PART IV

Technical change and the dynamics of income inequality

7. Technological revolutions, paradigm shifts and socio-institutional change

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The last decades of the twentieth century were a time of uncertainty and extremely uneven development. People in many countries and in most walks of life felt uncertain about the future for themselves and their workplaces, about the prospects for their own countries and for the world as a whole. Inside each country and between countries there were strong centrifugal trends generating unprecedented growth and wealth at one end of the socio-economic spectrum and increasing poverty, deterioration and degradation at the other. Among those old enough to remember, there was widespread recognition that the erratic, uneven and unstable climate of the 1980s and 1990s was profoundly different from the 'golden age' of growth of the 1950s and 1960s. This recognition is probably at the root of the revival of interest in long waves.

This chapter puts forth an interpretation of the long-wave phenomenon which offers to provide criteria for guiding social creativity in times such as the present. In it, I define this period as one of transition between two distinct technological styles – or techno-economic paradigms – and of construction of a new mode of growth. Such construction would imply a process of deep, though gradual, change in ideas, behaviours, organizations and institutions, strongly related to the nature of the wave of technical change involved.

Indeed, contrary to what is usually assumed, I suggest that long waves are not merely an economic phenomenon, though they certainly have economic manifestations. Long waves affect the whole system, the entire structure of society worldwide. This explains why economists have such a difficult time proving or disproving the existence of long waves, although historical memory and the people of each period clearly distinguish the 'good times' from the 'bad times'. In fact I will argue that the instability of the present period has a techno-economic origin and a socio-institutional solution.

According to my interpretation, the long-term fluctuations that we call long waves are the result of successive couplings and decouplings of two spheres of the system: the techno-economic on the one hand and the socio-institutional on the other. When a good coupling is achieved between those two spheres, there is a long period of two or three decades of stable growth, perceived as a time of prosperity. When a decoupling occurs, it results in an equally long period of irregular growth, recession or depression, perceived as a bad time. But why should this mismatch come about and what is the nature of the recoupling?

The causes for this behaviour of the system lie in important differences between the techno-economic and the socio-institutional spheres in terms of rhythms and modes of change. I suggest that there are mechanisms inherent in the way technologies diffuse which result in technological revolutions or changes of paradigm every 50 or 60 years, leading to long-term patterns of continuity and discontinuity in the techno-economic sphere which require matching transformations at the socio-institutional level. Yet inertial forces make the socio-institutional framework more resistant to change and rather slow to adapt to new conditions, except under critical pressure. Thus a mismatch occurs with each technological revolution and it takes decades to re-establish the coherence of the total system. But once a good match is achieved a period of prosperity ensues, leading to full deployment of the new wealth-creating potential.

If this is an acceptable explanation of the occurrence of long waves, the question remains as to what guides the adequacy of change in the institutional sphere. I suggest that each technological revolution, as it spreads, generates a set of best practice principles which serves as a conscious or unconscious paradigm for steering institutional change and for designing the social tools with which to master the new techno-economic potential.

Let us develop the argument beginning with the question of the great continuities and discontinuities in technology. For this we must examine the manner in which technologies evolve. This will be the content of the first section. In the second section we will see how and why technological revolutions gradually transform the whole productive system. In the third section I will discuss why the matching changes in the socio-institutional framework take time to occur. Finally, in the fourth section I will show how an understanding of the nature and characteristics of the emerging technologies can help in designing appropriate responses at the institutional level.

1. UNDERSTANDING TECHNOLOGY AND ITS MODE OF EVOLUTION

Everyone would agree that in order to assess the impact of technical change on society in general or on any particular aspect of human activity, it is necessary to have some basis for forecasting. If new technologies fall upon us like hailstorms or surprise us like earthquakes, there is little we can do as a society to master them or guide them for the common good. I will argue that in spite of the undeniable diversity of technologies, the unpredictable nature of inventions and the uncertain and risky nature of commercial innovations, there is a recognizable logic behind the main trends in technical change.

Let us begin by emphasizing that we shall view technical change not as an engineering phenomenon but as a complex social process involving technical, economic, social and institutional factors in a web of interactions. Single inventions as such do not change the world; widespread diffusion of waves of innovation does.

1.1 Inventions, Innovations and Diffusion

To develop the analysis we need a set of appropriate concepts for classification. The most basic are the Schumpeterian distinctions among invention, innovation and diffusion (Schumpeter 1939).

The invention of a new product or process occurs within what could be called the technoscientific sphere and it can remain there forever. By contrast, an innovation is an economic fact. The first commercial introduction of an innovation transfers it into the techno-economic sphere as an isolated event, the future of which will be decided in the market. In case of failure it can disappear for a long time or forever. In case of success it can either remain an isolated fact or become economically significant, depending upon its degree of appropriability – its impact on competitors or on other areas of economic activity. Yet the fact with the most far-reaching social consequences is the process of massive adoption. Vast diffusion is what really transforms what was once an invention into a socio-economic phenomenon.

So inventions can occur at any time, with different degrees of importance and at varying rhythms. Not all inventions become innovations and not all innovations diffuse widely. In fact, the world of the technically feasible is always much greater than that of the economically profitable, which, in turn, is much greater than that of the socially acceptable.

Thus our focus must be on innovation diffusion. Let us then establish a manner of classifying innovations which will help us understand the economic and social conditions for diffusion and will give us some insight into how meaningful trends in technical change can be discerned.

1.2 Incremental and Radical Innovations

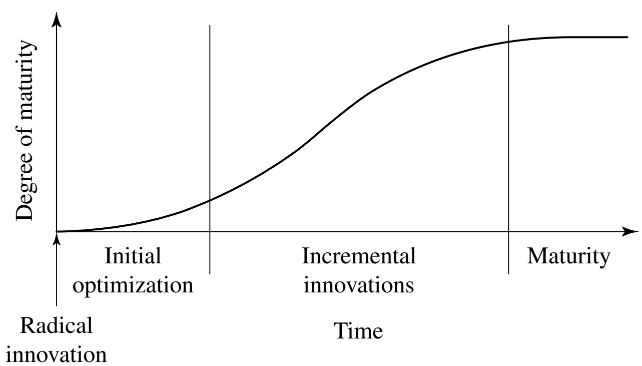
Incremental innovations are successive improvements upon existing products and processes. From an economic point of view, this type of change lies behind the general rate of growth of productivity, visible in the aggregate. The frequent increases in technical efficiency, productivity and precision in processes, the regular changes in products to achieve better quality, reduce costs or widen their range of uses, are characteristic features of the evolutionary dynamics of every particular technology. The logic guiding this evolution, called 'natural trajectory' by Nelson and Winter (1977) and 'technological paradigm' by Dosi (1982), is analysable and makes the course of incremental change relatively predictable. Given a technological base and the fundamental economic principles, it is possible to forecast with a reasonable degree of certainty that microprocessors, for example, will become smaller, more powerful, faster in operation and so on. Once catalytic refining was introduced, it was natural – knowing the profile of demand for oil derivatives – to expect that technological evolution would lead to successive improvements geared to increasing the yield of gasoline to the detriment of the heavier products with lower demand and lower prices. After the discovery of Chilton's Law, according to which doubling plant capacity increases investment cost by only two-thirds, it was easy to predict a trend towards obtaining scale economies in a whole range of process industries. So the great majority of innovations occur in a continuous flow of incremental changes along expected directions.

A radical innovation, by contrast, is the introduction of a truly new product or process. As both Freeman (1984) and Mensch (1975) observe, because of the self-contained nature of the trajectories of incremental change it is practically impossible for a radical innovation to result from efforts to improve an existing technology. Nylon could not result from successive improvements to rayon plants, nor could nuclear energy be developed through a series of innovations in fossil fuel electric plants. A radical innovation is by definition a departure, capable of initiating a new technological course. Although radical innovations are more willingly adopted when the previous established trajectory approaches exhaustion, they can be introduced at any point, cutting short the life cycle of the products or processes for which they substitute. Some radical innovations give birth to whole new industries. Television, for instance, introduced not only a manufacturing industry but also programming and broadcasting services, which in turn widened the scope of the advertising industry. In this sense important radical innovations are at the core of the forces behind growth and structural change in the economy.

1.3 Birth, Development and Stagnation of a Technology

The combination of these two concepts allows us to visualize the evolution of a technology from introduction to maturity (see Figure 7.1). Every radically new product, when it is first introduced, is relatively primitive. In the initial period there is much experimentation with the product and its production process, in the market and among the initial users. Gradually it consolidates a position in the market and the main trends of its trajectory are identified. This ushers in a period of successive incremental improvements in quality, efficiency, cost-effectiveness and other variables, a process which eventually confronts limits. At that point, the technology reaches maturity. It has lost its dynamism and its profitability. Depending on the type of product, this cycle can last months, years or decades; it can involve a single firm, dozens of firms or thousands. As the technology approaches maturity there is often a shake-out, leaving only a few producers. There is also a high likelihood that, at maturity, the product will be replaced by another or the technology will be sold to weaker producers with lower factor costs (as happened in the migration of mature industries to the Third World in the late 1960s and 1970s).

Thus forecasting in relation to single technologies is on relatively firm ground and is, in fact, quite common in the daily practice of engineers, managers and investors. For each individual product or process, incremental change is not random and its destiny, unless another radical innovation appears, is to reach maturity and exhaustion. There are, then, moments of discontinuity and periods of continuity in the evolution of each individual technology.



Sources: Nelson and Winter 1977, Dosi 1982.

Figure 7.1 Evolution of a technology (a technological trajectory)

This process on its own does not lead to long waves. Individual innovations – radical and incremental – are constantly happening in products and processes, in different industries and different places. Some are minor, some are major; some have long lives, others short ones. Indeed, if technologies developed isolated from each other the rise of the life cycle of some technologies would counter the maturity and decline of others. But technologies grow in systems.

1.4 New Technology Systems as Paths for Radical Innovations

Freeman, Clark and Soete (1982, Chapter 4) have defined new technology systems as constellations of innovations, technically and economically interrelated and affecting several branches of production. Rosenberg (1975) has described the way in which some innovations induce the appearance of others. Breakthroughs that increase the speed of operation of machine tools, for instance, induce innovative efforts in cutting alloys capable of withstanding greater temperatures and speeds. In general, incremental trajectories in a product, process or branch of industry tend to encounter bottlenecks which become incentives for innovations – even radical ones – in other industries. Nelson and Winter (1982) identify generic technologies whose natural trajectory of evolution encompasses that of a whole set of interconnected radical innovations. In petrochemical technology, for instance, one can identify several distinct but related systems: synthetic fibres, which transform the textile and garment industries; plastics, whose multiple impact, in the form of structural materials, generates whole new lines of equipment for extrusion, moulding and cutting, and whose versatility transforms the packaging industry and opens a vast universe of innovations in disposable products; and so on.

From the vantage point of a new technology system, then, there is a logic which joins successive interrelated radical innovations in a common natural trajectory. Once this logic is established for the system it is possible to forecast a growing succession of new products and processes, each of which, taken individually, appears to be a radical innovation, but when located within the system can be considered an incremental change. The series of durable consumer goods, made of metal or plastic with an electric motor, which begins with the vacuum cleaner and washing machine, goes through food processors and freezers, to later approach exhaustion with the electric can opener and the electric carving knife, is a banal example of this type of logic in the area of products. The succession of plastic materials with the most diverse characteristics, based on the same principles of organic chemistry, is an example in the field of intermediate products with enormous impact in generating innovations in the user industries. The 'green revolution' – the introduction of growing families of oil-driven agricultural machinery, together with multiple petrochemical innovations in fertilizers, herbicides and pesticides – is an example of the coherent evolution in the logic of a productive system.

The widespread impact of a new technology system stems from the 'wide adaptability' of the contributing innovations and from their multiple character (Keirstead 1948). The innovations are not merely technological. Each technological system brings together technical innovations in inputs, products and processes with organizational and managerial innovations. Further, they can induce important social, institutional and even political changes. The technological constellation of the 'green revolution' led to single-crop farming in great expanses of land and induced changes in the organization of production and distribution as well as in the structure of ownership. The automobile, the assembly line, the networks of parts suppliers, distributors and service stations, suburban living and commercial centres are only some of the elements of the technical, economic and social constellation gradually built around the internal combustion engine.

Yet technological systems, like individual technologies, eventually exhaust their potential for further growth and improvement. For a long time a new technology system provides multiple and growing opportunities for innovation and investment in complementary products, services or supplies. But the time comes when the system loses technological and market dynamism, reaches maturity, threatens the growth and profits of most of the firms involved and therefore stimulates a search for radical new products that will serve as the core of other new technological systems.

So at the level of technological systems we encounter the same phenomena of continuity and discontinuity in evolution. Again at first sight there is no reason to expect long waves to occur because of limits in the life cycle of technological systems. As with individual innovations, one could imagine a constant process of counterbalancing of the growth and decline of different systems in different parts of the economy. This would be the case if systems developed in isolation, but technological systems grow in interconnection with each other and with the surrounding economic, cultural and institutional environment.

1.5 Self-reinforced Processes of Growth and Exhaustion

The consequences of the exhaustion of a system are not overcome as simply as those of the obsolescence of individual products. When a system reaches maturity and loses dynamism, not only the producing firms are obliged to face change, but also all the social and institutional arrangements that had been set up around the system. The process of substitution is not one of eradication but of a slow and painful change in the proportions of the new against the old, but the end result is a radical change in the structures involved. Such was the case when cargo railways and ships were gradually replaced by trucks and aeroplanes, when natural materials were replaced by synthetics, when the reign of radio was replaced by that of TV and when vinyl records were replaced by CDs. Everyone from suppliers to consumers had to adapt in one way or another and these changes usually implied a reshuffling of the relative positions of all players (often including the elimination of some and the emergence of new ones), together with changes in the rules of the game. So once we visualize individual technologies within technological systems we can begin to understand the complex set of interactions that take place as technologies diffuse and the difficulties that discontinuities in technical change can create for the parts of society involved.

The deployment of each technological system involves several interconnected processes of change and adaptation:

1. The development of surrounding services (required infrastructure, specialized suppliers, distributors, maintenance services and so on).
2. The 'cultural' adaptation to the logic of the interconnected technologies involved (among engineers, managers, sales and service people, consumers and so on).
3. The setting up of the institutional facilitators (rules and regulations, specialized training and education and so on).

This adaptation of the economic, cultural and institutional environment to the requirements of technological systems is not passive. The environment in turn shapes the development of the systems in very important ways, including cases of significant resistance to diffusion, such as the resistance to nuclear energy. For our purposes, though, there is one particular phenomenon with far-reaching consequences: the social environment becomes a powerful selection mechanism for the inclusion or exclusion of particular innovations, making it easier and easier to invest in products and services belonging to the system and much less comfortable to invest in unrelated innovations

The adaptations that occur around a particular system generate conditions that strongly favour innovations that are compatible with – or can be fitted into – the systems already in place. What they provide, in fact, is a free and ready-made advantage for other similar products. After all homes have electricity, you can bring to market as many electric products for the home as you can invent. After grocers and homes have freezers, you can innovate all you want in frozen foods. After textile machinery handles synthetics, you can introduce further and further varieties of new fibres. Brian Arthur (1988) has shown how these 'lock-in' phenomena occur even at the level of individual products selecting among competing technologies. The triumph of VHS and the gradual exclusion of BETA technology in video cassettes, even though many experts held that BETA was superior, is an example of how certain market conditions favouring early diffusion of a particular product or technology can result in a permanent bias.

So the development of a system produces externalities facilitating radical innovations which follow well-trodden general trajectories or which are capable of creating related trajectories. This is because, among other things, these externalities reduce the expenses of introducing an innovation and convincing users, which are often the highest costs and the most difficult to recover in the market.

The consequences of this phenomenon are twofold. First, many potential innovations are either excluded or submitted to the existing logic, leaving out some of their most radical uses. When transistors first appeared, for instance, they became a means of making radios and other electrical appliances small enough to be portable. The early integrated chips in the 1960s were used mainly for hearing aids and a couple of minor military applications. The idea of putting them into computers existed, but the economic and market conditions for the success of this much farther-reaching application had not yet appeared. In fact, existing systems induce a sort of blindness which affects even the most forward-looking engineers and entrepreneurs. In the early days of electricity Werner Siemens thought that wiring every home was a utopia, and when IBM brought out the first commercial computers T.J. Watson Sr, IBM's CEO, thought that the world market would be saturated with a few such machines.

The other consequence of these increasingly powerful externalities is that the greater the development of a system, the shorter the life cycle of each radical innovation within it. The life cycles of the radical innovations that appear in the later stages of the development of a system are usually much shorter than those of the earlier ones. This is partly because the major innovations are generally those which give birth to the system while the later ones tend to be complementary. But it is also because once the supplies have been standardized, the habits established and the users conditioned, it takes very little time to make the whole series of incremental innovations and to reach market saturation and 'vegetative' growth. It took decades for every home to have an electric or gas cooker, a refrigerator and a washing machine, but it took only a few years to reach the great majority of possible consumers of electric can openers and electric carving knives.

So the mesh of mutual adaptation between technological systems and the economic, cultural and institutional environment tends to make the whole structure self-reinforcing, both in its development and in its exhaustion, in its inclusion and in its exclusion mechanisms. The problem arises when the firms that operate within mature systems face a serious threat to growth, profits and even survival.

1.6 Technological Revolutions as Rejuvenation of All Systems

In the early 1970s it was widely agreed (and feared) that the automobile industry had reached maturity. Its markets had lost dynamism and grew extremely slowly, if at all, inventories piled up, productivity stagnated and profits were threatened. Many experts declared that automobiles had become 'commodities' and that the future lay in complete standardization by moving towards the 'world car': engines would be produced in one country, gear boxes in another, bodies in the next, and so on, in order to increase productivity through maximizing economies of scale. This was the way imagined by the mentality of the time to confront the maturity of that technological system.

Few could foresee what actually happened. Japanese industry developed a different way of organizing production and markets, which at first threatened to overtake much of the world automobile industry but instead led to a thorough revamping of all firms and their forms of insertion, competition and interrelation. In the end, through a synergistic combination of the new managerial style and the introduction of information technology into production processes, products, administration and markets, the industry was completely renewed and set on a different and very dynamic trajectory of incremental innovation (Altshuler et al. 1982, Womack et al. 1990).

So maturity does not inevitably end in the marginalization of a system, nor is it necessary that a radical innovation in the core product itself should come to the rescue and replace the previous mature product. Both can and sometimes do occur. What is more likely to take place, especially at those times – such as the 1970s – when many interrelated systems tend to come to maturity more or less simultaneously, is that a general solution appears in the form of a technological revolution. What happens then is the diffusion of a new set of generic technologies, capable of rejuvenating and transforming practically all existing industries, together with the creation of a group of new dynamic industries at the core of radically new technological systems. These are the technological revolutions described by Schumpeter (1939) as 'gales of creative destruction'. They have occurred about every 50 or 60 years and they lie at the root of the so-called long waves in economic growth.

Schumpeter and many others after him have emphasized the powerfully dynamic nature of each of those great waves of new technologies as well as their capacity to profoundly modify the world around them (see for example Landes 1969, Nye 1990). Society has recognized their overarching influence by referring to the periods when these great technological changes have diffused as the Industrial Revolution, the Railway Era, the Age of Electricity and the Age of the Automobile. The industries at the core of these revolutions do indeed become the propellers of growth for a considerable length of time. They also lead to the proliferation of whole new industries and services complementary to the production and use of the new products, as was discussed above for technological systems of major importance.

Yet I suggest that they do much more than that. Technological revolutions change the 'commonsense' criteria for engineering and business behaviour across the board. In fact, in my view, each technological revolution merits that name, not only for the importance of the new industries it ushers in and the new technical possibilities it opens but also – and perhaps mainly – because it radically modifies the 'best practice frontier' for all sectors of the economy.

Each of these revolutions is in fact a constellation of technological systems with a common dynamic and including a set of generic technologies of widespread applicability. Its diffusion across the length and breadth of the productive sphere tends to encompass almost the whole of the economy and ends up transforming the ways of producing, the ways of living and the economic geography of the whole world.

Such all-pervasive revolutions generate, therefore, massive and fundamental changes in the behaviour of economic agents. What type of mechanism would be capable of serving as guiding force for a shift of this sort?

2. TECHNO-ECONOMIC PARADIGMS AS COMMONSENSE MODELS TRANSFORMING THE PRODUCTIVE SPHERE

2.1 A Cheap Input as Vehicle of Diffusion

Due to the exclusion mechanisms we have been discussing, the appearance of revolutionary new technologies will not automatically guarantee adoption from branch to branch and on a world scale. Diffusion in the early phase demands a simple vehicle of propagation, accessible to millions of individual decision agents and coherent with their decision-making criteria. That vehicle is long-term cost effectiveness. Although many of the products of each technological revolution can be inaccessibly expensive at first (as were computers, for instance), at the core of each of these great waves of innovation there is a key input which is very cheap, offers to remain cheap and, in conjunction with a constellation of generic innovations, radically transforms – in its favour – the relative cost structure confronting entrepreneurs, managers and engineers (Perez 1983).

Behind the spread of railways and the steam engine in the mid-nineteenth century there was an abundance of cheap coal. Behind the spread of electricity, heavy chemistry and heavy civil engineering at the turn of the twentieth century we find the Bessemer and Siemens Martin processes that made steel as cheap as iron. Behind the spread of asphalt roads and automobiles, electricity in every home and plastics and synthetics for every purpose, we find cheap petroleum and technologies that made energy and petrochemical products less and less expensive. Behind the present information and telecommunications revolution we find ever cheaper and more powerful electronic chips (Freeman and Perez 1988).

In each case the key input – or 'key factor' as I have called it (Perez 1985) – represents the new generic technologies in economic terms and steers engineering and investment decisions towards their intensive use.

2.2 Diffusion is Self-reinforced

So I suggest that there are two main reasons why a set of truly new technologies is able to spread in a world still dominated by the old: (1) the exclusion mechanisms have been weakened by the signs of exhaustion of the prevailing technologies, and (2) there are obvious changes in the relative cost structure which are seen to be permanent and act in favour of the new technologies. Therefore investment capital in search of better profits sees a good direction in which to plunge.

The process of switching over becomes self-reinforcing through several feedback loops. The greater the diffusion of its applications, the greater the demand for the 'key factor', which leads to economies of scale and lower costs, which in turn widens the range of applications. The more the new technology spreads, the more profitable it is to set up as a supplier to it or as a distributor, which further facilitates propagation. The more investment tends to incorporate the new technologies and equipment, the more the product mix of equipment producers moves to respond to this new dynamic demand and the more difficult it becomes to find the old type of equipment in the market. (This occurs even in consumer products: imagine the difficulties experienced by someone in the 1990s insisting on buying or finding maintenance services for a traditional manual – or even electric – typewriter.) The more consumers learn about using the products associated with the new technologies, the easier it is for them to accept the next product or the next generation of the same product. The more the process of innovation leads to extraordinary profits and growth in new industries and firms, the more likely are the waves of imitation, and so on and so forth.

2.3 A New Paradigm as a Quantum Jump in Potential Productivity for All

Yet the process overflows beyond the propagation of the key factor and the growth of the industries related to it. Each technological revolution also generates a wave of organizational innovation which, in synergy with the new generic technologies of widespread applicability, offers a quantum jump in productivity for all industries, however old and established (Perez 1986).

The principles of mass production, which applied the continuous flow of the chemical industry to the assembly of identical fabricated products, were first fully developed for the automobile but then diffused across all sectors. Ford's dictum in the 1920s, 'You can have any colour as long as it is black', could have been applied to mass charter tourism in the 1960s and 1970s. Du Pont's organizational innovation in its corporate structure, the 'm-form' with its many layers, functional departments and divisions, was originally created just for Du Pont, but it became the model for effectiveness and efficiency in all industries until very recently. Today the adaptability of the Japanese managerial network has been found to be one of the most appropriate forms of organization to take advantage of the flexibility of information technology. So it is diffusing through more and more sectors and being adopted and creatively adapted to different conditions locally and globally.

So each technological revolution brings a set of new industries, with a low-cost input at the core, and a set of generic all-pervasive technologies and organizational principles capable of renewing all the other productive activities.

2.4 A Techno-economic Paradigm as an Overarching Logic for the Technological Systems of a Period

This set of interrelated technical and organizational innovations gradually comes together as a best practice model – or a 'techno-economic paradigm' (Perez 1985) – capable of guiding the diffusion of each specific technological revolution. As it spreads, this new paradigm gradually takes root in collective consciousness, replacing the old ideas and becoming the new 'common sense' of engineers, managers and investors for the most efficient and 'modern' productive practice across the board.

Although for the direct actors this is often largely an unconscious process in response to changing circumstances, the underlying logic of change can be observed and analysed and its common general principles can be identified. Doing so – and helping change to occur – has become the business of thousands of consultants in this transition.

What this means is that each technological revolution establishes an overarching paradigm as the techno-economic common sense for a long period of five or six decades. This general logic guides not only the course of incremental innovations during each period but also the search for radical innovations and the evolution of successive and mutually reinforcing new technological systems. It also guides the upgrading and modernization of existing industries to bring them into harmony and synergy with the dynamic new industries.

2.5 Difficult Assimilation: The Shaping of a Paradigm Takes Decades

The process I have been describing does not flow easily; it can take decades. The construction and propagation of a paradigm is protracted and difficult, due to the many obstacles encountered in the economic actors themselves and in their environment.

At first there are the pioneers and the early adopters, who can go a long way in impressive growth of production and profits. But they soon encounter the limits to their full development within the environment of the old paradigm.

One of the areas of strong resistance to diffusion is found in the leadership of established firms. It is difficult to believe that the 'normal' way of doing things has become old style and ineffective. In Table 7.1 I suggest what it means to change managerial common sense, aspect by aspect, element by element (Perez 1989). Those who have vast experience in applying the old principles find themselves forced to learn a new way of thinking and behaving in order to get optimum results. Yet this internal resistance tends to be overcome by the threat to profits and growth from the exhaustion of the old technologies and practices, together with the increasing examples of success with the new paradigm and sometimes by the direct pressure in the market from competitors who have adopted it.

Another set of obstacles comes from the lack of adequate externalities. Each paradigm develops in strong feedback interaction with a particular infrastructural network. The deployment of information technology propels and is propelled by vast telecommunications systems, which must be reliable, low-cost, powerful and of high capacity and great flexibility. Without that, diffusion is stalled. That same sort of interaction characterized the deployment of automobiles and truck transport, which both facilitated and was spurred by the establishment of the networks of roads and fuel distribution services. A similar feedback loop takes place in relation to specific types of related suppliers and distributors, rules and regulations, trained personnel at various levels, and so on.

In other words, those elements which, when in place, are destined to

Table 7.1 The new versus the traditional paradigm: a radical and difficult shift in managerial common sense

	Conventional common sense	New efficiency principles and practices
Command and control	Centralized command	Central goal-setting and coordination
	Vertical control	Local autonomy/horizontal self-control
	Cascade of supervisory levels	Self-assessing/self-improving units
	'Management knows best'	Participatory decision-making
Structure	Stable pyramid, growing in height and complexity as it expands	Flat, flexible network of very agile units
		Remains flat as it expands
Parts and links	Clear vertical links	Interactive, cooperative links between functions, along each product line
	Separate, specialized functional departments	
Style and operation	Optimized smooth-running organizations	Continuous learning and improvement
	Standard routines and procedures	Flexible system/adaptable procedures
	'There is one best way'	'A better way can always be found'
	Definition of individual tasks	Definition of group tasks
	Single-function specialization	Multiskilled personnel/ad hoc teams
	Single top-down line of command	Widespread delegation of decision making
	Single bottom-up information flow	Multiple horizontal and vertical flows
Personnel and training	Labour as variable cost	Labour as human capital
	Market provides trained personnel	Much in-house training and retraining
	People to fit the fixed posts	Variable posts/adaptable people
	Discipline as main quality	Initiative/collaboration/motivation
Equipment and investment	Dedicated equipment	Adaptable/programmable/flexible equipment
	One optimum plant size for each product	Many efficient sizes/optimum relative
	Each plant anticipates demand	Organic growth closely following

Table 7.1 (continued)

	Conventional common sense	New efficiency principles and practices
	growth	demand
	Strive for economies of scale for mass production	Choice or combination of economies of scale, scope or specialization
Production programming	Keep production rhythm; use inventory to accommodate variation in demand	Adapt rhythm to variation in demand Minimize response time ('Just-in-Time')
	Produce for stock; shed labour in slack	Use slack for maintenance and training
Productivity measurement	A specific measure for each department (purchasing, production, marketing and so on)	Total productivity measured along the whole chain for each product line
	Percent tolerance on quality and rejects	Strive for zero defects and zero rejects
Suppliers, clients and competitors	Separation from the outside world	Strong interaction with outside world
	Foster price competition among suppliers Make standard products for mass customers Arm's-length oligopoly with competitors	Collaborative links with suppliers, with customers and, in some cases, with competitors (basic R&D, for instance)
	The firm as a closed system	The firm as an open system

generate a virtuous circle of self-reinforced diffusion are at first, by their absence, its main obstacles. This is because each technological revolution must make its way in a world fully adapted to the requirements of the previous techno-economic paradigm.

So as all these changes take place in the economy, many – even most – of the adaptations and readaptations that the social, cultural and institutional environment had effected suddenly become obsolete and counterproductive. However, this is not visible at first.

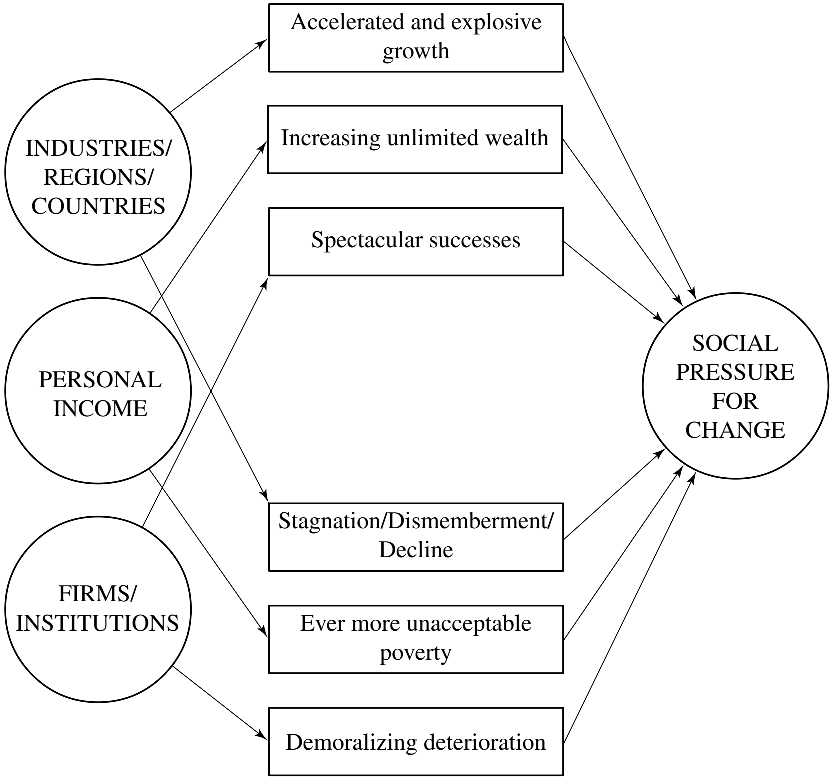
3. STRUCTURAL CHANGE IN THE ECONOMY AND SOCIO-INSTITUTIONAL INERTIA

The process of gradual abandonment of a declining productive model and of growing adoption of the new is not readily perceived as such. Existing institutions take a long time to grasp the pervasiveness of the transformations taking place in more and more points of the economic system. Traditions, established routines and past successes with the usual practices make it difficult to capture the meaning and the threat of these successive changes as a source of institutional mismatches and problems. The new technologies are very visible indeed – as were mass production, plastics and the automobile in the 1920s and 1930s and as information technologies have been in recent times – but their consequences take a long time to reach public awareness. Even those who realize the importance of the technological and economic changes do not often connect them with a need for adaptations in their own sphere of influence or changes in their own behaviour.

3.1 Institutional Inertia: The Upswing Delayed

Even when the need for change is understood, social institutions and the general framework of socioeconomic regulation (Aglietta 1976) have a natural inertia, partly as the result of past successes and partly due to vested interests. It is only when the diffusion of the new paradigm has reached a certain critical mass, imposing its new modernizing logic upon the rest of the productive system, that both the painful consequences of the process of 'creative destruction' and the obstacles to a full – and beneficial – deployment of the new potential become fully visible.

Indeed the social consequences of each transition are vast and profound, as is the human suffering. The consequences include widespread unemployment (Freeman and Soete 1994); the obsolescence of qualifications at all levels; the destruction of the livelihood of many; the geographic dislocation of people and activities; and the rapid growth of wealth at one end and poverty at the other end of the socio-economic spectrum, within each country and between regions and countries (Tylecote 1992) (see Figure 7.2). It is then that the social pressure for change is clearly felt, that the erstwhile effective recipes applied by governments and other institutions are revealed as powerless and that the need for a deep institutional renewal becomes more and more self-evident. But the necessary transformation is not easy nor can it happen quickly. There ensues an increasingly severe mismatch between a socio-institutional framework geared to supporting the deployment of the old paradigm and the new requirements of a techno-economic sphere brimming with change. Further, the persistent application



Sources: Perez after Tylecote 1992.

Figure 7.2 The transition period: sociopolitical impact of centrifugal trends

of the now obsolete practices can actually aggravate the situation and contribute to a collapse (as in the crash of 1929 and the ensuing crisis of the 1930s).

So during paradigm transitions there are very intense transformations in technology and the economy and a high level of inertia and confusion in the socio-institutional sphere. This difference in rhythms of change leads to a decoupling of the two spheres. The ensuing turbulence and tensions are characteristic of the downswing decades of Kondratiev long waves. The upswing decades begin as structural coherence is re-established by means of vast socio-institutional innovations in response to the requirements of the new paradigm and geared to facilitating the full transformation in the productive sphere.

Thus long-wave transitions are processes of 'creative destruction' not only in the economy, as shown by Schumpeter, but also in the socio-institutional sphere. The problem is that in such periods institutions face a chaotic and unaccustomed situation which requires much deeper changes than the great majority of their leaders and members have ever experienced. The difficulty is increased by the fact that there are no proven recipes and change has to take place by trial-and-error experimentation under the pressure of the very high social costs of the techno-economic transformation.

3.2 The Example of the Previous Socio-institutional Framework

Last time around, to overcome the Great Depression of the 1930s and to rebuild the economy after World War II, it was necessary to surmount the prevailing notions about the superiority of free-market mechanisms and accept the establishment of massive and systematic state intervention in the economy, generally following Keynesian principles. There is a very impressive list of institutional innovations which diffused widely in order to foster and regulate the growth of markets for mass production. At the national level it goes from the direct manipulation of demand mechanisms through fiscal, monetary and public spending policies to the official recognition of labour unions, collective bargaining and the establishment of a social security net, passing through the drastic reduction of the work week and year. Some of these innovations were made in the post-war period; some had existed before in some countries, for a short or long time. The important fact is that they were adopted almost everywhere, with all the variety resulting from vast differences in social, cultural, historical, political and other factors.

On the international level these national arrangements were complemented by the economic, political and military hegemony of the United States in the West (holding the Cold War balance with the Soviet system), Bretton Woods, the United Nations with all its specialized agencies, the GATT, the Marshall Plan, the IMF, the World Bank, gradual decolonization and other institutions and measures geared to facilitating the international movement of trade and investment as well as to maintaining political stability.

Today almost every one of these innovations, relatively effective and widely accepted until the 1970s, is under question. Some have already been partly or radically modified in one way or another. Indeed a successful transition will depend on the establishment of new rules of the game, regulatory mechanisms and institutions adapted to the new conditions. The process of institutional change has been under way nationally, locally and internationally with different visions and outlooks. Among the more coherent proposals are some that make an explicit connection with the nature of the present wave of technical change (Soete 1991).

3.3 Long Waves as Coupling and Decoupling of the System

In summary, I propose that long waves are related to the internal coherence of the system. They result from the fact that the techno-economic sphere experiences vast processes of widespread transformation and renewal – or changes of paradigm – about every half century, which in order to deploy their full growth potential require equally vast changes in the socio-institutional framework. Yet the changes in the economy take place at a much faster pace than in social institutions. The resulting mismatch, which historically has lasted two or three decades, brings about the 'bad times' (or the downswing of the long wave). When structural coherence is regained, through a succession of socio-institutional changes which achieve a good match, then there are two or three decades which are experienced as the 'good times' (or as the upswing of the long wave). The process then unfolds as shown in Figure 7.3.

4. TECHNO-ORGANIZATIONAL PARADIGMS AS GUIDELINES FOR CHANGE IN THE SOCIO-INSTITUTIONAL SPHERE

The question remains as to what guides adequate institutional change. Not just any change will do, however positive. The techno-economic paradigm is the best source of guidelines for social and institutional design. This implies that the viable changes have a recognizable direction, but I am not making a case for mere technological determinism.

4.1 The Wide Space of the Possible

What a paradigm determines is the vast range of the possible, and that space is very wide indeed. In the previous paradigm we can recognize at least four major modes of growth: Keynesian democracy, fascism, socialism and, in the Third World, what we could call 'state developmentalism'. There can be no doubt at all that these are profoundly different socio-institutional systems. Moreover the variety of versions of each 'model' was enormous. And yet at a certain level of abstraction they all share certain common features, which stem from the fact that the same mass production paradigm is the logic guiding wealth-creating activities in the production sphere. Among these shared characteristics one could mention:

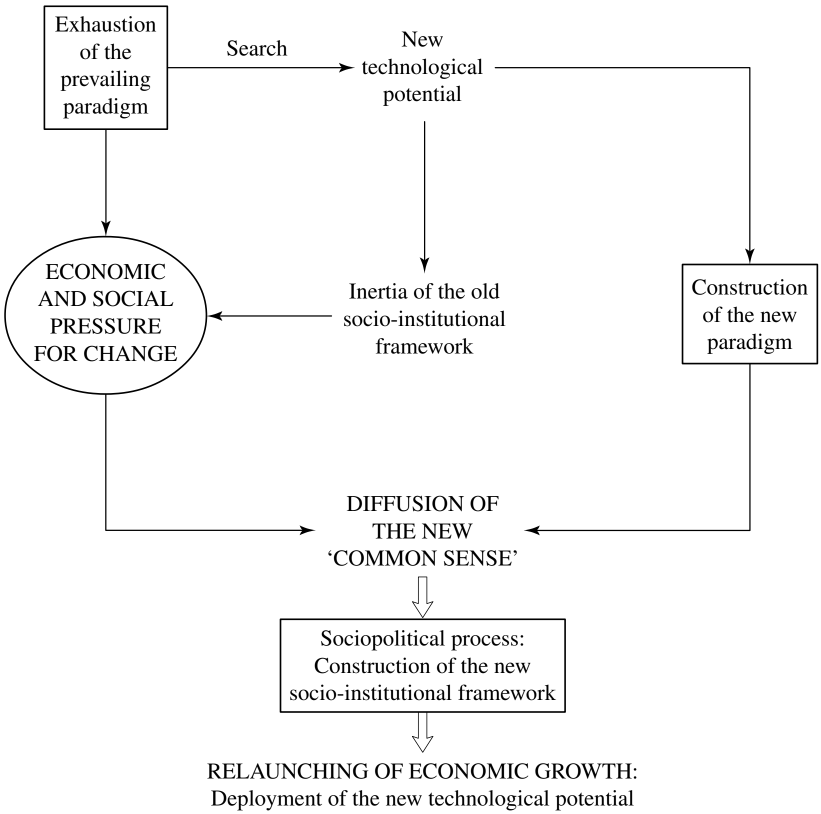


Figure 7.3 The process of creative destruction in long-wave transitions

1. An important role for a central government actively engaged in the economy, whether very directly or more indirectly.
2. The erection of the state as the main agent of redistribution of wealth, which is seen as the prevalent form of social justice.
3. A drive towards the 'homogeneity' of consumption styles within the nation-state, with an effort to reduce internal differences of nationality, language and so on.
4. Central representation of the provinces, generally by some form of direct elections.
5. 'Mass' character of political parties and other associations.
6. Government by one or very few main political parties (rarely more than two, even in countries with very democratic systems).
7. A separation of political leadership from 'technical' management (with measures for a degree of continuity of the latter).

The interesting phenomenon is that these similarities among systems otherwise so divergent have only become clearly visible with the diffusion of the new principles of decentralization and the increasing strength of the ideas which question the previously accepted role of the state. Furthermore, one can now also see a parallel between the typical forms of organization of the traditional big corporations and that of hospitals, universities, ministries and governments in general. As firms have begun to change to more open globalized networks, other structures have begun to question the effectiveness of their own forms of organization.

I am suggesting, then, that as the new wealth-creating potential unfolds in the economy, its logic propagates throughout society, modifying the commonsense criteria that guide all sorts of organizations and eventually resulting in maximum social synergy. Thus, understanding the nature of the paradigm can provide the most appropriate tools for becoming a fully conscious and effective actor in the process of institutional modernization.

4.2 The Notion of a Paradigm Can Be Understood on Three Levels

In practice each techno-economic paradigm is constructed and diffuses on three interrelated levels:

1. As a set of real new technological systems which grow and diffuse in the productive sphere (in the present case these would be the microelectronics, software and computer-related industries, plus modern telecommunications and all the services connected with them).
2. As a new 'best practice' model adapted to the new technologies and capable of taking best advantage of them. This model diffuses across all industries and productive activities, modernizing them and establishing the emerging managerial common sense for investment and innovation (at present this would be the flexible organizational model – in its 'Japanese' and other versions – fused with the consistent application of information technology).
3. As a more general set of 'commonsense' principles for organizational and institutional design (this would involve general principles such as decentralization, networking, interaction between the organization and its users or beneficiaries, continuous improvement, participation, consensus-building and so on). These principles can be said to conform to a techno-organizational paradigm.

These levels can be seen as a series of overlapping waves in time. The first to diffuse widely is the set of new technologies. Then, as it becomes clear that these cannot yield their promised fruits without organizational change, the new managerial model develops further and further and increasingly propagates. Finally, the third level develops as the paradigm overflows outside the economic sphere. When productive organizations discover the advantages of the new paradigm, so do many of their leaders, participants and observers. That is how the paradigm, in the form of general guidelines or principles, is gradually constructed in the minds of more and more people and starts becoming the new common sense for effectiveness more or less everywhere.

Obviously the variety of forms of adoption and application is immense. Technology enters a world where other very powerful influences, such as history, culture and politics, shape the manner in which it is taken up (or partly rejected) in each particular country or region, productive sector or territory, nation or social group. The power of these shaping forces is naturally greater the further one goes from the hard technology core towards the realm of ideas. In other words, the variety of forms of adoption increases as one goes from the first to the third level in the propagation of a paradigm.

Since it is in the third level that the new paradigm provides the criteria for viability and the guidelines for designing effective institutions and social action, it should be clear why the diversity of applications and forms of adoption was so great in relation to the previous mass production paradigm.

It is also at this third level that the old paradigm remains alive beyond its usefulness and becomes an obstacle to the new. For this reason, at each transition the traditional left–right divide is made more complex by the appearance in each group of another divide, which is between the old and the modern ideas, those looking backwards and those looking forward (see Figure 7.4).

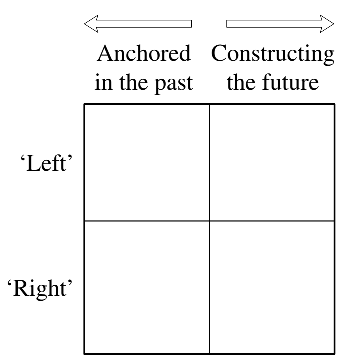


Figure 7.4 Political positions in the transition

4.3 General Principles: Many Forms of Application

So what the paradigm provides is not the goals but the forms and the technical and organizational tools with which to pursue them. Therefore the space for institutional creativity is very wide. Within it, the various social forces play out their confrontations, experiments, agreements and compromises. The result is the framework – or frameworks – which will ultimately mould, orient, select and regulate the actual paths the new potential will follow.

This means that each crisis, each period of technological transition, is a point of indeterminacy in history. A quantum jump in potential productivity opens the way for a great increase in the generation of wealth. But the specific sociopolitical framework that will handle – or squander – this new potential has to be designed and established. This, in turn, is what determines the mix of commodities that will compose that greater wealth and the way they will be produced and their benefits distributed. Historically, each transition has modified both the conditions of the various social groups within each country and the relative position of countries in the generation and distribution of world production.

However, the task is so ambitious that it is difficult to envisage. If someone in the 1920s or 1930s had held that in less than three decades practically all colonial empires could be dismantled and that in North America and Europe there could be full employment and most industrial workers could own cars and houses full of electrical appliances, he or she would have been met with general disbelief.

4.4 The Politics of Transition

The question of social and institutional change is political. Ideologies and vested interests have great power in determining the particular outcomes from the wide space of the viable at each transition. The level of political consensus, conflict or confusion strongly influences the speed and the ease or difficulty with which the new mode of growth is established.

Yet whatever the political position, it certainly makes a difference how one understands the present period. Insisting on the dichotomy between state and market, as the alternative automatic solutions, can only prolong the agony and retard the establishment of an appropriate socio-institutional framework. It is likely to be much more fruitful to see the present as a transition between two distinct modes of growth.

This means accepting the past with its ideas and its institutions, its successes and its failures, its promises and its achievements, as the way the societies of the time found to take advantage of the potential of a specific techno-economic paradigm, now exhausted. It also means facing the future with a commitment to the construction of a framework capable of making the best social use of the new wealth-creating potential. This implies a readiness to pursue a deep understanding of the characteristics and requirements of the new paradigm and a willingness to assimilate change and promote creativity at all levels and in all spheres.

Historically these transition processes have been long and difficult, with a very high cost in human suffering. It is to be hoped that a better understanding of the nature of the transformation could help to alleviate the social cost and to quicken the success of institutional experimentation.

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