Technology and Cycles of Boom and Bust

The ideas of a Russian economist in the 1920's are providing new arguments for investment in basic science

Sussex, England. A radical new theory of the relation between scientific research, technological innovation, and economic growth is generating an increasing following in Europe. Based largely on the ideas of a Russian economist, Nikolai Kondratiev, who died in Stalin's prison camps in the 1930's, the theory is being used by some to argue for increased support for basic research together with policies to offset unemployment caused by technological change.

Kondratiev put forward the hypothesis in 1925 that the industrial nations of the world, when looked at collectively, have experienced successive cycles of growth and decline since the beginning of the Industrial Revolution with a regular periodicity of between 50 and 55 years. The first cycle—now usually referred to as a "long wave"—was between the late 1780's and 1842, the second spanned the period up to 1897, and the third ran from then up to the depression of the 1930's.

Until relatively recently, debates about the legitimacy and significance of Kondratiev's hypothesis have been largely confined to academic circles. In the past few years, however, there has been a surge of interest—especially in Europe—in the so-called "long-wave theory," in particular because it may provide some crucial clues about the roles of science and technology in economic development. Fears of a return to the high levels of unemployment and their catastrophic political repercussions during Kondratiev's lifetime have also contributed to his intellectual rehabilitation in the West.

At one level, this enthusiasm is not difficult to understand. Just as the "limits to growth" controversies at the end of the 1960's took as their starting point extrapolations of the exponential growth of the two decades after World War II, so now the theory of long waves offers a perspective on the fact that this growth was followed by a steep economic decline in virtually all the world's industrialized nations during the 1970's. The idea that this might be part of a "natural" rhythm carries an implicit message of hope for the future.

In the United States, where the economic depression at the end of the 1970's was not so marked as in Europe, support for the theory of Kondratiev-style long waves as an explanation of technological innovation remains lukewarm, although a more conventional economic long-wave argument has been developed by economists such as Walter Rostow and Jay Forrester. "I continue to be very skeptical," says Nathan Rosenberg, professor of economics at Stanford University, who prepared a detailed paper for last December's annual meeting of the American Economics Association on the conditions which such a theory would have to fulfill if it were to be accepted.

Freeman's proposal may provide an alternative to Reaganomics

Nevertheless, Rosenberg predicts that a book published last year by three researchers at the Science Policy Research Unit (SPRU) in Britain's Sussex University, providing an extensive description of the long-wave theory and its potential application to science and technology policy, will have "a very considerable impact" in the United States. "It suggests in some very creative ways how we can look at this whole process," says Rosenberg.

Kondratiev's ideas, developed along lines already suggested by several European economists in the early years of the century, were based on a detailed statistical analysis of the economic behavior of the major industrial nations since the middle of the 18th century and carried out while he was head of the Institute of Economic Research in Moscow.

To traditional Marxists who believed only in short-term business cycles and in the long-term growth and decline of capitalism, Kondratiev soon became something of a heretic. However, his ideas were taken up in the 1930's by several economic historians in the West, most notably Joseph Schumpeter, who pointed out that each Kondratiev wave coincided with a spurt in technological innovation.

Schumpeter showed that the first wave, which occurred almost exclusively in Britain, was based largely on the new technologies in the textile industry which exploited the potential of coal and steam power; the second wave, again occurring largely in Britain, but this time with France and Germany as partners, drew directly on the development of railways and the mechanization of production. The third, shared by Germany and the United States, was based on electric power, the chemical industry, and the internal combustion engine.

Schumpeter's claims that technological innovation should be considered as an essential *input* into economic growth were rapidly overshadowed, first by World War II (which forced him to flee his native Germany and become a professor at Harvard University), and subsequently by postwar enthusiasm for the demand management policies initially proposed by John Maynard Keynes as a way out of the economic slump of the 1930's.

Yet with Keynesian and neo-Keynesian economics now largely discredited in Western nations, with growing levels of unemployment suggesting a return to the economic and social conditions of the 1930's, and, above all, with the fact that the growth and decline of Western economies since the last war seems to have closely followed both the pattern and the time scale described by Schumpeter in his 1939 book *Business Cycles*, it is perhaps not surprising that both Schumpeter and Kondratiev are coming back into fashion.

Economists in many European countries, especially Germany, Belgium, and the Netherlands, have recently been developing the long-wave hypothesis, and it has also formed a central component of historical research programs at the Ferdinand Braudel Center in New York. One of the most fervent promoters of both Schumpeter and Kondratiev has been Christopher Freeman, professor of science policy at Sussex University and director of SPRU since it was founded in 1966 until last year.

Freeman says that two factors first kindled his interest in Kondratiev's ideas about 5 years ago. One was his own research showing patterns of growth and

decline in the chemical and pharmaceutical industries. The other was a growing concern in Western Europe about the apparent link between technical change and unemployment, particularly because chronic high levels of joblessness—currently about 12 percent in many European nations—seemed to suggest that it was a structural as much as a transient phenomenon in the economies of industrialized nations. Thus it would not necessarily be removed by a new spurt of expansionism and market-determined technical change.

With two colleagues at SPRU, John Clarke and Luc Soete, Freeman was awarded a research contract from the Social Science Research Council to investigate these phenomena as part of a broader study of technical change and employment opportunities. The initial results of their work were published last year in a book *Unemployment and Technical Innovation* (Frances Pinter, London, 1982).

Freeman, who has since the 1960's been one of the most influential figures in European science policy debates, thinks that the theory of long waves has important implications for government support of science. "The angle of interest to basic scientists is a resurgence of interest in long-term phenomena," he says. He suggests that it represents a return to the philosophy of TRACES, a major study carried out by the National Science Foundation in the 1960's which attempted to challenge political demands that science policy should be based on short-term expediency.

"It shows, for example, that emphasis on the role of new branches of fundamental science is justified," says Freeman, suggesting, for example, that fundamental research in molecular biology has provided the basis for biotechnology which could be one of the new technologies forming the basis of a new "fifth Kondratiev wave." Microprocessors are another obvious candidate.

Even among supporters of the long-wave hypothesis, however, some of Freeman's arguments are controversial. The debate here focuses, not on whether Kondratiev waves exist, but on the type of relation they imply between the different factors that contribute to economic growth—and what the appropriate government policies should therefore be, including policies for science. Much of the controversy has revolved around an influential book *Stalemate in Technology*, first published in German in 1975 by Gerhard Mensch, now professor of economics and management at Case Western Reserve University in Cleveland. Mensch proposes a novel thesis relating technical change to economic growth. He claims that patent statistics and other data demonstrate a "bunching" of new basic technological innovations in four particular periods, namely, the 1760's, the 1820's, the 1880's, and the 1930's.

Each of these, says Mensch, were also periods in which the global economy was in recession. He therefore puts forward the hypothesis that depressions are largely *responsible* for surges in innovation, because they encourage governments and corporations to seek new technical solutions to their problems, and that the innovations which result form the basis for a new wave of expansion.

Mensch's ideas have had a considerable influence since they were published, not least because they seem to provide a relatively simple model with straightforward policy implications. Mensch himself predicts a new wave of innovation-based growth starting at the end of the 1980's and suggests that governments should introduce policies aimed at speeding up this process of technological change.

Some have used his ideas to argue that rapid technical change is an inevitable process to which society must adapt as quickly as possible. The British town planner Peter Hall, for example, argued in a recent issue of *New Society* that, because the science-based technologies of the new Kondratiev wave only appear to prosper in certain kinds of environments (Stanford's Silicon Valley is used to suggest that one condition was proximity to a major university), the British government should concentrate its efforts to promote industrial development on the southeast of England, moving the bulk of its active working population there and letting the rest of the country survive the best it can.

Similarly, John Langrish of the Institute of Advanced Studies at Manchester Polytechnic believes he has discovered cycles of confidence in science and technology that are expressed by industrial designers and coincide with Kondratiev's long waves. The last time this happened, he points out, was during the early 1950's, when scientists at London's Imperial College, for example, provided pictures of crystal structures as the basis for a range of textile and fabric designs at the Festival of Britain.

Building directly on Mensch's arguments, Langrish suggests that one way to help Britain out of its current economic difficulties would be to encourage enthusiasm for "new-wave" technologies, such as computer-aided design, home computers, satellite communications, and even new sources of energy such as wind and tidal power, among design students. "If enough people—investors, technologists, designers, and so forth—believe in a coming new age, it will appear sooner through the mechanism of the self-fulfilling prophecy," he told a conference at the Royal College of Art in London last July.

Yet Mensch's ideas—that society moves from the end of one Kondratiev wave to the beginning of the next through a relatively mechanical process by which depressions stimulate innovations—have been strongly criticized by Freeman and his colleagues at SPRU. They believe that many of the estimates of the timing of innovations used by Mensch are questionably subjective and that he does not give adequate attention to various important process innovations in the 1950's and 1960's in fields such as chemicals and pharmaceuticals. They charge as a result that "Mensch's empirical evidence is inadequate to support his conclusion." Second, Freeman says that a close study of the major innovations introduced in the 1930's and the 1940's shows that most were not stimulated by economic depression but specifically by the pressure for rearmament and wartime demands. Finally, Freeman and his colleagues argue that Mensch, by using a model in which new innovations are said to be primarily the result of *economic* pressures, understates the major, if serendipitous, contribution of fundamental science. They quote, for example, the contribution of basic chemical research on molecular structure in the 1920's to breakthroughs in polymer chemistry in the 1930's, or those in solid-state physics which provided the basis for advances in electronics and computers.

The SPRU research workers suggest a more complex model which attempts to take such factors into account by arguing that innovation takes place through a complex combination of "science-push" and "demand-pull" factors, neither of which is sufficient on its own. They also emphasize, like Schumpeter, the importance of appropriate systems of industrial organization—a factor which, they suggest, could help determine whether the United States or Japan takes the lead in the next Kondratiev wave.

Their own work has been controversial, both at a theoretical and a political level. Mensch, for example, strongly rejects the SPRU criticisms of his hypothesis, maintaining that his data are perfectly adequate to support his theory of "technological stalemate."

Langrish also takes issue with Freeman over the role of basic science. "Freeman's examples are not accurate," he argues. "The whole evolution of synthetic fibers was based on technological, mission-oriented research." A theory of polymers, he argues, was not needed for the new technology, even though it became a useful way of raising more money for research projects.

Debates over the political implications have been equally intense. Freeman sees a clear political message emerging from his analysis. The less controversial part is the need for sustained government funding of basic research, on the grounds that, even if unproductive in the short term, the results are the only firm basis for a future economic upswing.

More controversial is his argument that the economic situation facing Western nations, in particular the unemployment resulting from the shift from old to new technologies, represents a long-term and structural challenge, rather than one which is essentially short-term and fiscal. If so, suggests Freeman, current economic crises can only be overcome by "massive international investment in new technology systems," with full employment as a top priority, and cannot be left to the exigencies of the market.

Such arguments do not fit neatly with the ideas of conventional macroeconomists. They suggest either control of the money supply or neo-Keynesian demand stimulation, and tend to see the problems primarily in terms amenable to marketplace solutions, treating technical change as an "exogenous," relatively neutral variable.

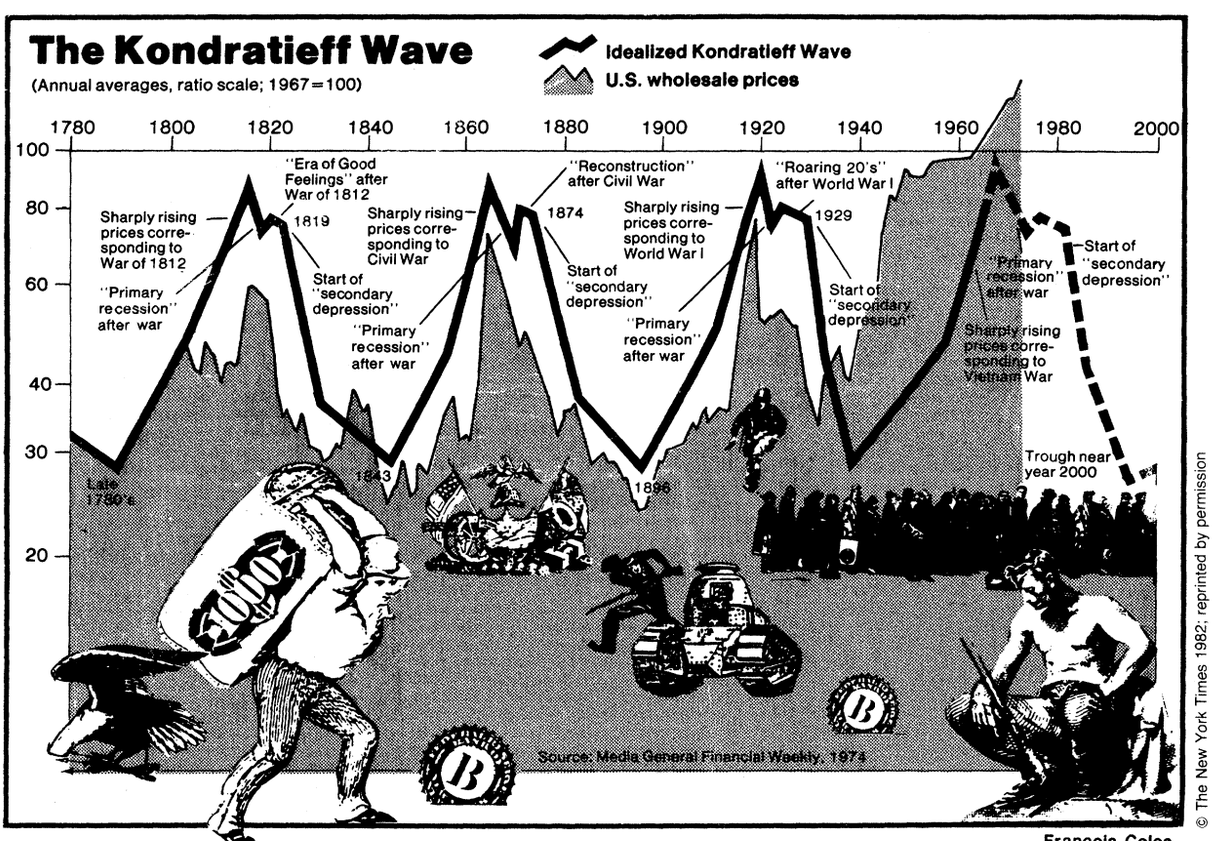
Two years ago, for example, a report *Technical Change and Economic Growth*, prepared for the Paris-based Organization for Economic Cooperation and Development (OECD), for which Freeman was one of the principal advisers, suggested the need for such a structural response. Strenuous efforts were made within the agency (especially by both U.S. and U.K. delegations) to make sure that the report remained merely the recommendation of "an ad hoc group of experts," and not an official OECD statement, which would have given the conclusions higher status in political circles.

Yet support for a structural response to the economic difficulties facing Western nations—as well as for the importance of science in the context of this response—continues to grow in popularity within the organization and several European capitals. "It is a way of internalizing innovation into economic theory," says Jean-Jacques Salomon, head of the science policy division of OECD. "From a policy point of view, the long-wave theory [as characterized by Freeman] implies that the possibility of emerging from the current economic crisis is closely related to levels of investment in research and development," an argument that OECD has been promoting since the 1960's.

Rosenberg at Stanford points out that OECD's interest in the long-wave theory is understandable, because it suggests a model for the aggregate economic behavior of the industrialized nations of the West, which is the organization's principal preoccupation. "It is also a very convenient way of explaining the poor performance of the last 10 to 15 years of the OECD countries," he says.

As far as the theory itself is concerned, Rosenberg says that the historical evidence for Kondratiev-type long waves "is far from convincing" and lists the many conditions that still have to be met. "For example, to show that technical innovations generate long waves in the macroeconomy, one would have to develop some type of quantitative measurement of the impact of innovation."

Until recently, the only significant group in the United States to have shown a detailed interest in the theory have been Marxist economists, who see the decline of the latest long wave as part of the crisis phenomena of Western capitalism. Indeed, one of the first Kondratiev



Kondratiev waves and U.S. wholesale prices

revivalists was the Belgian Marxist Ernest Mandel, who points out wryly that he was virtually alone in predicting an imminent slump in Western economies in the late 1960's, at a time when most economists were preoccupied with the implications of continuous growth.

Yet just as the theory of long waves has now generated its non-Marxist supporters in Europe (the French government, for example, has recently started collecting statistical data on the new innovations with the idea that this should form an integral part of its economic planning), so in the United States Rosenberg finds that "Americans are becoming increasingly interested in these ideas." One of the most unexpectedly crowded sessions at last December's annual meeting of the American Economics Association in New York was devoted to a discussion of Kondratiev's ideas and their contemporary relevance. According to Edwin Mansfield of the University of Pennsylvania, much of the U.S. interest is coming from business rather than academic economists. Mansfield describes himself as an "agnostic" on the validity of the theory of long waves.

Freeman's proposal for a technology policy that uses substantial government intervention in order to stimulate rapid technological innovation while, at the same time, taking conscious steps to maintain a high level of employment, is an alternative to Reaganomics that could be easily molded to provide a platform for next year's presidential elections.

As in Europe, the search for political solutions to economic conditions is beginning to stimulate a full-scale Kondratiev revival, which might itself show that, as Mandel has pointed out, almost 50 years after the publication of Schumpeter's major work on technical innovation and business cycles, interest in long waves has itself become a cyclical phenomenon.—**DAVID DICKSON**

Weapons Proposal Stirs Disquiet at Stanford

Some 300 faculty and staff members at SLAC have objected to a proposal for weapons-related work at the synchrotron radiation lab

A proposal to conduct weapons-related research at the Stanford Synchrotron Radiation Laboratory (SSRL) has stirred up a lively dispute in the high energy physics community at the university. Some 15 faculty and 280 staff members at the Stanford Linear Accelerator Center (SLAC) have signed letters and petitions objecting to the proposal, which is now under consideration by a peer review committee and by the Department of Energy's (DOE's) weapons program.

The proposal, which has been put together by scientists from the University of California, the Lawrence Livermore National Laboratory, the Los Alamos National Laboratory, and Sandia National Laboratory, involves basic physics; only a small fraction of the research would be directly related to weapons development, and none of it would be classified. In essence, the university scientists—whose part of the proposal is not related to weapons—are hoping to tap into the weapons program for support of fundamental research, a connection that could become more common as the military R & D budget continues to grow.

The proposal involves the construction of two new beam lines at SSRL to conduct research over a broad spectrum of ultraviolet and x-ray energies. A detailed description submitted to Stanford last December makes no direct reference to weapons-related work but lists a large number of basic research experiments. A proposal for funding sent to DOE, however, emphasizes the relevance of the research to the weapons program. Part of the work, for example, would involve the calibration of instruments for use in weapons tests to provide data for new warhead designs. "In the future," the DOE submission states, "laboratory experiments in which weapons conditions are simulated will be possible, and will likely require new and unique diagnostics systems." In other words, the proposed experiments at SSRL could help provide the basis for laboratory simulations of nuclear explosions if underground testing is ever prohibited.

> The proposal would enable academic scientists to tap into the weapons budget for basic research.

The plan is that DOE would contribute $5 million to construct the beam lines and the University of California would put up $1 million. Once the facilities are complete, however, experimental time would be divided equally between the university and the national labs. Thus, for a relatively modest investment the university would get a lot of time on the machine. The university has already approved the expenditure, but DOE's share of the funds were not included in the fiscal year 1984 budget request. According to Lloyd Multhauf of Lawrence Livermore, a principal investigator in the national labs group, DOE has not shut the door on funding; negotiations are still going ahead to channel some money into the project. First, however, the proposal must win approval from SSRL and that may be difficult.

An outside peer review committee has already conducted a preliminary look at the proposal and has asked for more information on several points. Ultimately, it will give its opinion on the scientific merits of the work to SSRL director Arthur Bienenstock, who will make the final decision. Bienenstock says that one other group has submitted a proposal to construct a beam line at the site proposed by the University of California–national labs team. Opposition from SLAC employees could be a factor in the final choice.

Although SSRL and SLAC are administratively separate, they physically joined. SSRL sits around SLAC's storage ring and obtains its synchrotron radiation from it. Thus SLAC provides the basic energy for all SSRL experiments.

Soon after the proposal was submitted to SSRL in December, a group of 15 faculty members at SLAC jointly drafted a letter to Stanford's University Committee on Research, expressing disquiet at the fact that if the work were approved, SLAC would be a participant in weapons research. The committee met with Bienenstock and SLAC director Wolfgang Panofsky last month to discuss the issue.

Shortly before the meeting, Mary James, an engineering physicist at SLAC, circulated a petition among