entrepreneurs, drawing upon the discoveries of scientists and inventors, create entirely new opportunities for investment, growth and employment. The profits made from these innovations are then the decisive impulse for new surges of growth, acting as signal to swarms of imitators. The fact that one or a few innovators can make exceptionally large profits, which they sometimes do, does no of course mean that all the imitators necessarily do so. Nobody else made such profits from nylon as Dupont, or from computers as IBM; indeed many woud-be imitators made losses. This is an essential part of the Schumpeterian analysis. When the bandwagon starts rolling some people fall off, profits are gradually ‘competed away’ until recession sets in, and the whole process may be followed by depression before growth starts again with a new wave of technical innovation and organizational and social change.

Whereas in the Keynesian framework the emphasis is on the management of demand, with Schumpeter it is on autonomous investment, embodying new technical innovation which is the basis of economic development. In such a framework economic growth must be viewed primarily as a process of reallocation of resources between industries. That process necessarily leads to structural changes and disequilibrium if only because of the uneven rate of technical change between different industries. Economic growth is not merely accompanied by fast growing new industries and the expansion of such industries; it primarily depends on that expansion.

Schumpeter justified on three grounds his view that technical innovation was more like a series of explosions than and incessant transformation. First, he argued that innovations are not at any time distributed randomly over the whole economic system, but tend to be concentrated in certain key sectors and their surroundings, and that consequently they are by nature lopsided and disharmonious. Secondly, he argued that the diffusion process is also inherently an uneven one because, first a few and then many firms follow in the wake of successful pioneers. Kuznets (1930) had already emphasized the cyclical pattern underlying the growth of new industries. Product life-cycle theory and international trade theory have since confirmed these insights: a hesitant start, fast growth and subsequent saturation followed by decline or stagnation constitute the main phases in the cycle. Finally, Schumpeter stressed that changing profit expectations during the growth of an industry are a major determinant of this sigmoid pattern of growth. As new capacity is expanded, at some point (varying with the product in question) growth will begin to slow down. Market saturation and the tendency for technical advance to approach limits, as well as the competitive effects of swarming and changing costs of inputs, all tend to reduce the level of profitability and with it the attractions of further investment. Exceptionally this process of maturation may take only a few yars, but more typically it will take several decades and sometimes even longer.

Schumpeter maintained that these characteristics of innovation imply that the disturbances engendered could be sufficient to disrupt the existing system and enforce a cyclical pattern of growth.

Hardly anyone would deny the first of Schumpeter's propositions: it is confirmed by a great deal of empirical observation and research as well as everyday commonsense. The difference between rates of growth in different branches of production are well-known and obvious, as is the fact that some industries decline while others grow rapidly. Moreover iti is now universally agreed that these structural changes are related to the flow of technical innovations. Energy and transport systems are obvious cases in point. The most R&D intensive industries are by and large the fastest growing. Most of them did not exist at all before this century. With industries such as electronics, aerospace, drugs, scientific instruments, synthetic materials, it is fairly clear that these extremely high growth rates were closely related to a flow of clusters of technical innovations. At the other extreme are industries in the process of decline or stagnation, with very little or zero R and D and in which much of the technical innovation that does take place comes from outside, from the suppliers of machinery, equipment and material.

As Kuznets (1940) pointed out, whether or not the very rapid growth of new leading sectors of the economy and new technologies offers a plausible explanation of long term cycles in economic development depends crucially on whether some these innovations are so large in their impact as to cause major perturbations in the entire system – as, for example, can plausibly be argued in the case of railways – or on whether such innovations are bunched together systematically in such a way as to generate exceptional booms and spurts of growth alternating with periods of recession. In view of this, exceptional interest attaches to the work of Gerhard Mensch, who in his book Stalemate in Technology (1975) attempted to demonstrate precisely such bunching and discontinuity in what he called 'basic' innovations. In his theory, bunches of basic innovations occur in the decades of deep depression. Mensch identified three such decades in his book: the 1830s, the 1880 and the 1930s. He claimed that various studies provided independent evidence of strong bunching of innovations in those decades. He also predicted a similar bunch of innovations in the 1980s.

The theory has two parts: the first argues that depressions (deep not minor recessions) induce basic innovations. According to Mensch, they do this because during deep depressions certain firms have no alternative but to try something completely new: they cannot any longer go on in the old way and therefore take up ideas which previously seemed impossible or not worth pursuing. For this reason, basic or radical innovations cluster in the deep depression decades. The second part of his theory relates to the periods of high boom. In such periods the basic or radical innovations are, according to Mensch, crowded out; people are too busy developing existing technologies and industries and consequently innovation shifts towards what he calls 'Schein-innovationen' (product differentiation and pseudo-innovations).

At first sight, this theory appears attractive and seems to fit rather well into a Schumpeterian framework. It was for this reason that we have at SPRU tried to test the theory and develop it further. Unfortunately, we have found the empirical evidence we could muster does not really support the theory. Mensch relies very heavily on lists of innovations compiled during the

1950s, for example from Jewkes' (1958) book on The Sources of Invention and Schmookler's book on Invention and Economic Growth (1966). These lists cannot possibly provide satisfactory evidence, as Mensch claims, of the relative flow of innovation in the 1950s and of course they do not even begin to look at the innovations of the 1960s. Often we do not know which are the really important innovations of a decade until some time after that decade has finished.

The empirical evidence for Mensch's theory can shown to be weak in other respects, too. SPRU has over the last few years developed a data bank on innovations spanning several decades (Townsend et al, 1981). As yet this work is not complete; our data set is provisional and does not cover all sectors. However, with the generous help of a large number of technical experts from both industry and government, we have now reached the stage of identifying about 200 of the more basic or radical innovations from a much larger total sample. This evidence does indeed show a peak of basic innovations in the 1930s, but also another peak in the 1950s and a further peak in the 1960s, so that the basic innovations appear to be spread much more widely in the most recent long-wave upswing than Mensch has suggested.

Nevertheless, we did find that there was a change in the nature of the innovations between the 1930s, the 1950s and the 1960s. Whereas in the 1950s the majority of innovations were basic product innovations, in the 1960s and 1970s they were mainly process innovations. The latter would become more attractive to entrepreneurs in periods of pressure on profit margins and during the downswing of long waves and even in depressions. So far as product innovations are concerned, the evidence does not support the notion that it is deep depression which induces innovation. None of the Jewkes case studies on which Mensch relies mentions the fact that depression stimulates innovation. On the contrary, some of the studies mentioned that depressions held back or limited the work, while ten of the studies mention a quite different factor acting as an innovation accelerator; these studies cover the jet engine, penicillin, radar, rockets, shell molding, silicones, titanium, tungsten carbide and computers. None of these studies mention depression as an accelerator, but rather war-time demand and/or government pressure and policies.

Reservation must in any case be expressed about the extent to which the acceleration of the gestation process of development is effective. Certainly there is some trade-off between cost and time and military crash projects have sometimes concentrated resources of high quality more quickly than would otherwise have been the case. However, there are clearly other cases where, despite the best efforts of R and D teams and lavish finance, specific technical problems could not be resolved. The cure (or cures) for cancer is an obvious case in point. In these cases the limiting factor is not the availability of development resources but the limitations of fundamental scientific knowledge. Basic research is even more uncertain than development and sometimes very difficult to accelerate. On the other hand, once a fundamental breakthrough in science is achieved, it may open the floodgates to a large number of new technical developments and innovati9ons. This seems to have been the case with macro-molecular chemistry in the 1920s through the work of Staudinger and Carothers; it seems to have been the case, too, with solid-state physics in the 1940s and 1950s and with biotechnology more recently.

So here again I would part company with Mensch, who maintains that science has no connection with the clustering of technical innovations. I would argue that there is a deep and extremely important connection between advances in fundamental science and technical innovations, albeit one that is difficult to relate to the state of the economy.

More fundamentally, in concentrating attention on the purely statistical aspects of enumerating discrete basic innovations, I believe that Mensch has actually missed the main point of Schumpeter's theory concerning the reciprocal effects of innovation and the state of the economy. The macro-economic effects of any basic innovation are scarcely perceptible in the first few years and often for much longer; what matters in terms of economic growth investment and employment, is not the date of the basic innovation, important though that may be for historians; what matters is the diffusion of basic innovation, the swarming process, the period when imitators begin to realize the profitable potential of the new product or process and start to invest heavily in that technology. This swarming may no necessarily occur immediately after a basic innovation, although it can do so if other conditions are favourable. Instead it may often be delayed for a decade or more until its profitability is clearly demonstrated, or until other enabling innovations, including social, managerial and organizational innovations, permit further advances. Once swarming does start, then it has powerful multiplier effects in generating additional demands on the economy for new capital goods, for components, for distribution facilities and of course for labour. This is turn engenders a further wave of induced innovations, of process and applications innovations, some of which may be more important than the original one. It is this combination of diffusion with related, induced and social innovations which give rise to expansionary6 effects in the economy as a whole.

Rosenberg has pointed out that the diffusion process of innovation cannot be viewed as one of simple carbon-copy replication, but frequently involves a string of further innovations, large and small, as an increasing number of firms become involved and begin to strive to gain an edge over their competitors. It will sometimes be the case that basic innovations which have a major impact in a particular long economic upswing will actually have first been made in a different Kondratiev cycle altogether. This will apply a fortiori to the international diffusion of technology and innovation. The main impact of the automobile on the US economy was in the third Kondratiev, but on the Japanese in the fourth. Detailed case studies of innovations often reveal extremely long gestation periods as well as large numbers of false starts. From this standpoint, the date of a particular basic innovation is less important than the interaction of a cluster of innovations with social and organizational change, which permits a market to grow rapidly or enables large amounts of capital to be raised and invested in new directions (whether through the public or the private capital market).System innovations are as important here as basic innovations.

Historians may argue or a long time when to date the railway as a basic innovation, whether 1817, 1825 or much earlier in the mines. But what mattered from the point of view of the economy (i.e. in terms of economic upswing and employment) was the development of a railway network and the enormous investment in the 1840s, 1850s and 1860 which led to many secondary innovations and to huge effects on the engineering and iron and steel industries. In this respect, the set of innovations which are diffused and exploited during a Kondratiev long-wave upswing will not only be those of the immediately preceding depression, but will also comprise some made earlier, some made during the depression and some made during the recovery and upswing itself. This explains why I would attach less importance to the purely statistical bunching of discrete basic innovations and much more to their linkage together in new technological systems.

Nevertheless, depressions may plausibly be held to bring about significant changes in the social and political climate (as opposed to business behaviour in firms). These in turn may generate conditions more favourable to the recovery and swarming process around older basic innovations which may have been introduced at various times in the past, but which are only able to flourish when the necessary social environment favours their adoption. This may be occurring at present in relation to the social and political conditions affecting telecommunications and information technology, as is shown for example in the Mercury project and satellite TV. The climate is clearly changing in Western Europe right now. Even in Britain, Informed opinion is beginning to favour the new public initiatives and investment (in turn attracting further large-scale private investment) which would enable these new technologies to take off.

2. RE-CONCEPTUALIZING INNOVATION THEORY

It is important to note here an important recent development of innovation diffusion theory. Following the first pioneering studies of the diffusion of industrial innovation by Williams (1958) (concerning tunnel ovens in the potteries), Mansfield (1961) and others developed in the early 1960s a standard model of diffusion. This model emphasised the role of profitability for potential adopters, the scale of investment required and the learning process within the population of potential adopters, as the main determinants of the diffusion process. But, as Gold (1981) and Rosenberg (1976) have pointed out, this model, although certainly useful for many purposes, neglects changes in the environment during the diffusion process (which may last decades) as well as changes in the innovation itself. What is being diffused at the end of a diffusion process may be rather different than that which started the diffusion process. For these reasons, Metcalfe (1981), Davies (1979) and others have recently developed new models of diffusion which take account of profitability for suppliers as well as adopters of innovations and which consider changes in the innovations during the diffusion process and changes in the social environment, all of which are extremely important. This means that the diffusion theory of earlier days is now linking up with the product-cycle and industry-cycle theories of the 1930s – the work of Burns, Kuznets and Schumpeter to which I have referred.

To relate together this extended set of arguments: the upswing of a long wave involves a simultaneous, explosive burst of growth in several major new industries and technologies. Such a take-off becomes possible only on the basis of the previous successful realization at whatever dates, of certain earlier basic innovations, such as the automobile and various electrical innovations in the 1880s and 1890s, or the computer, television, jet aircraft and families of synthetic materials in the 1930s and 1940s. The demonstration effect has to be on a sufficient scale and the social climate sufficiently favourable, to trigger Schumpeter's swarming process, with Rosenberg's caveat that diffusion is not simple replication but involves a further set of improvement and other related innovations. As the new industries grow, they generate a further set of process innovations linked in particular to the exploitation of economies of scale.

The early upswing of new industries often has an initial labour-intensive character, especially obvious in the early days of railways, passenger cars, electronics and computers. This generates a strong demand for labour, which is reinforced in turn by secondary and multiplier effects of the expansion on the economy as a whole. It may well be the case, as Forrester (1981), Tinbergen (1981) and Mandel (19 2) have all suggested, that additional long-wave generating factors are involved in the delayed response of the capital goods sector to the rapid expansion of demand in the new industries, thus requiring part of the increased output to be diverted to the expansion of the capital goods sector itself. Rostow (1978) has also suggested in his mammoth work on long cycle and economic development that similar lags exist in the response of the primary commodity and energy sectors to the demands of the long wave of expansion. In any event, the demand for labour typically becomes so strong at the peak of a long wave boom as to stimulate major flows of immigration (which occurred both in the period before the First World War and during the 1950s and 1960s), as well as facilitating the entry of new groups into the labour force, thus raising the female participation rate and even the return of older people to the workforce. Such changes in the labour market, with or without the intervention of trade unions, increasingly generate cost inflationary pressures. These are reinforced by the Hicks mechanism of comparability claims in the older less productive industries for wage and salary increases equivalent to those attained in the leading technologically-advanced sectors, which can afford the increases because of their high productivity growth rates, but which the traditional sectors cannot. Labour cost and other input cost pressures (Rostow has stressed the case of materials) combine with the Schumpeterian competition process to erode profit margins.

This pressure leads in turn to a shift of emphasis in investment, which changes from a simple capacity extension to rationalization and cost-saving investment. The pattern of investment in all OECD countries for the 1960s shows a shift from new capacity to rationalisation. The share of plant and machinery in total investment increases and the share of buildings associated with new factories diminishes. During the same period (i.e. well before the OPEC crisis of 1973) a marked change in the pattern of employment growth in manufacturing also became apparent. As the investment pattern changed, so0 employment growth leveled off and finally began to decline, in Germany as much as Britain.

The change in general levels of profitability is a important factor in the behaviour of the system, both at the upper and lower turning points of the long wave. At the upper turning point, it stimulates the search for labour and other cost-saving innovations and technical changes. But the time lags involved mean that it may take between five and twenty years for the full effects of such technical changes to work their way through the system. The search for energy-saving innovations has been intense in the 1970s, but it is only in the 1980s that their effects are being widely felt. There are lags both in the R and D system and in the implementation of available through rationalizing investment.

At the lower turning point, in addition to social innovations and government policies enabling new technologies to take off, other political and social changes can be important in providing the necessary stimulus to set expansion under way. They may take a variety of different forms, from measures to weaken the bargaining powers of unions, rearmament or protectionism, or more benign policies designed to restore incomes discipline and profitability, or, as Mandel proposes, complete system changes. As Salvati (1982) has pointed out, Kalecki's (1943) far-sighted prediction of the political effects of the adoption of Keynesian full employment policies after the Second World War had both a short-term and a long-term aspect. In the short-term it gave rise to the familiar 3-5 year electoral business cycle during the long wave upswing. In the longer term it undermined the basis for sustaining such short booms and led to more fundamental social and political tensions in the Kondratiev downswing, involving the partial abandonment of Keynesian techniques themselves. An industrial relations and political long cycle thus corresponds to the economic long cycle.

In this long wave context, many puzzles and paradoxes of innovation theory fall into place: for example, the age-old argument over 'demand-pull' versus 'technology-push'. Proponents of demand-pull theories of innovation have stressed the results of case studies and surveys which apparently showed that identification of customer requirements in the market is the vital ingredient of successful innovation. Schmookler (1966) provided more general evidence using statistics purporting to show that the number of patents in various American industries followed, rather than preceded the surges of investment in those industries. However, critics such as Mowery and Rosenberg (1979) pointed out that the theory was unsatisfactory in relation to the more radical innovations; one could not speak seriously about market demand for products which were so novel that the market had no knowledge of them and no means of evaluating them. They and others stressed instead the role of fundamental advances in science and in technology itself, for basic innovation. In the early day of a new technology they are surely right, but for the large majority of follow-up inventions and innovations, Schmookler may well be correct. There is an interesting parallel here between Kohn's 'paradigms' in fundamental science and technological 'paradigms' (Dosi, 1982).

An illustration of this point comes from the most important 20th century innovation, the electronic computer. Most of the early prototypes of electronic computers were designed and developed during the 1940s at various British and American universities and one German university – Charlottenburg Technical High School – as well as in Government laboratories. In these early days, work on computers was sustained by the enthusiasm of those scientists and engineers most closely involved and by the long-term patient sponsorship of a variety of Government agencies, both civil and military. Katz and Philips (1981) have recently completed a history of the US computer industry and in their account make extremely interesting comments on why private funds were not committed to the commercialization of electronic computers:

"The general view prior to 1950 was that there was no commercial demand for computers. Thomas J. Watson Snr. With experience dating from 1928, was perhaps as acquainted as anybody with business needs and capabilities of advanced computation devices. He felt that the one machine which was on display in the IBM New York offices could solve all the scientific problems in the world involving scientific calculations. He saw no commercial possibilities. This view moreover persisted despite the fact that some private firms who were potential users of computers – major life insurance companies, the telecommunications providers, the aircraft manufacturers and others – were reasonably well informed about the emerging technology. No broad business need was apparent."

The Korean war stimulated still further the US Government's interest and led at last to IBM's full involvement. IBM was by no means the first innovator in this industry but once the company had o meet contracts for a small number of machines for military work, it began to take a serious interest in the civil market potential. Even so, when the Applied Science Group at IBM proposed launching the 650 computer and forecast that they could sell 200 machines, the Planning and Product Sales department (who might generally be suppo0sed to be experts at detecting market demand) forecast that there would be no sales of the 650 at all. The dispute was resolved by Thomas Watson Jnr., who took the side of the scientists. The 650 went into production and 1.800 machines were sold. It my view this knocks a hole a mile wide in the theory of market demand leadership of innovation. More generally, other work at SPRU in relation to the chemical industry also reveals strong counter-Schmookler patterns with basic inventions and innovations (Walsh et al, 1979). Nevertheless, the Rosenberg theory may still be consistent with the Schmookler statistics for the reasons I have mentioned.

Other apparently paradoxical problems, such as the role of small firms in the economy and the seemingly inconsistent operation of 'Verdoorn's Law', are also more comprehensible within the framework of long waves of development. Innovative small firms are particularly important in the early take-off of new technologies, but as new industries mature and profits are competed away, a process of concentration sets in and economies of scale in R and D as well as in production and marketing, become increasingly important. But, as Schumpeter gloomily insisted, with each successive long cycle the overall level of concentration increases within the leading industrial economies.

Finally, whilst the greatest productivity gains are usually associated with the rapid growth of total production during Kondratiev upswings, it is also possible sometimes to achieve high productivity gains during periods of recession and depression through rationalization and scrapping of the least efficient plants in any particular branch of industry. The operation of Verdoorn's Law is associated mainly with the exploitation of economies of scale and with high levels of capacity utilization in rapidly expanding sectors. But it cannot encompass the phenomena of rationalisation in declining sectors, or of bankruptcies during depression, chopping off the 'tail' of low productivity firms and older vintages of capital.

3. SOME POLICY IMPLICATIONS

It is not easy to point to a simple set of specific policy conclusions arising from this analysis. Indeed, fatalistic attitude were often characteristic of the early Kondratiev long wave theories. They could be made to fit the idea that Governments can do very little about long-term recession and high levels of unemployment, except to cling to the hope that depressions may indeed stimulate innovations. The analysis I have presented does not, however, provide support for such a crude deterministic approach, rather the reverse. During periods such as the present depression there is a more urgent need to push forward the technological frontier, to build up strong and patient public policies for the support of fundamental science, fundamental technology and radical innovation. This calls for an <u>active public policy</u>, which has a dimension largely lacking both in present-day monetary constraint and in Keynesian stimulation policies. That dimension is the creation of the impetus and the infrastructure for a fifth Kondratiev long-wave upswing.

Space does not permit more than the briefest indication of the kind of policies this would involve. The radical innovations I have discussed are not always obviously and immediately profitable; take-off typically occurs only after a fairly long gestation period. This means that there must be positive and patient public policies of support, encouragement, experiment and adaptation. The computer is an obvious example which clearly shows that the unaided market mechanism is not enough. But perhaps this type of policy needs to be complemented by more ambitious long-term investment strategies and procurement strategies. The most effective public with the greatest employment effects are not those encouraging radical innovation, important though these undoubtedly are for the long-term; the greatest employment effects arise from policies involving public investment and the accompanying procurement of new products and use of new technology. For example, it might cost between 2 and 10 billion to wire up most urban areas in a country the size of the UK or the German Federal Republic in such a way that domestic and business users could take full advantage of the potential applications of information technology which will flourish in the next few decades, including two-way communication with distribution networks (tele-shopping), financial services (tele-banking) and so forth. While much private investment would undoubtedly be forth-coming, active government policies are essential in such areas as standards, definition of responsibilities, links with existing telecommunication networks and many other system-type social changes which are essential to facilitate the type of clustering and the emergence of new technologies which I have discussed.

In addition, public policy is extremely important in relation to the social services, where information technology could greatly improve the quality of service if imaginatively used. Without new initiatives of this kind, the social services are in danger of becoming the Cinderellas of the 1980s, whereas they could help to lead the way in the regeneration of the econmy.

The applications of micro-electronics and information technology in the public and private service sectors are likely to be of particular importance in the 1980s and 1990s. But there are of course other new technologies – such as energy conservation, new forms of public transport and many applications of biotechnology and robotics – which it is essential to promote through persistent and ambitious public policies.

Economists and a wider public are often rightly suspicious os governments putting public money into exotic new technologies because of disappointing past experiences with supersonic transport aircraft and certain military and nuclear projects. However, these were launched in quite different circumstances and often without much consideration of the economic and social aspects. Good technology policy requires considerable sophistication and co-operation between scientists, engineers and economists, as well as some luck and well-informed public debate. The discussion initiated by Eads and Nelson (1971) and followed up by Pavitt and Walker (1976), is extremely important in this respect. They have designated the circumstances in which public involvement can be useful and effective, emphasising in particular the extremely important distinction between ‘exploratory development’, which is relatively inexpensive and often merits support from government sources, and full-scale commercial development, which is usually far more expensive and more seldom justifies the commitment of pu7blic funds to R and D. The expensive failures, such as Concorde, which several countries have experienced, have lar ely stemmed from disregard of this basic distinction, from the power and prestige of specialized lobbies to influence government policies and from the associated absence of adequate public debate. Investment projects incorporating new equipment and procurement of new products which meet advanced technical specifications and satisfy social requirements may be a much more satisfactory form of public involvement at this stage than R and D subsidies.

Technology policy alone is not enough. Whether or not one accepts the Schumpeterian perspective I have described, there remain two very fundamental issues which will confront industrial economies in the nest twenty years. The first is the extent to which technical innovation and its diffusion may alleviate the inflationary pressures which are still present everywhere, even during this period of recession. The second related issue is the response of the workforce to technical change, to redeployment, to retraining and to the possibility of prolonged unemployment. One of the factors hindering a higher degree of public involvement and understanding of technical change is itself the prevalence of high levels of unemployment. It is hardly surprising that workers declared redundant at a time when opportunities for new employment are rather scarce should be lukewarm about labour-displacing technical innovation, or that they should be somewhat skeptical of the 'compensation' arguments advanced by economic theory. Not surprisingly, too, workers in Japanese corporations who enjoy a relatively high degree of job security – so called 'lifetime employment' – and are apparently fairly well informed and consulted about projected changes of technique in the plants in which they work are, it seems, more co-operative in implementing such changes. In turn, it would be surprising if the continuing high rate of technical change in Japan did not benefit from these circumstances.

Several other features of Japanese economic performance stand out from the now numerous attempts to explain its success. Firstly, the Japanese Government and particularly MITI have had a very deliberate and long-term policy towards the promotion of technical innovation and structural change in the Japanese economy. Their technology policy has not been switched on and off in response to an electoral cycle or a short-term business cycle; they have kept their technologic revolution red hot, if not white hot. Secondly, Japanese policy has been eclectic in the choice of means to promote the desired high rate of technical innovation, but has never hesitated to use the power of the Government and the associated financial and credit weapons to promote the R and D, the investment and the structural change on the scale believed to be necessary for long-term development. Thirdly, Japanese investment in physical equipment and in education and training both in universities and in industry, has been extraordinarily high and persistent and a close connection has been established between the introduction of new products and processes and training programmes and education programmes at all levels. There also appears to be close co-operation with the unions at plant level.

The Japanese experience in my view confirms that, contrary to superficial appearance, it is easier to maintain full employment with a higher rate of technical change <u>and vice-versa</u>. Clearly it would be difficult for other countries to imitate those features of Japanese society which depend on very strong cultural traditions and behaviour patterns; Japan in any case is far from being a utopia and certainly cannot offer complete solutions to the fundamental problems confronting all industrial economies in the last part of this century. Nevertheless, its experience does offer some useful pointers on how to achieve high rates of growth, high levels of employment, even in adverse world conditions and (I would say) how to get in a good position to lead the fifth Kondratiev long-wave upswing.

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He suggested that the first long cycle of economic development was based on the diffusion of the steam engine and textile innovations in the latter part of the 18th century; the second, largely on the railways and the associates changes in the mechanical engineering and iron and steel industries; and the third on electric power, the internal combustion engine and the chemical. industry. Interestingly, a personal comment on the relevance of SchumpeterÂ´s ideas came recently from Paul Samuelson (1981), certainly the economist best known to undergraduate students in the post-war period. Appropriat