SCHUMPETER'S 'BUSINESS CYCLES' REVISITED

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It was preceded by Alan Freeman's "An Introduction" ibid. pp. 37-46 and
followed by Carlota Perez's "From long waves to great surges.
Continuing in the direction of Chris Freeman's 1997 lecture" ibid. pp. 69-80

I. Introduction

It seems probable that Schumpeter thought of 'Business Cycles' at least before publication, as his *'magnum opus'*. It was of course immediately recognised, at least in the United States, as a major contribution to business cycle theory and economic theory more generally, and was accorded a major review article by Kuznets (1940) in the *American Economic Review*. Yet, half a century later it cannot be said that *Business Cycles* occupies a place in the history of economic thought comparable to the major works of Marx, Keynes or Ricardo, or even other works of Schumpeter himself.

The ambitious scope of the book is evident from the full title: *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capitalist Process* and its two volumes, comprising more than a thousand pages, bear further witness to the magnitude of the enterprise. Schumpeter always regarded business cycles not as a sideline or a speciality, but as a major manifestation of his theory of economic development and growth in capitalist economies. Already in the *Theory of Economic Development* he included a chapter on business cycles which foreshadowed his later work. Moreover, although he greatly admired Marx's intellectual achievement and gave him credit for being one of the first theorists to recognise cycles and address these problems, he nevertheless chided Marx *(Capitalism, Socialism and Democracy,* pp 36-39) for supposedly failing to develop any systematic theoretical explanation of crises and for holding an eclectic view embracing many possible causes. There is little doubt therefore that Schumpeter thought of *Business Cycles* as one of his most important contributions to economics, if not *the* most important.

Schumpeter remains the rogue elephant amongst 20th Century economists and although he has commanded the respect of the profession, he certainly has not won their allegiance.

Whereas some elements of his theory have earned a place at the centre of economic debate, such as his ideas on concentration, or on technological competition, it would still be difficult to make this claim for his business cycle theory.

This may of course simply be due to the myopic attitudes of much of the profession and to the continuing neglect of structural change. Even the central point of his whole life work: that capitalism can only be understood as an evolutionary process of continuous innovation and "creative destruction" is still not taken into the bosom of mainstream theory, although many now pay lip service to it.

It will be argued in this paper that, although Schumpeter certainly faced lack of receptivity for most of his major ideas, there were also some weaknesses in the book itself which have contributed to its relative lack of success. It is not just a question of style, although *Business Cycles* was not a well written book. The history of economic thought has conclusively shown that it is possible to write even longer and more indigestible books than *Business Cycles,* which are nevertheless influential both inside and outside the profession.

Nor is it just a question of statistics. The debate on the statistical evidence for long cycles is likely to continue indefinitely. Despite the best efforts of economic historians the evidence for the first and second Kondratieff cycles is bound to remain weak and controversial and relates in any case mainly to one country - Britain. Schumpeter already anticipated and answered that type of critic such as Weinstock (1964) or Solomou (1986), who maintained that aggregative statistical time series did not consistently demonstrate the existence of long cycles. Louçã (1997) has recently published a devastating critique of the purely econometric "refutations" of long cycle theory and has documented how uneasy Schumpeter was about the trend of econometric analysis in the Society that he helped to establish.

Schumpeter pointed out that his theory was concerned with the *qualitative* changes in the structure of the economy and that aggregative long time series could often obscure rather than reveal these changes: "Since the development generated by the economic system is 'cyclical' by nature, the task to be accomplished goes far beyond the description of spectacular breakdowns on the one hand, and of the behaviour of aggregate quantities on the other, into the formidable one of describing in detail the industrial processes behind them. Historians of crises primarily talk about stock exchange events, banking, price level, failures, unemployment, total production and so on - all of which are readily recognised as surface phenomena or as compounds which sum up underlying processes in such a way as to hide their real features". *(Business Cycles,* p. 221)

In my view, Schumpeter cannot be faulted for this approach and for concentrating attention on this underlying explanation of the spring tides and ebb tides of economic development.

There *have been* periods of deep structural adjustment in the 1830s, 1880s, 1930s and 1980s, which were regarded at the time and by historians since, as unusually difficult times for the economy. These periods cannot be treated in just the same way as the minor recessions of the 1950s and the 1960s or similar recessions in other periods of high boom, such as the 1850s and 1860s or the 1890s to 1913. Nor can the sense of these long boom periods as 'belles epoques' or golden ages of growth ('Les trente glorieuses") be dismissed as collective self deception because the untidy, uneven and imperfect measures of aggregate growth that we have do not always conform to the ideal requirements of some statisticians.

The criticisms of Schumpeter's *Business Cycles* which follow therefore do not refer to this "statistical" critique, nor to matters of style or presentation but to the fundamental concepts, i.e. to his theory of equilibrium, his theory of innovation and entrepreneurship and his theory of technology.

II. Schumpeter, Walras and Keynes

One of the problems which Schumpeter faced was the ascendancy of Keynesian ideas in the 1930s and 1940s and their greater-policy relevance. Many people have puzzled over the apparent inconsistency between various statements of Schumpeter about equilibrium. On the one hand, he said that the system never was and never could be in equilibrium and stressed the inherently disequilibrating effects of the stream of innovations characteristic of capitalism. On the other hand, he consistently praised Walras for his theory of general equilibrium and insisted not only that this was the greatest achievement of economic theory, but that it was close to reality. Precisely in Volume I of Business Cycles he insists that "Common sense tells us that the mechanism for establishing or re-establishing equilibrium is not a figment devised as an exercise in the pure logic of economics but is actually operative in the reality around us." (page 47)

Some critics have attempted to resolve this apparent inconsistency by arguing that he used the model of static general equilibrium simply as an expositional device, to contrast with his own dynamic model, and to make this more intelligible to the reader. But, as the quotation above

suggests, this cannot be reconciled with the fact that Schumpeter constantly emphasised the importance of equilibrium throughout his life from the first chapter of *Theory of Economic Development* (and his earlier book on economic doctrine and method) to his final work *History of Economic Analysis.* Shionoya (1986) is therefore right to insist that Schumpeter's admiration for Walras was no mere formal acknowledgement or passing phase, but was an integral part of his entire theory.

Both in *Theory of Economic Development* and in *Business Cycles* Schumpeter represents *boom* as a departure from equilibrium and recession as a return to equilibrium in largely Walrasian terms? In *Business Cycles* he also represents *depression* as a departure from equilibrium and the revival from depression as a return to equilibrium. He said of long cycles: "The phenomenon becomes understandable only if we start with the neighbourhood of equilibrium preceding prosperity and end up with the neighbourhood of equilibrium following revival." (page 156)

Whilst in *Business Cycles* Schumpeter regarded depression as an 'unnecessary' and pathological departure from equilibrium (pp. 150-155) which could be aggravated by scares or panics and whose depth could not be predicted, he nevertheless continued to stress the "natural" equilibrating tendencies of the system. Moreover, he believed that these equilibrating tendencies were inherent in the behaviour of the economy.

Paradoxically, therefore, he had greater faith in the resilience of the economy than Keynes and devoted very little attention either to the role of institutions or to the role of technology in achieving a more stable dynamic equilibrium.

In the 1930s, Schumpeter took up the position of the detached academic partly because he did not think that there was very much that should be done about the depression, or indeed could be done. Keynes took up the position of the scourge of "laissez-faire" theories because he thought that there was a great deal which could and should be done to counteract depressive forces in the British and in the world economy...

Already long before the publication of his own *General Theory* in 1936 in a BBC broadcast he was quite explicit (quoted in Eatwell, 1982):

"On the one side are those who believe that the existing economic system is, in the long run, a self-adjusting mechanism, though with creaks and groans and jerks and interrupted by the time lags, outside interference and mistakes . . . . on the other side of the gulf are those who reject the idea that the existing economic system is, in any significant sense, self-adjusting . . . I range myself with the heretics."

As is well known, Schumpeter wrote a highly critical, even vitriolic review of the "General Theory".

Paradoxically, despite his own reputation as a heretic, he was in some respects closer to the "self-adjusting" school, although he believed that the equilibrating mechanism operated through cycles of varying length. However, lack of immediate political applications would not in itself have prevented Schumpeter's theory of business cycles from becoming more influential, if the central ideas had proved themselves in the long term.

III. Schumpeter's Theory of Innovation and Entrepreneurship

It might seem strange to criticise Schumpeter's concept of innovation and entrepreneurship which was after all his most distinctive contribution to economics generally and not just to the theory of business cycles. There is no serious disagreement with his insistence that innovation incessantly revolutionises the economic structure and that "this process of creative destruction" is an essential fact about capitalism, (*Socialism and Democracy,* p. 83).

What is at issue is not this part of his vision, which does indeed give him a unique position among 20th Century economists. The problem lies rather in the abstract generalisations about innovation and diffusion which predominate in the basic theory of business cycles, although much less so in the historical sections. This abstract "pure theory" of innovation is closely related to his theory of entrepreneurship since an entrepreneur is defined as the individual responsible for an innovation. Both his theory of innovation and and his theory of entrepreneurship carried over directly from the *Theory of Economic Development.*

In some ways Schumpeter's definition of innovation was a wide one. He included not only technical innovations, but organisational and managerial innovations, new markets, new sources of supply, financial innovations and 'new combinations'. There are passages in *Business Cycles* where he appears to accept the introduction of a new product into another country or another region as 'innovation' *(*p. *374)* rather than 'imitation', although elsewhere he is dismissive of 'imitators' as mere routine managers rather than genuine entrepreneurs.

But despite the breadth of his definition and the occasional extension of the concept to some aspects of diffusion his conceptualisation of innovation was in other ways very limited. He scarcely discussed the origins of innovation, had virtually nothing to say about the interactions of science and technology and largely neglected the cumulative nature of technology, despite his earlier recognition (1928) of the role of industrial R&D departments in large corporations. He substituted a theory of entrepreneurship both for a theory of the firm and for a theory of innovation. It is almost as though his vision of innovation and entrepreneurship was frozen at the level of the first formulation in *Theory of Economic Development* in 1912. Shionoya (1986) was justified in describing this formulation as failing to explain what circumstances determine innovation and in commenting that "innovation remained an exogenous factor to the economic system despite his contrary assertion." Ruttan (1959) put the matter more bluntly when he said:

"Neither in *Business Cycles* nor in Schumpeter's other work is there anything that can be identified as a theory of innovation. The business cycle in Schumpeter's system is a direct consequence of the appearance of clusters of innovations. But no real explanation is provided as to why innovations appear in clusters or why the clusters possess the particular types of periodicity which Schumpeter identified..."

Tsuru (1993) makes the interesting point that for Schumpeter it was this business cycle theory which determined his theory of capitalism itself, since profit was defined as arising only from entrepreneurship which disturbed equilibrium. For Marx it was the other way about: his theory of business cycles was derived from his theory of the instability and conflicts of interest engendered by capitalist relationships.

Instead of discussing the circumstances which may encourage or hinder innovations, and why they cluster together, Schumpeter simply insists that they are the product of super-normal individuals with exceptional intelligence and energy. Innovation is described as "an act of will" rather than of intellect. Whilst there is certainly an element of truth in Schumpeter's perception of the exceptional difficulties facing many innovators and the exceptional persistence which is often needed to see them through, this conceptualisation is lacking in depth and, surprisingly, in historical perspective. Moreover, it leads to relative neglect of some of the elements which are actually essential for a satisfactory theory of the business cycle itself: the interdependence of many innovations both technologically and economically and the existence of technological trajectories. It also leads to a relative neglect of incremental innovations, which are less obviously the product of 'heroic' entrepreneurship but whose cumulative effect is nevertheless extraordinarily important. Finally, it fails to focus attention on the specific features of each new wave of technical change, which is supposedly the driving force of each long cycle of economic development.

These are harsh comments but it was these weaknesses which made it possible for Kuznets (1940) and others to make two basic criticisms of Schumpeter's Business Cycles to which he had no adequate response.

1. Which innovations were so big in their scale that they could possibly drive long cycles of the entire world economy? There are tens of thousands of inventions and innovations every year. Surely some theory of the clustering of innovations would be necessary to relate innovations to major waves of investment and long cycles of development

2. Why should a long cycle last about half a century? If it is entrepreneurial energy which drives the whole system then, Kuznets asked ironically, did the heroic entrepreneurs get tired every 50 years?

The answer to the first criticism is actually *implicit* in much that Schumpeter wrote in *Business Cycles* and *Capitalism, Socialism and Democracy* and in some passages, it is explicit as for example, in the following:

"When some innovation has been successfully carried into effect, the next wave is much more likely to start in the same or a neighbouring field than anywhere else. Major innovations hardly ever emerge in their final form or cover in one throw the whole field that will ultimately be their own. The railroadisation, the electrification, the motorisation of the world are instances." (*Business Cycles*, p. 167)

But although in this and other passages, there is the embryo of a full-fledged theory of the long-term diffusion of interdependent clusters of technical and organisational innovations, elsewhere the approach is far more discursive and resembles a listing of various scattered innovations, rather than a more systematic account of constellations of technologically, economically and socially interrelated innovations, connected by cumulative advances in science and technology and knowledge accumulation in specific types of firm and leading sectors.

In Business Cycles Schumpeter does use the expression "industrial revolution" both to describe the first Kondratieff wave in 18th Century Britain and to characterise the changes in the third Kondratieff cycle, but he does not develop the concept systematically in either case. This failure may be attributed partly to the fact that he was actually far more interested in the financial side of business cycles than in the technology. Only about a hundred out of a thousand pages in the book deal mainly with inventions and innovations. But this was not the main problem. More important was his pre-occupation with the *individual* entrepreneur and the individual innovation and his reluctance to conceptualise invention, innovation and technology accumulation as a social process. This is related to his theory of diffusion with its sharp distinction between true entrepreneurs and routine managers and imitators.

Schumpeter's threefold distinction between invention, innovation and diffusion of innovations has been widely adopted by economists and there is no doubt that it has been analytically valuable. At least conceptually, it *is* essential to distinguish between the original *idea* for a new product or process (which may often be patented) and the translation of this idea into a commercially realisable innovation. The capacity of an enterprise to design, develop, produce and market a new product is *not* identical with inventive activities and nor do the two activities necessarily co-exist in the same organisation. Schumpeter's insistence on this point was a major contribution to the understanding of innovation, even though there is an important overlap and interaction between inventive and innovative activities, and the very process of design, development, production and marketing may often give rise to further inventions. Similarly in the case of the distinction between innovation and diffusion of innovations.

There is a difference between the very first commercial introduction of a new product or process and the subsequent process of diffusion (or "swarming" as Schumpeter so aptly named it). But again this distinction can be overdone. Economists who have studied diffusion processes in depth

(e.g. Rosenberg, 1976) have emphasised very strongly that the product or process which is diffusing through an adopter population at the end of the diffusion often bears little resemblance to the one which started the whole process. Schumpeter was certainly aware of this point. He emphasised himself that "the motorcar would never have acquired its present importance and become so potent a reformer of life if it had remained what it was thirty years ago and if it had failed to shape the environmental conditions - roads among them - for its own further development." (*Business Cycles*, p. 167).

Nevertheless, as so often in his work there was a co-existence of two apparently contradictory elements. On the one hand there was an insistence on looking at technical journals and company histories to understand the real process of technical change, and a real appreciation of many features of technical innovation. But on the other hand, this existed side by side with an *a priori theory* of entrepreneurship which is largely a-historical.

If we look at the history of science, technology, invention, innovation and diffusion of innovations, then we find of course recognition of the contribution of outstanding individuals in all parts of the system. But we also usually find recognition of innumerable minor contributions and of the role of institutions in the accumulation, dissemination and application of new knowledge.

At one end of the spectrum are some historians who put the main emphasis on outstanding individuals and at the other end of the spectrum are those who stress the innumerable, sometimes anonymous contributions of a wide variety of scientists, technologists, engineers, workers, managers and users. Examples of the latter are theories of "learning by doing" and "learning by using", Gilfillan's (1935) theory of invention as proposed in his book on *Sociology of Invention* and Hessen's (1931) theory of scientific discovery. Examples of the former are Jewkes' (1958) study of the "Sources of Invention" and Schumpeter's own theory of entrepreneurship.

In both these cases, there is of course some recognition that 'pygmies' as well as 'giants' play some part in the process and some recognition that social institutions, such as research laboratories, design departments, universities and firms may facilitate the activities of inventors and innovators.

Schumpeter did recognise (*Business Cycles*, p. 346) that the function of entrepreneurship could be performed within public institutions and he also recognised that it could be split between a number of individuals (*Business Cycles*, p. 327). Jewkes also recognised that some important inventions did emerge from the R&D laboratories of large firms and that it was sometimes hard to ascribe them to any single individual or even to several. Schumpeter went further and maintained that large oligopolistic or even monopolistic firms would have a competitive advantage in research and innovation. It may therefore seem strange to classify him with the 'heroic' individualist school. His position was contradictory since he also maintained that the bureaucratisation of innovation would lead to the death of entrepreneurship and of capitalism itself.

Despite the later developments in his theory in the 1920s and 1930s (Schumpeter "Mark II") his basic theory of entrepreneurship was scarcely modified in *Business Cycles* compared with the Theory of Economic Development. He failed to develop the notion that the function of entrepreneurship could be exercised differently in different types of firm and with different types of innovation in each successive industrial revolution. He had a theory of entrepreneurship without a theory of the firm. This prevented him from recognising the full significance of the 'partnership' form of company organisation in the first Kondratieff wave (the original "industrial revolution") as well as later changes in company structure, culminating in the "networking" organisations of today.

Numerous empirical studies of innovation have confirmed Schumpeter's recognition of the importance of the entrepreneurial function in taking an invention to the market. They have confirmed his view that an entrepreneur is not the same as a capitalist. But they have also shown that the way in which the function of entrepreneurship is performed varies across different types of firms, different countries, different technologies and different historical periods. Characteristically

they also show multiple sources of information inputs from within and from outside the innovating organisation and the importance of the "national systems of innovation" - the supporting network of scientific and technical institutions, the infrastructure and the social environment. These things are surprisingly lacking in Schumpeter's theory of innovative entrepreneurship.

Thus, although his theory went beyond the mainstream theory of the firm as a rational profit maximising agency, operating with perfect information and foresight in any country, any culture and any period of history, it suffered to some degree from the same tendency to postulate from pure logic a single universal essence for entrepreneurship.

This was important for his theory of "business cycles" because it meant that he made little or no attempt to examine the changing pattern of international technological leadership and related patterns of entrepreneurship or the influence of innovation on patterns of international trade.

IV. A New Theory of Innovation and Long Cycles

It would be impossible in this paper to do justice to the enormous range of empirical and theoretical work on innovation, diffusion, entrepreneurship, and their relationship to business cycles, which has been carried out since Schumpeter's death. Much of it was inspired directly or indirectly by Schumpeter's own work and this is the best tribute to his achievement. It is possible here only to select and condense from a few contributions some of the results which seem most relevant to this discussion and to indicate some elements of a new theory.

One of the difficulties which Schumpeter confronted was precisely the lack of empirical and theoretical studies in his field of investigation. Rogers (1962) and Rosenberg (1976) have pointed out that there were scarcely any studies of diffusion of innovations in industry before the 1960s. There were also very few case studies of innovation which took into account technological, economic and entrepreneurial aspects. The history of technology was a relatively neglected area even by comparison with the history of science. Today, the situation is undoubtedly much improved although this improvement relates mainly to the period since the Second World War rather than to the long-term historical studies. Nevertheless, it is now possible to make tentative generalisations about some aspects of innovation, diffusion and entrepreneurship with a little more confidence than was possible in Schumpeter's time. The task of economic theory has been to develop a theory of the firm which does not assume as its foundation either hyper-rationality of individual entrepreneurs or groups, nor yet supernormal intelligence and energy (Dosi and Orsenigo, 1988). This research programme is sometimes described as "neo-Schumpeterian".

Technical innovation emerges from this research not only as a disequilibrating, uncertain, disturbing element, but also quite often as an element of continuity, with rather well-defined trajectories, and sometimes offering rather clear-cut investment opportunities for future development of new products, processes, systems and markets. It remains true that in other circumstances, described so vividly by Schumpeter, technical innovations and their diffusion can be a severe shock to the system. This means, however, that it is not necessary to found a theory of business cycles on the supposed dichotomy between the destabilising effects of innovation and the supposed equilibrating effects of "normal" economic behaviour in absorbing these shocks in recession and recovery periods. Rather is it important to identify in what circumstances *technical innovation* itself may stimulate and restore business confidence and in what circumstances the reverse may occur (Freeman and Perez, 1988).

This analysis cannot be restricted to the level of the individual innovation or to counting of numbers of innovations; the qualitative aspects and the systems inter-relatedness of innovations must be taken into account. Furthermore, it must recognise that it is *diffusion* of innovations which underlies waves of investment, not the first attempts. Under favourable conditions, the Schumpeterian band-wagons roll and business confidence improves leading to an atmosphere of "boom" in which, although there are still risks and uncertainties attached to all investment decisions, animals spirits

rise. Such favourable conditions include complementarities between equipment, materials and component innovations and the emergence of an appropriate infrastructure as well as some degree of political stability and institutions which promote or at least do not hinder too much the diffusion of new technologies. In these favourable circumstances the growth of new markets and the profitability of new investments appears to offer a fairly stable prospect of future growth, despite the uncertainties, which are always present.

But there are also circumstances when technical change can initially have the opposite effect and can destabilise investment by undermining confidence in the future prospects for the growth of some firms, industries or economies. Moreover, as technologies and industries mature over a long period, diminishing returns and declining profitability may set in leading to sluggish investment behaviour. If this is at all widespread it may take major social and political changes to restore confidence in the future growth of the system on the basis of new technologies. The "natural" equilibrating tendencies of the economy are not sufficient as they involve a complex process of institutional and structural change, now commonly described as "structural adjustment".

On several of these problems Carlota Perez (1983, 1985, 1986, 1997) has made an important contribution to formulating a new and more plausible theory of the relationship between innovation and long cycles of development. In particular, she has provided a convincing answer to Ruttan's point about clusters of innovations and Kuznets' original criticisms of *Business Cycles*, by suggesting the notion of a pervasive change in technology underlying each of Schumpeter's "successive industrial revolutions". As we have seen, Schumpeter himself hinted at such a concept but failed to provide any empirical or theoretical foundation for his idea. A number of authors, such as Keirstead (1948) with his "constellations" of innovations or Freeman, Clark and Soete (1982) with their "new technology systems" or Dosi (1982) with his "technological paradigms" have demonstrated both a technological and an economic basis for the clustering of innovations. But Perez went beyond these formulations in several important respects. Her concept is that of a "meta-paradigm" change affecting all or almost all branches of the economy, directly or indirectly.

She uses the expression "techno-economic" rather than "technological paradigm" (Dosi, 1982) because the changes involved go beyond engineering trajectories for specific product or process technologies and affect the conditions of production and distribution throughout the system and because the 'glue' which links the innovations together is not merely technology. Her concept corresponds to Nelson and Winter's concept of "general natural trajectories" and once established as the dominant influence on engineers, designers and managers becomes a "technological regime" for several decades. From this it is evident that she views Schumpeter's successive industrial revolutions as a succession of "techno-economic paradigms".

A new techno-economic paradigm develops initially within the old, showing its decisive advantages already during the "downswing" phase of the previous Kondratieff cycle.

However, it becomes established as a dominant technological regime only after a period of great turbulence (a crisis of structural adjustment) involving deep social and institutional changes, as well as the replacement of the motive branches of the economy by new leading sectors. This point is an important one as several theories have suggested that Kondratieff upswings were based on a cluster of innovations introduced immediately before the upswing (Mensch, 1975). Schumpeter, on the other hand, pointed several times to the long gestation period for the diffusion of key innovations and to the fact that they were sometimes made long before the upswing in which they became predominant, as in the case of railways (*Business Cycles*, pp 254-255) or the related case of steam engines (von Tunzelmann, 1978), which became the predominant technological regime only in the second and not the first Kondratieff cycle.

As has already been made clear, Perez's conception of a techno-economic paradigm" is much wider than "clusters" of innovations or even of "technology systems". She is referring to a combination of

interrelated product and process, technical, organisational and managerial innovations, opening up an unusually wide range of new investment and profit opportunities.

Such a paradigm change implies a unique new combination of decisive technical and economic advantages.

The organising principle of each successive paradigm and the justification for the expression "techno-economic paradigm" is to be found not only in a new range of products and systems, but most of all in the dynamics of the relative cost structure of all possible inputs to production. In each new techno-economic paradigm, a particular input or set of inputs, which may be described as the "key factors" of that paradigm, fulfil the following conditions:

1. Clearly perceived low and rapidly falling relative cost. As Rosenberg (1976) and other economists have pointed out, small changes in the relative input cost structure have little or no effect on the behaviour of engineers, designers and researchers. Only major and persistent changes have the power to transform the decision rules and "common sense" procedures for engineers and managers (Perez, 1985; Freeman and Soete, 1987).
2. Apparently almost unlimited availability of supply over long periods. Temporary shortages may of course occur in a period of rapid build-up in demand for the new key factor, but the prospect must be clear that there are no major barriers to an enormous long-term increase in supply. This is an essential condition for the confidence to take major investment decisions which depend on this long-term availability.
3. Clear potential for the use or incorporation of the new key factor or factors in many products and processes throughout the economic system; either directly or (more commonly) through a set of related innovations, which both reduce the cost and change the quality of capital equipment, labour inputs and other inputs to the system.

Perez maintains that this combination of characteristics holds today for microelectronics and few would deny this. It held until recently for oil, which underlay the post-war boom (the "fourth Kondratieff' upswing). Before that, she suggests that the role of key factor was played by cotton in the first, by coal and iron in the second and by low cost steel in the third Kondratieff (Tables l-4). In *Business Cycles,* p. 372, Schumpeter had already commented on the enormous range of innovations in machinery and metal products which were facilitated by the universal availability of cheap steel (Table 5).

Clearly, every one of these inputs identified as "key factors" existed (and was in use) long before the new paradigm developed. However, its full potential was only recognised and made capable of fulfilling the above conditions when the previous key factors and their related constellation of technologies gave strong signals of diminishing returns and of approaching limits to their potential for further increasing productivity or for new profitable investment.

Table 1

COAL PRICES IN BRITAIN BY REGION
1800-1850
(Shillings per Ton)

	London	Birmingham	Manchester
1800	46	9	16
1810	38	12	13 (1813)
1820	31	13	10 (1823)
1830	26	6 (1832)	10 (1833)
1840	22	8	7 (1841)
1850	16	5	6

(von Tunzelmann, 1978)

Table 2

Price of Steel Rails in USA

Year	Steel Rails $ per Ton Prices	Consumer Price Index
1870	107	38
1875	69	33
1880	68	29
1885	29	27
1890	32	27
1893	28	27
1895	24	25
1898	18	25
1910	28	28
1920	54	60
1930	43	50

Source: US Historical Statistics

Table 3

KEY FACTORS: VOLUME AND PRICE

OIL

"Real" Crude Oil Price $ per Barrel
(1991 Base Year)

1860	30
1870	34
1880	10
1900	12
1910	7
1920	10
1940	8
1960	7
1970	3

(Cambridge Energy Research Associates quoted in "*The Prize*", Yergin, 1991)

World Crude Oil Production
(Billion Barrels)

1939	2.1
1950	3.8
1960	7.7
1973	20.4
1991	22.6

(Price 1991 = $18.1)

Table 4 Estimates of Increase in ICT Capacity

Area of Change	(1) Late 1940s-Early 1970s	(2) Early 1970s-Mid 1990s	(3) Mid 1990s Onwards "Optimistic" Scenario
OECD Installed Computer Base (Number of machines)	30,000 (1965)	Millions (1985)	Hundred Millions (2005)
OECD Full-time Software Personnel	> 200,000 (1965)	> 2,000,000 (1985)	> 10,000,000 (2005)
Components per Micro-electronic Circuit	32 (1965)	1 Mega-bit (1987)	256 Mega-bit (late 1990s)
Leading Representative Computer: Instructions per Second	10^3 (1955)	10^7 (1989)	10^9 (2000)
Cost:Computer Thousand ops. per $US	10^5 (1960s)	10^8 (1980s)	10^{10} (2005)

Source: Freeman and Soete (1994)

Table 5

NEW APPLICATIONS OF CHEAP HIGH QUALITY STEEL
1880-1914

Steel ships

Steel alloys
- High speed machine tools

Heavy electrical equipment
- Turbo-generators
- Pylons

Steel Structures
- Chemical plant
- Oil refineries
- Pipelines
- Overhead cranes
- Skyscrapers
- Offices

Agricultural machinery

Armaments
- Krupp
- Vickers

This point complements Schumpeter's analysis in terms of the erosion of profitability through the swarming process.

Perez argues that from a purely technical point of view, the explosive surge of interrelated innovations involved in a technological revolution, could probably have occurred even earlier and

in a more gradual manner. But there are strong economic and social factors at play that serve as prolonged containment first and as unleashing forces later. The massive externalities created to favour the diffusion and generalisation of the prevailing paradigm act as a powerful deterrent to change for a prolonged period. Paul David (1985) demonstrated some of the ways in which the economy may become "locked in" to a particular technology and Brian Arthur (1988) has provided convincing evidence of the strength of these "containment" forces in his theory of path-dependent processes. It is only when productivity along the old trajectories shows persistent limits to growth and future profits are seriously threatened that the high risks and costs of trying the new technologies appear as clearly justified. And it is only after many of these trials have been obviously successful that further applications become easier and less risky investment choices.

The new key factor does not appear as an isolated input, but rather at the core of a rapidly growing system of technical, social and managerial innovations, some related to the production of the key factor itself and others to its utilisation. At first, these innovations may appear (and may be in fact pursued) as a means for overcoming the specific bottlenecks of the old technologies, but the new key factors and related sectors soon acquire their own dynamics and successive innovations take place through an intensive interactive process, spurred by the limits to growth which are increasingly apparent under the old paradigm. In this way the most successful new technology systems gradually crystallise as an 'ideal' new type of production organisation which becomes the common sense of management and design embodying new 'rules of thumb', restoring confidence to investment decision-makers after a long period of hesitation. This process can be seen very clearly today with the inter-related growth of micro-electronic components, computers, telecommunications and a wide range of new services and manufactured products.

The full constellation - once crystallised - goes far beyond the key factor(s) and beyond technical change itself. It brings with it a restructuring of the whole productive system. Among other things as it crystallises, the new techno-economic paradigm involves:

(a) a new "best practice" form of organisation in the firm and at the plant level (Table 6);

(b) a new skill profile in the labour force, affecting both quality and quantity of labour and corresponding patterns of income distribution;

(c) a new product mix in the sense that those products which make intensive use of the low cost key factor will be the preferred choice for investment and will represent therefore a growing proportion of GDP;

(d) new trends in both radical and incremental innovation geared to substituting more intensive use of the new key factor(s) for other relatively high cost elements;

(e) new trends in the location of investment both nationally and internationally as the change in the relative cost structure transforms comparative advantages;

(f) a particular wave of infrastructural investment designed to provide appropriate externalities throughout the system and facilitate the use of the new products and processes everywhere (Table 7) (Antonelli, 1992);

(g) a tendency for new innovator-entrepreneur type small firms also to enter the new rapidly expanding branches of the economy and in some cases to initiate entirely new sectors of production.

From this it is evident that the period of transition - the downswing and depression of the long wave - is characterised by deep structural change in the economy and such changes require an equally profound transformation of the institutional and social framework. The onset of prolonged recessionary trends indicate the increasing degree of *mismatch* between the techno-economic subsystem and the old socio-institutional framework. It shows the need for a full scale reaccommodation of social behaviour and institutions to suit the requirements and the potential of a shift which has already taken place to a considerable extent in some areas of the techno-economic

sphere. This reaccommodation occurs as a result of a process of political search, experimentation and adaptation, but when it has been achieved, by a variety of social and political changes at the national and international level, the resulting 'good match facilitates the upswing phase of the long wave. A climate of confidence for a surge of new investment is created through an appropriate combination of regulatory mechanisms which foster the full deployment of the new paradigm.

Table 6

CHANGE OF TECHNO-ECONOMIC PARADIGM

"Fordist" Old	ICT New
Energy-intensive	Information Intensive
Design and engineering in "drawing" offices	Computer-aided designs
Sequential design and production	Concurrent engineering
Standardised	Customised
Rather stable product mix	Rapid changes in product mix
Dedicated plant and equipment	Flexible production systems
Automation	Systemation
Single firm	Networks
Hierarchical structures	Flat horizontal structures
Departmental	Integrated
Product with service	Service with products
Centralisation	Distributed intelligence
Specialized skills	Multi-skilling
Government control and sometimes ownership	Government information, co-ordination and regulation
"Planning"	"Vision"

Source: Adapted from Perez (1990)

Table 7

SUCCESSIVE WAVES OF TECHNICAL CHANGE

LONG WAVES OR CYCLES		KEY FEATURES OF DOMINANT INFRASTRUCTURE			
Approx. timing	Kondratieff waves	Science Technology Education and Training	Transport Communication	Energy Systems	Universal and Cheap Key Factors
1st 1780s-1840s	"Industrial Revolution" Factory Production for textiles	Apprenticeship, Learning by doing, Dissenting Academies, Scientific Societies	Canals Carriage Roads	Water Power	Cotton
2nd 1840s-1890s	Age of Steam Power and Railways	Professional mechanical and civil engineers, Institutes of Technology, Mass primary education	Railways (Iron) Telegraph	Steam Power	Coal Iron
3rd 1890s-1940s	Age of Electricity and Steel	Industrial RD Labs, Chemicals and electrical, National Laboratories, Standards Laboratories	Railways (Steel) Telephone	Electricity	Steel
4th 1940s-1990s	Age of Mass Production ("Fordism") of Automobiles and Synthetic Materials	Large scale industrial and government RD Mass higher education	Motor Highways Radio and TV Airlines	Oil	Oil Plastics
5th 1990s - ?	Age of Micro-electronics and computer networks	Data networks RD global networks Lifetime education and training	Information Highways Digital Networks	Gas/Oil	Chips
6th ? - ?	Green techno-economic paradigm	Humanities and arts reconnected with social and natural sciences	Telematics Teleworking	Renewable Energy	?

Source: Freeman and Perez 1988

Since the achievement of a 'good match' is a conflict-ridden process and proceeds very unevenly in differing national political and cultural contexts, this may exert a considerable influence on the changing pattern of international technological leadership and international patterns of diffusion.

The uneven and varied response of governments, firms and industries to the threats and opportunities posed by a new wave of technology tends to accentuate the uneven process of development. Newcomers are sometimes more able to make the necessary social and institutional innovations than the more arthritic social structures of established leaders. This means that changes of techno-economic paradigm are likely to be associated with the temporary aggravation of instability problems in relation to the flow of international investment, trade and payments.

It has been possible to give only a brief summary of some new developments in the theory of innovation and long cycles. But they do indicate a real possibility of overcoming some of the weaknesses in Schumpeter's pioneering formulation. To continue in this direction would be the best tribute to the spirit of his work.

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