

THE CARRIER WAVE

New Information Technology
and the geography of innovation,
1846–2003

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Long waves, New IT and the geography of innovation

Long waves of economic development, the starting point and main organizing concept of this book, have long been the subject of impassioned intellectual controversy. Yet – whatever their cause, whether or not they even exist – on one point there can be no debate: there is a definite long wave in academic interest in them. And it runs a countercyclical course: booming in the recessive 1920s and depressive 1930s, moribund in the expansionary 1950s and 1960s, recovering in the recessionary 1970s, flourishing again in the depression-ridden world of the 1980s (Mandel 1980; van Duijn 1983). The reason, evidently, is that the obsessions of social scientists mirror the state of the world outside the ivory tower: in periods of economic upswing, economists study the conditions of economic development and geographers produce models of growth; in periods of recession, economists rediscover the business cycle while geographers analyse the anatomy of job loss. And both turn to the study of innovative, high-technology industry, which has become ‘the economic development strategy of the 1980s ... the only economic development game in town’ (Saxenian 1985c, 121).

The ghost of Kondratieff

So, neglected and almost forgotten for a third of a century, the name of Nikolai Kondratieff has returned to haunt the halls of academe. It is easy to see why. Kondratieff, an early Soviet economist whose classic papers were published in the mid-1920s, certainly was not the first to discover long waves; but he did use them to provide both an explanation of why capitalism should experience major economic crises at approximately half-century intervals, and an analysis of the way in which it would – just as

predictably – escape from them (Kondratieff 1935). Perhaps, though the ostensible excuse was that he was trying to organize an opposition party, that was the real reason why Stalin had him arrested and sent to Siberia; there, according to Solzhenitsyn's *Gulag Archipelago*, he died insane (van Duijn 1983).

Long waves, according to Kondratieff, were accompanied by changes in technology, but were not triggered by them; for new techniques could be exploited only when the economic conditions were right. But a decade after Kondratieff wrote, Joseph Schumpeter came to apply his theory in detail, and stood it on its head (Schumpeter 1939). He argued that the start of each long wave was indeed caused by a new bunch of innovations, which created whole new industries: coal, iron and steam in the first Kondratieff (1785–1842), steel and railways and steamships and machine tools in the second (1843–97), cars and electrical goods and chemicals in the third (1898–). So, in the subtitle of the book by Gerhard Mensch (1979), *Innovations Overcome the Depression*. This, of course, represented a direct challenge to the conventional Keynesian, and behind that the entire neoclassical, economic tradition, which had almost totally ignored the rôle of technological change; and the challenge came just when some economists, and many policy makers, were becoming disenchanted with Keynesian analyses and remedies. Small wonder that in the 1980s interest in Kondratieff and Schumpeter should revive; and nowhere more than in the UK, long the sick man of the capitalist world.

The resulting flood of literature has thrown much empirical light on the waves, but has generated no agreement as to their dating or their causes. Among the researchers, there is now at least general consensus as to the existence of a long wave of some 50–60 years' duration. There is however much difference in detail on their precise timing, with a special degree of disagreement about the current, fourth, Kondratieff. There is also some agreement that technological innovation plays a rôle. But there is very fierce debate as to the causal relationships. Does innovation really peak at approximately half-century intervals? Is it, so to speak, autonomous, surging at regular intervals according to laws of its own? Or does it respond to crises of capital accumulation? What is the rôle of organizational and, indeed broader social innovations? Do innovation waves depend on strictly contingent and random events, like wars? But do not wars also follow a long-wave pattern, as Kondratieff asserted? All these questions are still exciting sharp controversy and a flood of literature.

An alternative approach: New IT and the geography of innovation

Much of this debate has taken place at a very high level of historical generality. Other, more detailed, work has had a restricted time-span. In this book we try to take a different approach: we look at one complex of technologies and industries over the span of three Kondratieff cycles. We have chosen the group of industries that during this long period – not least, during the recent fourth Kondratieff downswing – have increasingly been at the leading edge of technological innovation, and may fairly be called the key industries of the current fourth Kondratieff downswing: the so-called New Information Technology (hence, New IT) industries, embracing the technologies – mechanical, electrical, electromechanical, electronic – that record, transmit, process and distribute information.

New IT, as will emerge, was born during the 19th century. For centuries before that there had been information technologies: writing, printing, simple forms of telegraphy. But the invention of the electrical telegraph in the 1830s, and that of the telephone and the typewriter and the phonograph in the period 1875–1890, marked a distinct new era of technological development: hence the term New IT, NIT for short. More recently, in the 1970s and early 1980s, we have witnessed another burst of innovation which is increasingly producing a convergence of formerly separate New Information Technologies, particularly the computer and the telephone. Some literature refers to this latest development as 'New IT'. Since for us the term refers to the cluster of information technologies that began in the 1870s and continued through the third and fourth Kondratieffs, we shall call the newer development 'Convergent IT', CIT for short.

Our aim in studying the genesis and development of the New IT industries has been twofold. First, we hope that thereby we shall throw greater light on the precise nature of the innovative process and on its historical contribution to the creation of new industrial traditions, particularly the impact of major new technological systems on economic and social development. But that is ancillary to our second and main purpose: to understand the changing geography of innovation. Evidently, over the course of capitalist history the fortunes of the main industrial nations have waxed and waned. In the first Kondratieff, Britain was pre-eminently the major, almost the sole, industrial nation. In the second, it was increasingly challenged by Germany and the USA. In the third,

these two challengers took the lead; by its end, the United States was indisputably world industrial leader. During the fourth, it retained its leadership but was increasingly challenged by a relative newcomer, Japan. Precisely the same sequence applies for the New IT industries, which first appeared in the second Kondratieff.

And, just as on the international stage, so within each of the leading national economies: the locus of the leading-edge innovative industries has switched from region to region, from city to city. From the birth of New IT in the second Kondratieff and on through the third, Berlin and the Boston–New York Corridor were the main global centres of innovation; during the fourth, they were supplemented or supplanted by new urban centres such as Southern California, Silicon Valley, the Western Crescent around London, the Stuttgart–Munich Corridor, and the Tokaido Megalopolis. Our central question is why these shifts should have occurred. Do they truly reflect changes in innovatory energy? And if so, what forces could be responsible?

The structure of the book

The book has a simple structure, evident from the table of contents. It is divided into five parts.

Part One is introductory to the main subject matter. Chapter 2 aims to provide a succinct overview of the burgeoning literature on long waves and the main lines of the long-waves debate. It further develops the point that right from the start there were important differences – not least between Kondratieff and his leading exponent, Schumpeter – on the causal mechanisms. It documents the criticisms by Kuznets and others, during the 1940s and 1950s, of the long-wave concept, including the suggestion of a shorter (20–25-year) construction cycle: the Kuznets cycle. It summarizes the work of Mensch, which essentially relaunched the whole debate during the 1970s, and examines the detailed criticisms of his thesis by the Science Policy Research Group and others. Finally it tries to sum up the state of the debate at the time of finishing this book, Autumn 1986.

Chapter 3 turns to the New Information Technology industries themselves. It seeks to isolate their distinguishing characteristics, especially *vis-à-vis* the older information technologies which they supplemented and partly replaced. It discusses some of the problems of defining and measuring them, especially across international boundaries and across decades. It concludes with a summary of the main technologies and their evolution over the

long period from 1842 to the present: the period of the so-called second, third and fourth Kondratieffs.

Thereafter, the book is organized chronologically in three parts, corresponding to these three long waves. The treatment becomes increasingly dense and detailed as we move from one part to the next. That is first because the necessary information, especially the necessary statistics, becomes increasingly plentiful as we move towards the present day; secondly because the NIT industries play an increasingly important role, marginal in the second Kondratieff, significant but indirect in the third, increasingly dominant (in the form of CIT) during the fourth Kondratieff downswing. In the fourth Kondratieff, indeed, they begin to play a role like steel and ships in the second, transformers and cars and pharmaceuticals in the third: by the downswing of that long wave, in a Schumpeterian sense, they become the true technological carriers of the wave.

The main focus in these chapters is on a comparison between the major nations producing New IT: the UK, Germany, the USA, Japan. And in particular – given that the research was conducted in the UK, against a background of intense interest in the future of high-technology industry there – it puts the UK, and its relative competitive failure, front-of-stage. But an important subsidiary theme, closely linked to the international comparison, is the regional and urban locus of innovation.

Chapter 4, forming a single-chapter part on the second Kondratieff, outlines the origins of New IT at the start of this long wave, in the form of the electric telegraph. Discovered almost simultaneously in Great Britain and the USA in the 1830s, it was the first electrical innovation. It soon became the first agent of instant communication between countries and continents, engendering a new complex of industries which made the pieces of apparatus and above all the cables which connected them. The UK and the USA were the logical seats of these industries, though Germany soon began to challenge them. It also triggered a series of further innovations to improve the system and develop specialized applications, above all in the developing financial markets of the world, associated with the name of Thomas Edison. These, plus the discovery of the telephone by Alexander Graham Bell, a Scots emigrant to the USA – gave that country a pronounced innovative lead towards the end of the second Kondratieff – a lead it never afterwards lost.

Chapter 5, the first of four on the third Kondratieff, represents a massive but necessary diversion from the main story. It recounts the birth of the modern electrical industries, arising from an extraordinary cluster of innovations in the generation and transmission of heavy power during the 1870s and early 1880s. These

came especially from Germany and above all – thanks again especially to Edison – from the USA. In turn they almost instantly created new industrial giants, organized from the start on a huge scale and depending on massive research and development, in these three countries: carriers, together with cars and chemicals, of the third Kondratieff which is dated from the second half of the 1890s.

The reason why this is a necessary diversion is explained in Chapter 6: the new electrical technologies, though they might seem natural partners of NIT, were not effectively married to it for at least another three decades. Instead, a whole series of further innovations of the 1870s and 1880s – many associated with Americans like Edison, others coming from Germany – brought a whole range of New IT industries depending on mechanical, not electric, power: the typewriter, the gramophone, the dictation machine, the rotary stencil duplicator. Only after the development of effective valves in the first decade of the 20th century, making possible wireless telegraphy and ushering in the electronic age, was electric technology again applied to the task of transmitting information. And, down to the 1930s, the radio industry, a belated product of the third Kondratieff, was almost the sole industrial outcome. Consequently, though this Kondratieff could fairly be called the electrical age, in much of it New IT went down a mechanical byway.

In Chapter 7 the study turns to consider the geographical implications, first on the international stage. It poses the question: Why, during the third Kondratieff, did the UK suffer such a massive competitive setback? For, right from the start of this long wave, the UK's major emerging competitors – Germany and the USA – wrenched world leadership from her. Partly that was because many of the basic innovations were made there; partly it had to do with their subsequent exploitation. In both those countries the new electrical industries were organized from the start in giant oligopolistic companies, based partly on links with major financial houses. These provided the large scale investment necessary for the more rapid diffusion of the new technology and joint development of the electrical supply and equipment industries, and which soon reached agreements to regulate and to share all or part of the market. This was particularly evident after the turn of the century in radio, where at the beginning the UK took a substantial lead through the Marconi company, but where first Germany and then the USA reacted by trying to create virtual monopolies. This marks the fact that, increasingly, the state was beginning to intervene in the development of these industries: first

in Germany, later in the USA, it encouraged mergers, regulated competition, promoted education and research, and finally, through its defence ministries, began to become a major customer for high-technology products. In all these respects the UK, still wedded to a 19th-century *laissez-faire* concept of the state's rôle but pervasively wedded to archaic regulation and older forms of industrial structure, progressively fell behind: such is the thesis of the chapter.

Chapter 8 develops this theme on the regional and local scale. In the third Kondratieff the great national metropolitan regions (Berlin, New York–Boston, London) were the major seats of global innovation in both electrical and New IT technologies: the Silicon Valleys of their day. The reasons were complex: in Germany above all, the demands of government and especially of the war machine; in New York especially, the demands of finance capitalism; in both Berlin and Boston, the concentration of high-quality technological education. As R&D increasingly became concentrated in large, well organized industrial laboratories, financed out of profits, these economies of urban agglomeration became less pressing; such laboratories, as the economists say, internalized their externalities. Some of them were thus able to move out of the metropolitan milieu, attaching themselves to production centres like Schenectady or Pittsburgh; but others, on the model of Edison's pioneering venture of the 1870s at Menlo Park in New Jersey, stayed within the general sphere of the great metropolis, moving at most to its rural fringes. And again, London, though it remained Britain's indisputable centre of high-technology research and production, limped behind its major metropolitan competitors.

Chapter 9 brings us to the fourth Kondratieff, the origin of which is generally dated as the late 1940s. Paralleling Chapter 5, it outlines the sequence of critical innovations that ushered in the electronic age. The central technology is of course the computer in all its manifestations. But the computer is an assemblage of electronic components; crucial to its effective and efficient operation, and therefore the key technology on which all else rests, is the semiconductor, first developed in the form of the transistor at Bell Laboratories in December 1947. As it came into mass production it was initially applied to existing electronic products – radio, above all television – which themselves were carriers – minor ones, admittedly – of the subsequent economic upswing. But parallel to that, the transistor and its successor technologies – the integrated circuit, the microprocessor – were embodied into exotic aerospace products, produced to the demands of government agencies in response to the missile and space races that began in the mid-1950s and continued, sometimes waxing, sometimes waning, through the

following decades. Above all in the USA they thus created a vast complex of new industries, sometimes producing large civilian technological spinoffs in their wake.

Chapters 10 and 11, accordingly, take up the story of these industrial repercussions. Because by now the story is denser in detail, it comes in two halves: one dealing with the growth of the new industries in the expansionary phase of the 1950s and 1960s, the other with the challenges they faced in the downswing of the 1970s and early 1980s. The main question, again, concerns the changing fortunes of the main industrial economies. The USA, as might be expected, starts from a pre-eminent position and, bolstered both by a huge lead in innovation and a burgeoning military demand, reinforces it. Europe, which at the end of World War II seems to be the major challenger, progressively falls away. In the case of Germany this can be explained partly by the catastrophe of 1945, from which the country's long tradition of New IT research and development never quite recovered. In the case of the UK, which had actually made up much of the ground lost in the earlier decades of the previous Kondratieff, the relapse remains a mystery awaiting further analysis. What is evident is that Europe's, and above all the UK's, loss is eastern Asia's gain: Japan in the 1960s, the Asian newly industrializing countries in the 1970s and 1980s, now emerge as the USA's major challengers.

Since the British failure remains a puzzle, Chapter 12 takes it up. It first documents the continued loss of markets in one after another of the major New IT sectors, confirming that far from compensating for the UK's decline in the more traditional industries, New IT has perversely shared their fate. Then it goes into causes, reaching conclusions that in many respects contradict the comfortable conventional wisdom; in particular, it appears that by the fourth Kondratieff the UK was no longer a significant industrial innovator. So the chapter goes on to ask why. It concludes by posing the question: Are there any lessons from the British experience for other mature industrial nations, above all for the USA, whose recent evolution shows some disturbing similarities?

Chapter 13, concluding this section, parallels Chapter 8: it looks at the changing regional and urban locations of the New IT industries during the fourth Kondratieff. This long wave was marked by major geographical shifts: the abrupt, even catastrophic, decline of Berlin, once electrical capital of the world; the movement of the New IT industries from London to its neighbouring Western Crescent; the continuing strength of the Boston–New York axis but also the rise of whole new high-technology complexes in Southern California and Silicon Valley. The chapter reviews the

alternative explanations, advanced in the literature, to reach a view on the forces that help keep such industries in their traditional locations, or alternatively help to trigger the development of whole new industrial regions.

Finally, Chapter 14 sums up. It tries to review the evidence for the links between innovation and industrial growth. Also it asks whether there are useful or consistent generalizations that can be made about the changing locus of innovation. In particular, it concentrates on some major themes that emerge both in this study and in the general literature: the rôle of industrial organization and industrial scale, the precise nature and significance of state policies, the part played by demand and thus by the evolution of the general economy outside the narrowly defined high-technology sectors. Thus it returns to a central question posed in Chapter 2: How far do bunches of industrial innovations create not merely new industries, not merely even complexes of related industries, but also a whole new technological–industrial paradigm that transforms the entire nature of economic and social processes and relationships? This brings it to a final question: What are the likely carriers of the coming fifth Kondratieff, what will be their impact on the structure of economic life, and what does all this say for the competitive prospects of the British and American economies?

would peak in 1989, suggesting that the fifth Kondratieff would begin sometime around the year 2010. This, coming at a time when the capitalist world was just descending into the worst recession for 50 years, could hardly fail to make an intellectual impact. Much of the subsequent explosion of long-wave studies in the Anglo-American world has centred on a reaction to his work.

Just as with the reaction to Schumpeter in the 1930s, much of it has predictably taken the form of technical criticism. The weightiest has come from Christopher Freeman and his colleagues at the Science Policy Research Unit (SPRU) at the University of Sussex, who pioneered the study of long waves in the UK (Freeman *et al.* 1982, Freeman 1984, 1985, Rothwell & Zegveld 1981). They argue that his data are incomplete and biased, both as to selection and dating, and that analysis of a fuller list of innovations, drawn from the same source, shows no such innovatory swarming (Freeman *et al.* 1982). They tentatively accept the existence of long waves, but incline to share Mandel's interpretation: that there is no single triggering mechanism, certainly no automatic one, endogenous to the economic system. Rather, individual long waves appear to be initiated by unique exogenous events such as gold discoveries, wars or major social or institutional changes. More recently, a weighty technical criticism has come from Solomou, who concludes that Mensch's results are faulty on at least two counts: an unrepresentative choice of innovations, and an inappropriate statistical test. He thus supports the SPRU group's conclusion that 'the flow of innovation is not responsive to long-wave phases' (Solomou 1986, 111). But other work, including the very thorough analysis of an extended list of innovations by van Duijn, and Kleinknecht's testing of equally comprehensive data from Mahdavi, both conclude that depression-triggered innovation bunching has occurred (van Duijn 1983, Kleinknecht 1984). SPRU researchers have sophisticated the concept of the long wave by suggesting that a particular innovation, the automobile for instance, may act as a carrier of more than one wave, diffusing from one country or continent to another as it does so (Freeman *et al.* 1982).

At the same time, other economists have attacked the theoretical foundations of the long wave. Rosenberg and Frischtak have argued that the theory must be shown to meet certain rigorous, interdependent criteria. It must show that innovation is the causal agent, and explain its timing; it must then demonstrate the resultant backward and forward linkages through the economic system, and finally show why the process should recur. Like Freeman and his colleagues, Rosenberg and Frischtak incline to the view that long wave upswings may result in part from exogenous

forces, in part from the revival of older technologies rather than the impact of new ones; thus the recovery of the late 1930s was triggered partly by military investment in the shadow of World War II, and partly by the long-established automobile industry (Rosenberg & Frischtak 1984).

But doubts remain. If the long waves do measurably exist, and if they are so regular, to explain them by exogenous forces requires either some regularly recurring mechanism in the outside socio-political process or an extraordinary set of historical coincidences. The 'exogenists' deny also the first, so they are left with the implausible second. The work of Forrester's global modelling team at MIT strongly suggests that the long wave, albeit a result of the complex interaction of the physical structure of the economy with the decision-making processes of individuals and firms, is indeed generated endogenously, and does not depend on random shocks such as gold discoveries to account for its persistence or turning points' (Sterman 1985, 128-9). In the MIT group's view it has two causes: firstly the fact that firms amplify unanticipated changes in demand, thus creating potential oscillations in the adjustment of productive capacity to demand; secondly, the fact that these tendencies are amplified through the linkages of firms to each other, to the labour market, and to the financial markets. The result is fluctuations in the demand for capital created by individual firms. So, rather than an innovation-based theory of long waves, the MIT researchers posit a theory of innovation based on long waves: midway through a capital expansion, based on commitment to an existing mix of technologies, opportunities for applying inventions are poor; but in the downturn the old capital depreciates, old bureaucracies are weakened, companies based on old technologies go bankrupt, and traditional methods cease to be sacrosanct (Sterman 1985).

Table 2.1 The four Kondratieff waves: different chronologies.

	First	Starting dates		
		Second	Third	Fourth
Kondratieff 1926	1790	1844-51	1890-96	
de Wolff 1929	?	1849-50	1896	
Schumpeter 1939	1787	1842-43	1897-98	
Dupriez 1947-78	1789-92	1846-51	1895-96	1939-46
Rostow 1978	1790	1848	1896	1935
Mandel 1980	?	1845	1892	1939-48
van Duijn 1983	1782	1845	1892	1948

Source: van Duijn (1983).