BACKGROUND MATERIAL FOR A MEETING ON LONG WAVES, DEPRESSION AND INNOVATION SIENA/FLORENCE, OCTOBER 26-29, 1983

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Eds.

August 1983
CP-83-44

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
2361 Laxenburg, Austria

PREFACE

In recent years there has been a renewed interest in "long waves" -- cyclical economic movements of a span of fifty to sixty years – as had been investigated at an earlier time by such noted economists as Kondratieff and Schumpeter. This revival may, in part, be attributed to the prolonged recession the world economy has experienced since 1973.

Within the last few years, a (limited) number of renowned research institutions and distinguished scholars have substantially contributed to the advancement of the theory on long waves, with, however, little or no contact between them.

For this reason, IIASA and IRPET agreed to convene a meeting (Siena/Florence, October 26-29, 1983) to which all the authors of recent major contributions in the field of long waves should be invited. In order to ensure the utmost efficiency of this meeting, its deliberations were limited to five topics; all potential active participants were invited to submit preliminary statements on any of these five topics, to be distributed to all the other participants well in advance.

This Collaborative Paper contains all the contributions received by the end of August 1983. The main purpose of this Collaborative Paper is to serve as background material for the Siena/Florence meeting. The present volume may further be regarded as a preliminary summary of the state of the art. It is hoped that revised versions of these contributions, together with the proceedings of the meeting, will form a more cohesive reader to be published elsewhere.

Further to this primary purpose of the present volume, it also contains information on the organizing institutions, IIASA and IRPET, and the program of the meeting, together with a few introductory summaries of the present state of the long wave debate.

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IRPET
Istituto Regionale per la Programmazione Economica della Toscana

IRPET – Regional Research Institute for Economic Planning of Tuscany – was established in 1968. According to regional law, IRPET's main tasks are:

- to carry on research projects on economics, social and territorial aspects of regional development;
- to provide for studies requested by regional planning process;
- to contribute to the training of young scientists in planning disciplines.

Currently, the major activity steams of IRPET are:

- reporting on annual performances of the regional system and its components (export, tourism, public expenditure, employment, etc.);
- carrying on a set of field research about topics such as international and regional role of Tuscany; behavior of the most relevant productive sectors as well as of the public sector, also in their subregional aspects; social structure of Tuscany.

The emphasis of IRPET's work is on relationships among analysis objects rather than on sectoral description. On this methodological path was built up an integrated regional system of Input-Output models which could be considered as the most relevant result of the scientific cooperation with IIASA, developed since 1980. Other significant IRPET's scientific relationships are, for the time being, those with the Centre for Environmental Studies (London), the Town and Country Planning Department (Newcastle), and the Hessische Landeszentrale für Politische Bildung (Wiesbaden).

IIASA

International Institute for Applied Systems Analysis

IIASA -- the International Institute for Applied Systems Analysis – is an international, non-governmental, research institute sponsored by scientific organizations from seventeen nations, both East and West.

It was established in October 1972 on the initiative of the United States of America and the Soviet Union to bring together scientists from different nations and different disciplines for joint investigation of complex problems of international importance which require the joint efforts of many nations in order to find approaches able to meet the challenges of the future. The Institute's analyses cut across traditional disciplinary, institutional, and national boundaries with the aim of:

-- promoting international collaboration
-- advancing science and systems anaysis
-- applying its findings to policy problems of international importance.

IIASA's key research interest currently focuses on issues of economy, food and agriculture, environment, energy.

IIASA has National Member Organizations from:

USSR, Canada, Czechoslovakia, France, German Democratic Republic, Japan, Federal Republic of Germany, Bulgaria, USA, Italy, Poland, Austria, Hungary, Sweden, Finland, Netherlands, United Kingdom (in formation).

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The Long-Wave Debate

In its last issue, *Options* brought a contribution by Cesare Marchetti, "Recession: Ten More Years To Go?" The vivid interest and the surprisingly large echo that this article met induced *Options* to invite Gerhart Bruckmann to analyze the state of the art in the renewed activities on long-wave theory in a wider context.

The longer the recession lasts, the more economists have begun to wonder about its nature. After 1945, industrialized countries all the world over experienced three decades of steady growth; no wonder economic theory concentrated on "equilibrium growth" on the one side, on short-term business cycles (*Konjunkturzyklen*), of a duration of four to five years each, on the other side. "Recession" assumed the meaning of (a couple of years of) below-average growth, but alas! there always was growth, and to utter a phrase like "Limits to Growth" was blunt heresy. Parallel to this, governmental economic activity increased substantially, giving rise to a noticeable yet spurious correlation between the amount of government intervention and GNP: the more government, the more affluent we became.

We are not yet fully aware of the extent to which this thirty year experience has come to dominate our thinking. We continue to speak of a "prolonged recession", as if the next (short-term!) upswing were just lurking around the corner, and we look at government to finally *do* something about it.

A few months ago, an Austrian economist remarked: "The valley seems to be a low plain." If the distance between successive valleys is more than four to five years, there may be quite a way to go before we reach the next peak, and if governments continue to provide us with mountain climbing equipment to get us more quickly ahead through the Great Plains (as they did, more or less successfully, in all previous valleys) it will be as costly as it will be futile.

There is something peculiar about the toolchest of economics, as compared to the toolchest of other sciences (let's say, engineering or physiology). In economics, it is much more difficult to locate the right tool, and there is much more disagreement among the mechanics as to which tool to use. But the toolchest as such is much larger: it is crammed with tools that seem obsolete but may, all of a sudden, prove useful again, if (a) found and (b) properly adapted. The longer the recession lasted, the more economists remembered the work done by an earlier generation on the theory of long waves – took it out from the chest where it lay, badly neglected, found it fascinating, and began to adapt it, not so much in the light of changed circumstances as on the basis of all the wealth of economic data and knowledge accumulated meanwhile.

The pioneers of the older generation had been Parvus, Van Gelderen, Pareto, De Wolff, and finally Kondratieff, who was the first to attempt to base long-wave theory upon empirical data, and whose name is, ever since, associated with any analysis of economic movements with a life-span of forty to sixty years (Kondratieff cycles). Kondratieff concluded that such long-term cycles are characteristic of the whole of the capitalist economies, as a result of differing phases of capital accumulation.

The work of this first generation culminated in the writings of the Austrian economist Joseph Schumpeter, mainly in his book *Business Cycles* (1939). Schumpeter conceived the notion that the irregular *clustering of innovations* was the main cause of a regular succession of four phases – prosperity, recession, depression, and recovery. In a historical perspective, four such full cycles can be identified: the first one characterized by the steam engine, the second by the railroad, the third by the chemical industry and electricity, and the fourth by the automobile.

The year in which Schumpeter's book appeared was all but favorable to his ideas. Overshadowed first by the political developments of World War II, then by reconstruction and steady growth, his ideas fell into obsolescence. Long-wave theory became a Sleeping Beauty, waiting for a prince to kiss it awake. The prince's kiss had its prophets – amongst them Colin Clark and Ernest Mandel; irritatingly enough, however, most voices to announce "Limits to Growth" – well before the so-called oil crisis – came from outside the economists' guild.

Whatever really happened in 1973, it certainly revolutionized economic thinking, shattering, in various respects, the dearly beloved paradigm of equilibrium growth. In particular, several leading scientists began, more or less independently, to resume work on long waves. No one prince cut his way all alone through the thorn bushes – the thorn bushes themselves were erased by a fire blast. Apparently the area around the haunted castle still remained unattractive – so far, only very few noblemen found the journey worthwhile. Most of their names can be found in the special issue the journal *Futures* devoted to "Technical Innovation and Long Waves in World Economic Development" (August 1981). In that issue, Jos Delbeke gives a classification scheme of the new approaches to the phenomenon of long waves, according to what the respective authors see as the main causes: innovation, capital, labor, and raw materials. Let us follow Delbeke.

Innovation

In direct continuation of Schumpeter's reasonings, Gerhard Mensch and Alfred Kleinknecht regard technological innovation as the primary driving force of economic development. In a thorough historical analysis, Mensch gave Schumpeter's theory an empirical base. According to Mensch, around the years 1825, 1886, and 1935 new clusters of basic innovations occurred, generating completely new sectors. Competition, rationalization, and concentration raise the capacity of the new

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industrial sectors. However, at a certain point the capacity becomes too great for the domestic market, so the export market becomes vital. Since foreign industrial countries have also gone through this same process, competition grows among a diminishing number of large concerns on the world market. Aware of the growing saturation, these concerns invest less money in the industrial sectors and more on the international money and capital markets. In the next stage, the monopolies try to sell their surplus in the less developed countries with the help of massive credits. Ultimately, these countries reach their credit limits, and the saturation of demand is complete.

During this critical period, which begins with recession and lasts until the end of the depression, the economy has no fundamental solution other than the creation of basic innovations and new sectors: only "innovations will overcome depression." Mensch calls the situation in which society is forced to innovate the "technological stalemate" – a period of reorientation, in which economic policy cannot offer fundamental solutions to the crisis, at least in the short run. All governments can do is to create a favorable climate for innovation.

Kleinknecht defends both the empirical data base and the conclusions of Gerhard Mensch; furthermore, he claims that what seems to be a contradiction between his view and that of other authors can also be seen as different yet compatible views of the same phenomenon.

Capital

Delbeke lists two approaches which consider varying intensity in capital goods production as the most important characteristic of the long wave: the approaches used by Mandel and by Forrester.

Ernest Mandel defines the industrial cycle as the successive acceleration and deceleration of capital accumulation. When the acceleration of capital accumulation reaches a certain point during the upswing, it becomes impossible to invest the total mass of accumulated capital at an adequate rate of profit. This is overaccumulation, and it must be understood as a relative phenomenon: there is simply too much capital available to attain the expected social average rate of profit. Consequently, the average rate of profit of the total accumulated mass of capital declines. Conversely, in the crisis and depression phase, capital is devalorized. Underinvestment now occurs: less capital is invested than would be expected at a given level of surplus-value production and at the given (rising) average rate of profit. This periodic devalorization and underinvestment has the function of again raising the average rate of profit of the entire mass of accumulated capital, which in turn allows the intensification of production and capital accumulation.

Jay Forrester has developed a new method of analyzing growth dynamics in which the capital goods sector plays the crucial role. Forrester's theory is based on two important pillars that create endogenous fluctuations. The first is a multiplier accelerator mechanism that transmits the fluctuations in investment to the rest of the economy and works on the long term. The second is rational behavior along a capital-stock adjustment model, which causes alternating phases of capital hunger and capital saturation. The economic agents continually exaggerate: they expand the capacity of the capital sector too much in the upswing to catch up with demand, and they let the capital stock collapse to a level below the long-term average in the downswing. The entrepreneur is rational *ex ante* but not *ex post* because of perception delays.

It may be surprising that Forrester views innovation not as a cause but as a consequence of the long wave. The Forrester system dynamics model generates long-wave behavior even without technological change. According to Forrester, each phase of the Kondratieff cycle offers a different climate for innovation; hence what can be observed as "clusters" or "bunches" of innovations in the sense of Schumpeter or Mensch is not an exogenous input, but rather a result of the model. In a system dynamics model, however, every major variable is at the same time the cause *and* the consequence of the system's behavior. In particular, it would be presumptuous to claim, as some authors do, that in Forrester's theory innovation plays no major role: within the system, it certainly has a definite impact upon all other economic variables.

Labor

In all long-wave theories discussed so far, labor was either ignored or played only an insignificant role. Yet unemployment is of the utmost social and political concern, much more so than innovation or investment. The book published by Christopher Freeman together with his associates John Clark and Luc Soete *Unemployment and Technical Innovation* therefore represents a cornerstone in long-wave research.

In their thorough analysis, they arrive at the following conclusions: "During the upswing, after decades of preliminary scientific and technical work, major new technologies generate both new investment and new employment on a large scale, thus becoming substantial new branches of activity.... The main employment effect during

the upswing is a steep increase in employment....

"After about a quarter of a century, the new branches of industry are firmly established, and their role as generators of additional new employment diminishes and eventually disappears. During the downswing, competitive pressure within industry becomes stronger, capital intensity grows, and investment continues, but labor-saving and material-saving technical changes become increasingly important.

"The loss of impetus for the growth of employment in the new industries is reinforced by the acceleration of labor-displacing technical changes, and by economies of scale which arise from the success of the new technology itself. This process is the most intense during the Kondratieff downswing."

The open debate between Freeman and his associates on one side and Mensch and Kleinknecht on the other side focused not so much on the importance of innovations as such, as on the social and economic factors that influence the timing of such "clusters" of innovations and their reciprocal influence on the behavior of the economy. According to Freeman, the key aspect of the long wave lies in the investment behavior. In his view, capital intensity grows in the downswing; in Forrester's approach it declines. Both Freeman and Forrester, however, emphasize the increasing unemployment of production factors in industry during the downswing – labor for Freeman, capital for Mandel and Forrester.

Raw Materials

W.W. Rostow, more than the other authors considered here, emphasizes the dynamics of growth in a world perspective. He sharply distinguishes and relates three distinct phenomena: the forces set in motion by a leading sector in growth, by changes in the profitability of producing foodstuffs and raw materials, and by large waves of international or domestic migration. In his view, the second factor is particularly important because it generates a price revolution, i.e. a short period of a sharp rise in the relative prices of food and raw materials at the expense of the prices of industrial goods. If the producers of the former are the less developed countries and of the latter the developed countries, then a price revolution means a period of deteriorating terms of trade for the developed countries.

As Delbeke points out, Rostow's theory does not correspond with the actual post-war situation, but it definitely throws light upon the present price revolution. The new shortages of primary goods and especially energy fit well into the adjustment theory and are likely to create new leading sectors on the input side of the economy: new energy sources (nuclear, solar, wind), new raw material sources (ocean reclamation), new foodstuffs industries (bio and genetic industries), environment industries, and so on.

Delbeke's classification scheme definitely proves useful as a first guideline; but, as he points out himself, no such scheme is capable of paying full tribute to the thoughts developed by the different authors. The headings chosen should clearly not be mistaken for monocausality. In particular, both Forrester and Freeman apply a systems approach: Forrester by means of the system dynamics methodology, Freeman by applying what he calls "reasoned history": the attempt "to interpret the statistical evidence of changes in the international economy over a long period in the light of a discussion of the incidence of major technical and organizational innovations and their assimilation in the economies of the industrialized countries."

As the different publications appeared and the various theories became known, emphasis shifted toward multicausality as a more adequate approach to the complex phenomenon of the long wave. In particular, Van Duijn set out to integrate several theories. He constructs his synthesis by combining the innovation theory of Schumpeter and Mensch, the hypothesis about the life-cycle of industry along an S-curve, and Forrester's multiplier accelerator mechanism of investment, which intensifies the growth and saturation of basic innovations. The role of time lags is considered essential for the particular behavior and length of the long wave.

Policy Implications

Long-wave theory is developing rapidly; several important books are to appear within the next few months. In this rapid development, however, some basic questions have been bypassed – the most basic question of all being whether the long wave exists at all, whether it is a reality or just a myth. Different authors distill, from the same set of empirical data, different theories. On one extreme, there are distinguished scholars who claim that what is regarded as a long wave cannot be signif-

icantly differentiated from white noise. On the other extreme, Cesare Marchetti is convinced that the long wave is a precisely predictable cycle, a law of "anthropological significance". In the last issue of *Options*, Marchetti stated: "The distance between their center points – when half of the innovations in the waves have been made – is precisely fifty-four years." Marchetti, like Freeman and Mensch, focuses his analysis on innovation; starting from a different angle, he explains the innovation cycle as a result of mechanisms of market saturation.

Between these two extreme views, the nonexistence of the long wave and the long wave as an anthropological law, there lie all the other theories. The question which of these views is correct goes far beyond esoteric theoretical interest – it is of the utmost policy relevance. If the distance from centerpoint to centerpoint is exactly fifty-four years, are not any measures to get more quickly out of a depression *a priori* doomed to fail? Marchetti bluntly states: "The curve will not start rising again until the 1990s." And if the long wave is a myth, what other explanation of the present world economic situation can be given? Obviously, understanding what is happening now is a prerequisite for any policy recommendations.

Hence, the most important task for the coming years will be to put the disconnected pieces of the puzzle together, to attempt to arrive at some more integrated theory which may have to incorporate additional aspects hitherto neglected. Even more important, however, will be a more thorough analysis of the impact of institutional and social changes; several authors claim that "innovation", in the decades to come, will have to be perceived not only in the traditional sense as product or process innovation, but increasingly as institutional innovation, both on an entrepreneurial and on a political level.

This is the point where another question, concerning long-wave theory as a whole, comes up. As Delbeke says: "Perhaps the most fundamental problem is the question of whether our industrial society is itself behaving along a life-cycle of economic development. Should this be the case, we are the witnesses of the transition from a growth economy to an equilibrium economy." It may well be that future historians will divide the economic history of man into three major periods: the preindustrial period, the industrialization era (characterized by four Kondratieff cycles), and the post-industrial period which began in the last quarter of the twentieth century. The beginning of this new macro-phase would, in retrospect, be characterized by man's hitting against ecological limits and, having reached certain saturation levels in the industrialized countries, by a shift in demand from material goods to immaterial goods. Or, as Forrester put it: "A balance between human population and environment may now be the most fundamental requirement for political and social innovation for its own sake." Investigation of this alternative view is not in contradiction to previous research on long waves; it only requires a widening of the context.

In summary: the state of the art seems as fascinating as it seems messy. But oddly enough, as different and even contradictory as the various theories may look, there is far less divergence between the sets of policy recommendations to be drawn from them. No matter whether innovation is a cause or a consequence of cyclic behavior, *all* scientists working in this field will agree that one of the foremost tasks of government will lie, in the years ahead of us, in enhancing a climate favorable for innovation, and if innovation is understood to include institutional and social changes, even those who do not believe in a fifth Kondratieff cycle will go along. So, when Freeman calls for "an active public policy, which has a dimension largely lacking either in present day monetary constraints or post-Keynesian demand-stimulating policies," he finds himself in line with Marchetti who proposes to help entrepreneurs "by putting at their disposal, for nominal fees, the research capabilities of the state." And, when Marchetti bluntly states: "Reaganomics, Thatcherism. Mitterandism, etc. are bound to break their promises, together with the monetarists, nervously turning disconnected knobs," he finds himself in agreement with both Freeman and Rostow.

And all this in turn is again not in contradiction to Forrester when he says "We are entering a time when creative management, more than creative technology, can make the difference between corporate death and survival.... In the next few years, political innovation will be needed; it will be tried, and we should see that it is guided constructively...."

And this is what makes additional research in long waves particularly promising. Optimistically, from this research could emerge, before too long, a somewhat consistent set of policy instruments. If more time elapses in which the traditional instruments continue to fail, the threshold may be reached from whence onward this (yet to be developed) set of policy instruments will be believed and implemented. Pessimistically, further research could at least lead to better understanding of the economic phenomena of our time.

IIASA's Role in Long-Wave Research

In its new research plan, IIASA has now institutionalized its "clearinghouse activities" under the leadership of Tibor Vasko. Some of these activities represent a spillover from earlier IIASA research; some, however, are activities in a newly emerging field, such as the revived interest in long waves. Much as it did ten years ago with regard to global modeling, IIASA intends to provide a forum function, bringing together the leading scientists in the field. As a first step, in conjunction with the Municipality of Florence, a top-level workshop on "Long Waves, Depression, and Innovation: Implications for National and Regional Economic Policy" will be held in Florence, Italy, from 26 to 28 October 1983. This workshop will bring together, for the first time, the leading scientists working in this field, with the explicit double goal of advancing theoretical insights into the *problématique* and of examining policy implications on the national and the regional level. Furthermore, this workshop may be expected to form the starting point for whatever international scientific cooperation might emerge.

RECENT LONG-WAVE THEORIES

A critical survey

Jos Delbeke

The author gives a critical overview of some recent long-wave theories, which, although not complete, does seek to diminish the present confusion in the literature and to emphasise the complementary character of the different approaches. A classification scheme is developed, based on the alternating scarcity and abundance of production factors in the upswing and downswing phases of the long wave. In this way theories have been classified as: those which consider the role of innovation (ie entrepreneurship) as crucial (Schumpeter and Mensch); the capital theories (Mandel and Forrester); the labour theory (Freeman); and the raw materials and foodstuffs theory (Rostow). The importance of institutional and social changes is emphasised.

A REMARKABLE revival of interest in economic fluctuations and especially in long waves has occurred since the second half of the 1970s. This renewed interest may be attributed to the present world economic crisis and the failure of short- and medium-term analysis to account for it.

Although there is widespread scepticism about any long-wave 'law', there are authors who forecast the present crisis on a theoretical basis. In 1944, Colin Clark[1] wrote in *The Economics of 1960:* "at some date in the 1960s the world will probably again reach an abrupt termination of this capital-hungry phase and another capital-sated phase will follow". In 1964, E. Mandel[2] was expecting a slowdown of the post-war boom to occur in the following few years. It is also misleading to presume that the present economic experiences are unique in history. The first sentences van Gelderen[3] wrote in 1913 in his study *Springvloed* can be read in any newspaper today: "It is almost a commonplace to say that we live in an expensive time. No economic phenomenon of an international nature is so much the subject of public discussion as the continual rise of prices".

However, most economists have not been flexible enough to change their analytical framework. Too quickly, many seemed to forget the difficult events of

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0016-3287/81/040246-12$02.00 © 1981 IPC Business Press

the 1930s, and from the 1950s the theory of economic fluctuations was gradually replaced by growth theory. The neoclassical model, stressing the equilibrating tendencies of the system, became the cornerstone of economic thinking and analysis. The conditions for convergence to steady-state growth have been investigated in detail: identical growth rates of total output and capital stock, a constant profit rate, identical growth rates of real wages and labour productivity, and constant income distribution between labour and capital.[4] There was a tendency to assume in the 1960s that real world growth approximated this ideal model.

Against this, van Duijn argued that rational economic behaviour *ex ante* appears to generate uneven economic development *ex post*, and that therefore equilibrium growth is a mental construct, an ideal image that is never achieved because we do not act that way.[5]

Widespread belief in neoclassical economics, however, is not the only cause of the recent neglect of economic fluctuations. Other reasons are that the long-wave theories are dispersed over a vast amount of literature, and that they show tendencies toward monocausality, and to confusion between cause and effect in explaining the phenomena. Many authors construct theories without empirical testing or simply present time series of fluctuations without a theory. One reason for this is that empirical testing and verification are inherently difficult because the sample contains only 3·5 long waves. Therefore, a more intensive application of mathematical and statistical methods may not eliminate the existing confusion between the various theories.[6]

The long-wave pioneers—Parvus, van Gelderen, de Wolff and Kondratiev —observed the long wave by means of price data, and considered 1815, 1849, 1873 and 1896 as years of crucial turning points. They held that a relationship existed between price fluctuations and economic development in a broad sense. They also considered the long wave as a phenomenon inherent in the capitalist way of production, and they sought to explain it as a cyclical and endogenous process.[7]

Kondratiev, the best known long-wave pioneer, emphasised the discontinuity in the production and duration of long-term fixed capital as the most powerful force behind the long wave.[8] Karl Marx's conjunctural theory was clearly the starting point for his explanation. But he overestimated the role of price fluctuations and he was unable to take full account of fluctuations in industrial production and changes in productivity. His theory has also been discredited because of inability to incorporate consistently endogenous variables in the explanation of turning points. Although he considered technological development as an important factor, he underestimated its powerful influence.

Building further on the work of Kondratiev, several authors refined his analysis, and dated the long waves in slightly different ways using the four phases—prosperity, recession, depression, recovery—which Schumpeter[9] developed (see the paper by van Duijn in this issue, Table 2).

Since the work of Schumpeter, there have been several theories which have taken into account his increased emphasis on the role of innovations in long waves. These theories are the subject of this survey, as of the special issue as a whole. This survey compares and criticises the theories, classifying them

according to the relative scarcity or abundance of the various production factors—entrepreneurship, capital, labour and materials. The analysis concentrates on the first three of these as they are the ones represented in the special issue of this journal. Moreover, we do not intend to discuss theories that consider the outbreak of wars and monetary factors as important variables. We recognise, however, that the money and credit supply, even if it does not influence the very long-term development of the economy, seems to be important for the determination of the turning points.[10]

The scarcity and abundance of entrepreneurship

In this section, we analyse the relationship between the long-wave movement and the frequency and intensity of innovational activity. Some authors, such as Schumpeter and more recently Mensch and Kleinknecht, assign technological innovation an almost exclusive role as the engine of economic development.[11] Theories that do not consider technological change to be of such primary importance are discussed later.

Schumpeter considered the irregular clusters of innovation to be crucial for development. His theory can be summarised as follows: economic development appears in the form of innovations; it occurs in cycles; and entrepreneurship is an innovative action while management is not.[12] The upper turning point of the cycle is caused by the disappearance of profit (the shift from monopolistic to pure competition), the lower occurs after the creative destruction of a depression. The fundamental solution arises when new consumer goods and new methods of production and transport appear, when new markets are created, and when there are breakthroughs in the forms of industrial organisation. However, Schumpeter is unclear about why clusters of innovation take place every 45 to 60 years.

The theory of Mensch

Mensch updated Schumpeter's theory and gave it an empirical base. Around the years 1825, 1886, and 1935, new clusters of basic innovations took place and generated completely new sectors. Massive new markets allowed these sectors to grow rapidly and to improve the products and the production processes. Competition, rationalisation, and concentration raise the capacity of the new industrial sectors. However, at a certain point, the capacity becomes too great for the domestic market so the export market becomes vital. Since foreign industrial countries have also gone through this same process, competition grows among a diminishing number of large concerns on the world market. Aware of the growing saturation, these concerns invest less money in the industrial sectors and more on the international money and capital markets. In the next stage, the monopolies try to sell their surplus in the LDCs with the help of massive credits. Ultimately, these countries reach their credit limits, and the saturation of demand is complete.[13]

During this critical period, which begins with recession and lasts until the end of the depression, the economy has no fundamental solution other than the creation of basic innovations and new sectors. Only "innovations will overcome

depression" ("Innovation überwinden die Depression").[14] Mensch calls the situation in which society is forced to innovate the 'technological stalemate' (*das technologische Patt*). "Der menschliche Drang zur Neuerung wird im technologischen Patt zur wirtschaftlichen Notwendigkeit, zur Sachzwang".[15] The technological stalemate is a period of reorientation, of crisis in the sense of the Greek κρίσις , which means turn, change. We can observe such periods in 1814–27, 1870–85, 1925–39, 1975–?.

In the technological stalemate, economic policy cannot offer fundamental solutions to the crisis, at least in the short run. The government can only *finessieren*, ie play for time and avoid a collapse of domestic and foreign demand. In the long term, it has to stimulate the search for new and basic innovations by supporting innovative projects with massive amounts of money (which can be found on the international markets).[16] Since fundamental changes occur only in the microeconomic cell, government cannot control the outcome and nature of the basic innovations, it can only create a favourable climate. In any event, Mensch argues that the economic policy of deficit spending is not the most satisfactory. *Schubladenprojecte* ('drawer projects') do not have a positive multiplier effect, because they do not affect the essential problems of stagnation, which are the lack of basic innovations and the saturation of demand in the leading sectors.[17] In short, the only fundamental solution to demand saturation is an aggressive innovation policy.

Mensch makes interesting distinctions between different kinds of innovations. The basic innovations change essentially the direction of economic development and create new leading sectors, which will form the basis of the prosperity of the next upswing. They only occur under the pressure of demand saturation of the existing leading sectors when entrepreneurs are looking for new and profitable investment opportunities. Once entrepreneurs invest in these new and risky sectors, turbulent technological development begins in the same direction: these are the improvement innovations of products and production processes. The new products start a development with an S-shaped life cycle. Along with the maturing of the new industry and the increasing demand saturation, a concentration movement develops, and the monopoly firms try to protect their market share by means of *Schein-Innovationen* (pseudo-innovations), which also cause price rises. An important characteristic of the technological stalemate is that pseudo-innovations become more important than improvement innovations.[18]

Comment

Mensch's analysis is interesting because of its updating and statistical testing of Schumpeter's theory and the emphasis it places on demand and innovation as crucial factors for economic development. But Mensch skirts dangerously close to monocausality and neglects other crucial factors, which we consider in the following sections.

Mensch does remedy a major lacuna of most theories, namely the neglect of demand as the engine for long wave movement. However, we do not agree with the position that expansionary innovations are always more demand-inducing than rationalising innovations because of the different income effects they generate.[19] Rationalising innovations surely can induce a larger demand if the

more efficient use of production factors is translated into increased purchasing power and unemployment is neutralised by job creation in other sectors, eg the tertiary sector. However, when there is a technological stalemate, we do agree that rationalising innovations will be less demand-inducing than expansionary ones because of the difficulties in creating alternative employment because of the slowdown of economic growth. In short, Mensch's comparative statics do not always give the same dynamic results.

A major weakness in Mensch's empirical research is the lack of a good criterion for identifying the basic and improvement innovations. Although the difference is crucial, the interpretation of a concrete innovation is difficult and risky. For this reason, it is difficult to integrate into Mensch's theory those innovations that needed two long waves to exert their full effect on economic growth, eg automobile construction. Because these sectors have undergone intensive changes, it is uncertain whether they should be classified in terms of basic or of improvement innovations.

An important feature of innovation theory is the emhasis on the discontinuity, the clustering, of basic innovative activity. Periods of scarcity and abundance of entrepreneurial activity seem to alternate in economic development. But there is a sharp contrast between the Schumpeterian way of treating innovations, and the way macroeconomic and management literature deal with them. In macroeconomics, technological innovation is considered as a continual and even process, so only improvement innovations are dealt with. Such an approach fails to take account of the revolutionary character of basic innovations. The same idea of continuity is paramount in management literature, but with a more normative character: "Innovations do not happen, they are made to happen".[20]

In conclusion, Mensch provides a fruitful analysis of the current situation and implications for the study of the long wave, and the theory's importance is increasing as part of a multicausal explanation.

Scarcity and abundance of capital

Many authors who have dealt with the long wave, and particularly the pioneers because of their Marxist orientation, have considered varying intensity in capital goods production as the most important characteristic of the long wave. We discuss here the approaches used by Mandel and Forrester.

The theory of Mandel

Mandel defines the industrial cycle as the successive acceleration and deceleration of capital accumulation. In the upswing period, the mass and rate of profit, and the volume and rhythm of capital accumulation all increase. Conversely, during a crisis and the subsequent period of depression, these factors all decrease.[21]

When the acceleration of capital accumulation reaches a certain point during the upswing, it becomes impossible to invest the total mass of accumulated capital at an adequate rate of profit. This is the situation of overaccumulation, and it must be understood as a relative phenomenon: there is simply too much

capital available to attain the expected social average rate of profit. Consequently, the average rate of profit of the total accumulated mass of capital declines. Conversely, in the crisis and depression phase, capital is devalorised. Underinvestment now occurs: less capital is invested than would be expected at a given level of surplus-value production and at the given (rising) average rate of profit. This periodical devalorisation and underinvestment has the function of again raising the average rate of profit of the entire mass of accumulated capital, which in turn allows the intensification of production and capital accumulation. The capitalist industrial cycle thus appears to be the consequence of accelerated capital accumulation, overaccumulation, decelerated capital accumulation, and underinvestment. The rise, fall, and revitalisation of the rate of profit correspond to and determine the successive movements of capital accumulation.[22]

The periodical underinvestment of capital also makes the introduction of fundamental innovations possible: "It [the periodical underinvestment] ... creates a historical reserve fund of capital, from which can be drawn the means for additional accumulation needed over and above 'normal' extended reproduction to allow a fundamental renewal of productive technology ...".[23] The fall in the rate of profit indicates the watershed from which idle capital becomes available, first relatively and then absolutely. At a particular point, however, this additional capital is expended on a massive scale because there is a sudden increase in the rate of profit, because of sociopolitical changes and the breakthrough of technological and institutional innovations.

Comment

Mandel's theory is essentially supply-oriented and tends to neglect the role of final demand. Actually, one reason for the fall in the rate of profit is that the final demand is saturated, and this situation can only be overcome by technological and/or institutional innovations.

Furthermore, it is not clear why the average rate of profit has to increase suddenly, which Mandel repeatedly emphasises. It would be reasonable to assume that the rate of profit at first becomes high in only a few small sectors, and that it takes years before massive amounts of capital are invested in new fields because of their risky nature. In contrast, other authors, such as Forrester, consider time lags involved in investment as the essential engine of the dynamics of the long wave.

Along with the supply side and the investment goods sector, Mandel emphasises fundamental revolutions in technology—especially the machine production of steam-driven motors since 1848, of electric and combustion motors since the 1890s, and of electronic and nuclear-powered apparatus since the 1950s. Technological innovation spreads through the economy in two distinct phases. During the upswing the technology itself undergoes a revolution (eg the creation of production sites for the new means of production), while in the downswing the new production means become adopted generally in all branches of industry and the economy. Although Mandel does not investigate thoroughly the pressures that generate innovation, the distinction between the effects of technological innovation in the capital goods sector and the spin-off in the other sectors is extremely important.

The theory of Forrester

Forrester has developed a completely new method of analysing growth dynamics in which the capital goods sector plays the crucial role.[25] Using system dynamics computer simulation, he is able to combine masses of descriptive information with the inherent complexity of economic dynamics. Forrester's theory is based on two important pillars that create endogenous fluctuations.[26] The first is a multiplier accelerator mechanism that transmits the fluctuations in investment to the rest of the economy and works on the long term. The second is rational behaviour along a capital–stock adjustment model, which causes alternating phases of capital hunger and capital saturation. The economic agents continually exaggerate: they expand the capacity of the capital sector too much in the upswing to catch up with demand, and they let the capital stock collapse to a level below the long-term average in the downswing. The entrepreneur is rational *ex ante* but not *ex post* because of perception delays.

'Bootstraps' and lags in the construction of industrial infrastructure are the cornerstone of Forrester's theory. Bootstrap structures occur when a sector uses a part of its own output as a production factor. If consumer demand is increasing fast enough, the capital sector has to expand its own production capacity, but the only way to acquire capital equipment is to divert it first from the consumer goods sector that is generating the higher demand. Therefore, there is a tendency to supply less capital equipment in response to the demand for more. "The bootstrap structures tend to be highly destabilizing and to lengthen substantially the periods of fluctuation that might otherwise prevail ... In the model, the bootstrap linkage around capital creates the 50-year cycle out of what would otherwise be a 20-year medium cycle in capital acquisition".[27]

Forrester claims that the central generating structure of the cycle has changed very little over two centuries because the "fundamental causes revolve around the life of capital plant, the bootstrap structure around the capital sector, and the perception delays in human decision making".[28]

Comment

Forrester's analysis has some interesting features, not the least of which is that it is a quasi-complete endogenous model of growth dynamics. He emphasizes the importance of destabilising constraints of human actions such as perception delays and bootstrap structures. The role he assigns to final demand, however, is too passive, certainly for the interpretation of the present crisis. Moreover, although the results are spectacular, the method is very mechanistic and is based heavily on capital formation data, which are difficult to assemble accurately.

The most surprising feature of his analysis, however, is its neglect of the special dynamics that technological innovation can generate. He simply consolidates the new technology into the successive upswings, each with its compatible infrastructure. After a major depression, during which the new plant construction rate has been at a minimum for several years, the country has to replace its aging plant, and it is unlikely that the technology of 20 years before will be revived because two or three decades of unused inventions and innovations are available. Industry begins to develop a whole new kind of

infrastructure. When the upswing has progressed half way, the style and pattern rigidify, and only minor improvements take place. Here Forrester's theory resembles that of Mensch. Radically different ideas and inventions must wait until the next upswing. Still, Forrester neglects the non-continuous nature of the birth of technological innovation, despite continuing R and D activities. It is the result of pressure. The system dynamics model clearly needs a more dynamic demand function because, with the assumption of passive consumer demand, one cannot expect saturation pressures with which growth sectors could be confronted. Moreover, recent experience (eg electronics) shows that technological innovation itself has a more active influence on investment activity by rendering the production infrastructure obsolete more rapidly. Therefore, we are inclined to assign a greater role to technological innovation in the behaviour of the long wave than does Forrester.

Scarcity and abundance of labour

It is surprising that the long wave has only recently been studied by means of an explicit employment approach. The Keynesian interest in full employment and the recent failure of this policy have stimulated research in this direction: "Neither Kondratiev nor Schumpeter explicitly discuss the possibility that a particular wave of innovation might first of all have employment generating effects but at a later stage employment displacing effects. They were apparently thinking mainly in terms of the general 'climate of investment' and accumulation and fluctuations in the overall level of investment".[29]

The theory of Freeman

During the upswing, after decades of preliminary scientific and technical work, major new technologies generate both new investment and new employment on a large scale, thus becoming substantial new branches of activity. As a result of rapid technical change and increasing competitive pressures, relative prices of new goods fall and their cost advantage increases. The main employment effect during the upswing is a steep increase in employment. There will probably be shortages of specific types of labour which create an upward pressure on wages and induce ultimately labour-saving innovations.

After about a quarter of a century, the new branches of industry are firmly established, and their role as generators of additional new employment diminishes and eventually disappears. During the downswing, competitive pressures within industry become stronger, capital intensity grows, and investment continues, but labour-saving and material-saving technical changes become increasingly important. For example, employment in the US automobile industry reached a peak in the 1920s, and although output expanded, the labour force did not.

The loss of impetus for the growth of employment in the new industries is reinforced by the acceleration of labour-displacing technical changes, and economies of scale which arise from the success of the new technology itself. This process is the most intense during the Kondratiev downswing.[30]

Freeman applied his theory to the present observable evolution in the electronics industry. In the 1960s, the importance of the sector shifted from data

processing towards control, monitoring, regulation and automation. After the product innovations of the upswing, process innovations prevailed in the downswing. The applications of the electronics industry spread out increasingly through the rest of the economy, and affected production methods in a revolutionary way. This process was stimulated intensively by astonishing improvements in quality, accompanied by drastic reductions in the production costs of electronic components. Therefore, "the competitive substitution pressure in a wide range of industries and services will become intense in the last quarter of this century".[31]

Comment

Freeman's theory is of importance for the present because of its ability to deal with the intensive job destruction effects of the electronics sector. However, it may be queried whether the electronics sector is having a more devastating effect on jobs than did the earlier leading sectors. An empirical test would be complicated, because one would have to know how much unemployment is caused by the process innovation, and how much by the saturation of consumption demand. Still, research in this field could be fruitful.

The distinction between process and product innovations is useful and more adequate than the distinctions between basic and improvement innovations developed by Mensch. The most interesting features of Freeman's theory, however, are those that accord with the capital-oriented long-wave theories. The key aspect of the long wave lies in investment behaviour, for example, in the production of electronic capital goods and its influence on other sectors via automation. A major difference is that capital intensity grows in the downswing in the labour approach, but declines in Forrester's capital approach. Furthermore, both long-wave theories emphasise the growing unemployment of production factors in industry during the downswing: labour for Freeman, and capital for Mandel and Forrester.

Scarcity and abundance of foodstuffs and raw materials

The theory of Rostow

More than the other authors considered here, Rostow emphasises the dynamics of growth in a world perspective.[32] He sharply distinguishes and relates three distinct phenomena: the forces set in motion by a leading sector in growth, by changes in the profitabiity of producing foodstuffs and raw materials, and by large waves of international or domestic migration. The second factor is particularly important because it generates a price revolution, ie a short period of a sharp rise in the relative prices of food and raw materials at the expense of the prices of industrial goods. If the producers of the former are the LDCs, and of the latter the developed countries, then a price revolution means a period of deteriorating terms of trade for the developed countries.

The price revolution reflects the disequilibrium between supply and demand of foodstuffs and raw materials at the end of the period of declining prices. Growing population and rising real income create an increasing pressure on the supply of food. In the same way, developing industrialisation creates a pressure on the available supply of raw materials. Within the existing structures, the

supply of these goods becomes less flexible because of the declining marginal returns of improvement in exploitation. This disequilibrium is reflected in an enormous price rise, measured by historical standards. The opportunities for profit in these sectors change radically, so growing numbers of people and large amounts of capital are attracted to them. People search for fundamental solutions to this relative scarcity, and leading sectors, with important secondary effects, can develop. Once the scarcity of foodstuffs and raw materials is overcome, a new period of falling prices begins. During the downswing, the price decline of raw materials accelerates the diffusion of the new sectors through the economy.

Comment

Rostow has introduced some interesting elements into long-wave theory, although his analysis does not adequately integrate the post-war situation. At first sight, perversely, the 1951–72 period is considered as a downswing, with the upswing starting in 1972. However, Rostow's theory seems to be enlightening for the analysis of the present price revolution. The new shortages of primary goods and especially energy fit well into the adjustment theory and are likely to create new leading sectors on the input side of the economy: new energy sources (nuclear, solar, wind), new raw material sources (ocean reclamation), new foodstuffs industries (bio and genetic industries), environment industries, and so on.[33]

Conclusions

The theories we have dealt with emphasise different aspects of the long-wave movement, and have different starting points and assumptions. In reality, they are more complementary than we have so far suggested, multicausality being clearly a better approach to the complex phenomenon of the long wave. Along with Rostow and van Duijn, who integrated several theories, we also prefer an eclectic approach.

Van Duijn[34] constructs his synthesis by combining the innovation theory of Schumpeter and Mensch, the hypothesis about the life cycle of industry along an S-curve, and Forrester's multiplier accelerator mechanism of investment, which intensifies the growth and saturation of basic innovations. The role of time lags is considered essential for the particular behaviour and length of the long wave.

It is likely that the newest leading sectors will be reactions to the present scarcity of primary materials. This corresponds with recent research on new forms of energy and raw materials.[35] In this context, we are convinced that long-wave researchers have to investigate further the link between, on the one hand, the relative prices and the substitution of production factors, and on the other, the behaviour of industry and the economy during the long-wave movement. Rostow's theory about changing relative prices should be extended to include wages.

It is important to take into account how much the social and institutional framework has changed since the industrial revolution. It is valuable, therefore, to study the different long waves more in their historical context. Often,

institutional changes took place unevenly and in step with the long wave, and technological innovations seemed to break through accompanied by them. According to Freeman, "It is important to remember that a major technology requires not one or two but a whole cluster of related inventions and institutional changes, which in combination enable it to take off ...".[36] And Mandel asserts: "...it is plain that this ascent and decline (of the rate of profit) is not determined by one single factor but must be explained by a series of social changes...".[37]

Moreover, many authors interpret the major economic crisis from the viewpoint of institutional innovations. Referring to the downswing in the last quarter of the 19th century, Chandler has stated: "In that period, the basic innovations were more in the creation of new forms of organisation and new ways of marketing. The great modern corporation ... had its beginnings in that period. Such organisations hardly existed, outside of the railroads, before the 1880s. By 1900 they had become the basic business unit in American industry".[38] Analogously, Akerman presents an institutional interpretation for the crisis of the 1930s, although he considers technological factors primary for the 1870s: "Si cette frontière structurelle [ie the 1870s] a des causes avant tout techniques, celle de 1920–29 est due essentiellement à raisons politiques: le passage du principe du profit à une structure d'économie dirigée".[39]

The question arises whether future technological innovations will be accompanied by institutional changes, and, if so, what their nature will be. While the McCracken report forecast further economic growth based on the institutional pillars of the past, the more recent INTERFUTURES report emphasises important social and institutional changes that are now breaking through.[40] These consist of changes in the ideas of the post-war generation *vis-à-vis* economic life and especially labour; the growing economic and political power of the LDCs; the increasing political pressure for better income distribution, both domestically and internationally; and the growing interdependence of the world economy.

If there is such a close link between economic and institutional change, a fundamental analysis of the long wave has to deal with it. And particularly in empirical testing, attention has to be paid to important changes in the parameters and the specification of the model. Perhaps the most fundamental problem is the question of whether our industrial society is itself behaving along a life cycle of economic development. Should this be the case, we are the witnesses of the transition from a growth economy to an equilibrium economy.[41] Such a possible change presents a challenge to aggressive research on economic and industrial growth dynamics in the very long term.

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COMMENTS ON TOPICS 1 AND 5

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TOPIC 1: THEORIES OF THE LONG WAVE

If there is a long wave in economic activity, it is likely that many economic variables are affected by it. Economic growth rates might display a wave-like pattern, but so could industrial production growth rates, investment growth rates, employment rates, capacity utilization rates, prices, interest rates, profit rates, wage rates, money growth rates, innovation rates, etc. Worker militancy, war activity, political attitudes or even climates might also vary over time in a wave-like fashion. Observing recurrent waves of some 45 to 60 years' length in a multitude of socio-economic variables does not, however, give a direct insight into what ultimately causes these waves. It is up to the students of the long wave to look for the underlying mechanisms. Engaged in this process they run into chicken-and-egg questions: is the falling profit rate the cause of a downturn, or the result of it? Does innovation follow investment activity, or does innovation have to come first?

At this point in time there is disagreement among economists about a lot of things. It is quite easy to list ten or even more causes of the depression. Depending on whether one asks a neo-classicist, supply-sider or long-wave economist, different causal factors will be given. Even long-wavers, however, do not agree. They see a wave, but disagree on when the last downturn started, what caused it, and when it will end.

It is unlikely that the theoretical issues concerning the long wave will ever be resolved. Economists still disagree on the causes of the precious Great Depression. Within the current group of long-wave researchers, however, there seems to be some consensus growing. The following list of theories might therefore suggest more disagreement than actually exists at this moment.

I would argue that at least five groups of theories could nowadays be distinguished:

(I) Investment theories (Forrester)

(II) Schumpeterian innovation theories (Freeman, Mensch, van Duijn)

(III) Price theories (Rostow)

(IV) Marxist theories (Mandel)

(V) Social structure theories (Gordon)*

If we would also want to include the pre-war literature, other groups of theories would have to be added: notably the monetary theories, war theories, and agricultural theories. These are not adhered to anymore -- not in a narrow sense, that is. I will now briefly describe the various theories, and see to what extent they are compatible or incompatible with each other.

(I) INVESTMENT THEORIES

When dealing with cyclical fluctuations it is quite natural to take investment behavior as the ultimate cause. Many cycle theories do, and all major cycles we know of (Kitchin, Juglar, Kuznets, and Kondratieff) can be and have been theoretically explained as resulting from the fluctuations in a particular investment category: inventory investment in the case of the Kitchin cycle, investment in machines and equipment in the case of the Juglar, investment in buildings to explain the Kuznets-cycle, and infrastructural investment to account for the Kondratieff wave. Kondratieff himself sought for a clue to the long wave by pointing at what he called investment in 'basic capital' (railroads, bridges, roads, waterworks). I myself, too, tend to give great significance to the role of infrastructural investments (industrial complexes, harbor complexes, road systems) in explaining fluctuations of the long-wave type.

The interesting aspect of the contributions made by Forrester c.s. is that they can generate long waves by specifying investment behavior, in general, without exclusively relying on capital goods of long duration. Forrester c.s. divide the economy in two sectors: the capital goods sector (mining, construction, steel, heavy equipment, and other basic industries) and the consumer-goods sector. If the demand for goods and services increases, the consumer-goods sector must expand its capacity. But to supply this capacity, the capital-goods sector must expand is own capacity. Since it has to acquire capital goods from itself, there is 'self-ordering'.

Forrester c.s. would argue that the boom of the 1950s and 1960s started with this self-reinforcing feedback. In order to satisfy demand from the consumer-goods sector and to rebuild its own infrastructure, the capital-producing sector had to expand beyond the long-run needs of the economy. Thus, towards the end of the 1960s, excess capacity began to develop in the basic industries.

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*The names associated here with the various theories serve only as indications of the various groups of people involved in long wave research. Forrester is seen as representative of the MIT-group which also includes researchers such as Graham, Senge and Sterman; Freeman leads a group of economists at the University of Sussex (including Soete, Clark and Dosi); Kleinknect has been an associate of Mensch's; while Gordon has done work with Bowles and Weisskopf, and with Edwards and Reich.

Note that Forrester c.s. do not need fluctuations in the rate of innovations in order to generate long waves. A constant rate of growth of consumption demand will do. However, in more recent publications the group has recognized that the long wave influences the climate for innovation and that a certain bunching of innovations may in fact occur.

(II) SCHUMPETERIAN INNOVATION THEORIES

Schumpeter, although not being very specific himself about the 'swarm-like appearance' of innovations, has inspired a number of scholars to further explore the notion that a bunching of major innovations could be the cause of observed alternations in rapid growth and slow growth of industrialized economies.

There is no doubt that Gerhard Mensch has given the main impetus to the renaissance of Schumpeterian models for economic development. By being the first to rethink the swarming hypothesis, he has drawn both praise and criticism.

It is clear to all Schumpeterian long-wave researchers that technological change does not proceed at an even pace. They all recognize that upswings of the long wave involve an explosive burst of growth in a number of major new industries -- industries which incorporate the advances of modern technologies. It is also clear that the transition from upswing to downswing may be related to a lessening of the growth potential of the innovations which carried the upswing phase.

The main debate, however, has been on the lower turning-point of the long wave. Does depression in itself stimulate the introduction of new basic innovations, as Mensch has argued, or is some form of technical recovery necessary before entrepreneurs adopt and implement the new technologies which are available? The latter position has been defended by Schmookler. This position would require an 'outside' force to engender the lower turning-point of the long wave. This force could be replacement investment. In this view the investment and innovation theories would be complementary.

Another issue concerns the nature of the bunch of innovations that give rise to the upswing. In Mensch's original work the suggestion was made that this bunch could consist of various, totally unrelated innovations, which somehow were driven by the same forces of economic depression. Case studies of particular innovations have made clear that a more detailed look is necessary. Industry life cycles should be taken into account, as well as the nature of innovations (product vs. process innovations as a first subdivision). It is clear that macroeconomic conditions have an impact on the propensity to innovate, but long-wave depressions could not act as the sole force influencing this propensity.

A third issue in the debate between the Schumpeterians concerns the importance of the introduction of innovations vis-a-vis the diffusion of innovations. Freeman c.s. have repeatedly pointed out that, while the moment of introduction of an innovation is of significance, it is the rapid diffusion which causes the upswing of the long wave.

I myself have found the concept of S-shaped growth to be extremely helpful for understanding the role of innovations and of investment in the long-wave growth process. In my view innovation theories cannot do without a consideration of the investment demand generated by new, innovative industries.

Conversely, investment theories which disregard the role of technological change -- both in the field of product innovations and of process innovations -- cannot fully explain the process of long-term economic development.

(III) PRICE THEORIES

A great deal of confusion around the long wave is caused by the fact that two distinct kinds of long cycles seem to exist. There is a price cycle and there is a production cycle. The two are not the same, but they are usually mixed up. The most important modern theory on the long wave in prices has been developed by W.W. Rostow. Rostow has argued 'that trend periods, or Kondratieff cycles, as he has interpreted them, were caused primarily by periodic undershooting and overshooting of the dynamic optimum levels of capacity and output for food and raw materials in the world economy'.

Deviations of actual from optimum capacity are caused by three distinctive characteristics of major investment in foodstuffs and raw materials:

(1) a recognition lag -- the lag between the emergence of a profit possibility and the investment decisions designed to exploit it;

(2) a gestation lag -- the lag caused in part by large prior infrastructure outlays before production can begin;

(3) an exploitaton lag -- the lag between the completion of the investment and its maximum efficient exploitation, often involving large domestic or international migration.

In agriculture and raw material production, these lags are longer than in manufacturing. In the former, productive capacity increases discontinuously in large, discrete steps and these increases involve long time lags. Protracted upward shifts in the relative prices of basic commodities act as the catalyst which sets in motion the expansion of productive capacity. However this expansion overshoots the dynamic optimum level. The subsequent period of decline in relative prices of basic commodities leads to an investment decline. Demand for basic commodities continues to grow in response to population growth and the trend expansion of industry, and the neglect of investment ultimately causes a reversal of the relative price movements when surplus capacity has been worked off. A new round of expansion of productive capacity follows.

Rostow's theory produces a long-wave chronology, which is quite different from those of other researchers. Whereas most economists, whether they have a bent for the long wave or not, would consider the 1933-1951 interval and the post-1972 years as belonging to a downswing period, Rostow argues that these have been upswing years, due to the fact that the price level of raw materials and foodstuffs was rising. Conversely, the 1951-1972 period was a downswing period in Rostow's theory, as the 'basic sector' prices were slightly going down.

It is interesting to note that Rostow, who has been one of the exponents of the 'leading sector' concept, finds himself in a different camp than those Schumpeterians, who see the long wave upswing phases as carried by the same leading sectors. Rostow recognizes that one of the outstanding characteristics of leading sectors is that they incorporate te major technological changes of the time; yet he arrives at a different periodization.

The answer to this seeming contradiction is that Rostow regards the 1950s and 1960s as an extension (interrupted by the Great Depression and the Second World War) of the set of technologies which created the upswing of the first decades of the 20th century: electricity, new chemicals, and the internal combustion engine. It was the postwar shift in the terms of trade in the industrialized countries which favored this extenson.

I find it difficult to agree with Rostow on this point. While the automobile complex surely was a leading sector in Japan and Western Europe after World War II, the synthetic fibers, artificial resins, electronics and aircraft industries were definitely based on technologies which were not available before the 1930s. Even so, I find Rostow's explanation of long-term price fluctuations as the result of output and capacity changes in the 'basic sectors' of the world economy, very appealing. It would seem, however, that his cycles are different from the ones studied by other long wave theorists.

(IV) MARXIST THEORIES

The long wave can be said to have been discovered by Marxists. Parvus (pseudonym for A.I. Helphand) was the first in line, followed by the two Dutchmen, Van Gelderen and De Wolff. Kondratieff, however, noted the very non-Marxist implications of the long wave theory. It is not surprising, therefore, that Mandel, the most prominent modern Marxist who has dealt with the long wave, does not see this wave as a true cycle, but as a series of interruptions of the secular decline in the rate of profit. Each upturn of the long wave is therefore explained with the aid of non-economic factors, such as wars of conquest, extensions and contradictions in the area of capitalist operation, class struggle, revolutions and counterrevolutions, etc. Thus the upturn after 1940 is explained by Mandel by 'the historic defeat suffered by the international working class in the 1930s and 1940s'.

While Mandel needs outside forces to explain the lower turning point of the long wave, his explanation of the upper turning point would allow us to classify his theory in the group of investment theories. He also recognizes that an upturn, once it has set in, sets the stage for a technological revolution. Both elements of the investment and innovation theories of the long wave are therefore present in mandel's interpretation of it.

Starting with the exogenous shock, Mandel's long wave develops as follows: Environmental changes cause a 'sudden' upturn in the rate of profit. The increase in the rate of profit causes an upsurge in the rate of capital accumulation. This allows for a technological revolution, which, by itself, gives an additional spur to the rate of profit. Economic growth leads to strong increases in employment, strengthening labor and flattening out increases in the rate of surplus value. Class struggles and international competition intensify. Credit explosions are necessary to maintain growth. The rate of profit starts to decline, due to the disappearance of technological rents (and presumably also due to previous overaccumulation of capital). Monetary instability increases. Rates of investment decline. A search for new ways to reduce labor costs develops. The sharpened crisis of capital valorization spreads into prolonged social and political crisis. At this point a new exogenous shock will be needed to reverse this pattern again.

(V) SOCIAL STRUCTURE THEORIES

Most long wave theories are economic theories. Some long wave theories are also 'economic' in the sense that they do not at all consider the that long waves might have a multidimensional character whatever the ultimate causes might be. Economic as well as other aspects of the long wave merit attention.

In the social structure theory of the long wave developed by Gordon c.s., social structure comes first and economic behavior is seen as largely determined by a particular social structure. Periods of boom are the product of the success of a social structure in facilitating capital accumulation. However periods of prosperity contain endogenous contradictions that ultimately bring prosperity to an end. The ensuing crisis is a period of instability that requires institutional reconstruction for renewed stability and growth. The resolution of this period of crisis involves certain unpredictable political elements. Therefore, just as in Mandel's theory, exogenous events may also play a role in the transition from one period of prosperity to another. In the work of Gordon, Edwards and Reich the connections between long waves and social structures of accumulation are summarized in a series of propositions:

(1) A period of expansion is built upon the construction and stabilization of a favorable social structure of accumulation.

(2) The favorable institutional context for capital accumulation generates a boom of investment and rapid economic activity.

(3) The success of the capital accumulation process pushes investment to the limits that are possible within the social structure of accumulation. Continued rapid capital accumulation requires (among other changes) either a reproduction of the conditions existing at the beginning of the boom or a transition to a new organizaton of the labor process and labor markets. The initial conditions are difficult to reproduce, and needed reforms are not easily achieved.

(4) Accumulation slows and the period of stagnation is entered. Attempts to alter the institutional structure are met with opposition, especially in a stagnationary context.

(5) Economic stagnation promotes the further dissolution of the existing social structure of accumulation.

(6) The restoration of the possibility of rapid capital accumulation during an economic crisis depends on the construction of a new institutional structure.

(7) The internal content of this institutional structure is profoundly but not exclusively shaped by the character of the class struggle during the preceding period of economic crisis.

(8) The new social structure of accumulation is virtually certain to differ from its predecessor, thereby generating a succession of stages of capitalism.

(9) Each stage of capitalism is likely to feature a long period of expansion, then a subsequent long period of stagnation.

The theory of Gordon c.s. may be seen as complementary to the economic theories of the long wave, both Marxist and non-Marxist. Marxists of course have traditionally paid attention to underlying social structures, bit, according to Gordon c.s., insufficiently so. While the social structure theory may overemphasize the role of institutional factors at the expense of the traditional economic ones, combining the two groups of theories could produce a richer

view of the changes a capitalist society goes through in the course of a long wave. It also could provide a better insight in the conditions that have to be met before an economy can make the transition from depression back to prosperity.

perity.

TOPIC 5: NATIONAL AND REGIONAL ASPECTS

(I) THE CIRCLE OF INDUSTRIALIZED COUNTRIES AND THE OUTSIDE WORLD

1. Long waves originate in the industrialized world as a whole

Long waves are a truly international phenomenon. There are various reasons for this: the interconnection of countries through international trade is the most important. The markets for many products have become world markets. Steel is a world market commodity, and so are rubber, oil, and many other products. If world trade declines, as in 1982, the shipping and shipbuilding industries suffer, all over the world. It cannot be said that long wave upswings and downswings originate in one particular country, and spread to the rest of the world from there. Whenever industrial production takes place on a world scale excess capacity will develop for the industrial world as a whole; saturation of demand will be noticed everywhere. Improvements of communication and transportation infrastructure will mean a further integration of the world economy, and this would imply that long waves will become stronger, and not weaker, over time.

Of course there may be slight differences in the timing of upswings and downswings. The propensity to innovate may not be the same in all industrialized countries; the climate for innovation may also differ between countries. As a result some countries will benefit more from the diffusion of innovation than from their own introduction of innovation. In principle, however, a pool of technological knowledge becomes available for all advanced countries to draw from.

2. The non-industrialized countries are affected by long waves through their participation in world trade

The world economy can be divided up in a number of blocs: the OECD, the communist bloc, the oil exporting countries, and the non-oil exporting developing countries. Among the latter, the NICs are a distinct category.

It is probably fair to say that the rhythm of the world economy is determined in the industrialized countries of the OECD-bloc,. The centrally planned economies of the communist bloc have maintained a rapid growth pace after World War II, and have suffered less from cyclical fluctuations, but it appears that they have not been able to stay clear from the problems of stagnation which have beset the OECD-countries. One reason for this is the international trade between the two blocs. Another may be that the centrally planned economies too encounter problems of saturation and excess capacity.

Recent history has made clear that the oil producing as well as the developing countries are very much dependent on the growth impulses emanating from the other blocs. With the exception of the NICs, their industrial base is still too small to generate their own growth.

3. World economic recovery depends on the long wave recovery in the industrialized countries

One consequence of the foregoing argument is that world economic recovery will have to originate in the industrialized countries. If these countries recover, on the strength of innovation and investment demand, the rest of the world will benefit. In this respect it is of importance to point at the current debate regarding the position of the Third World. Should their economies be supported through a massive transfer of funds from the North to the South, or should preference be given to the recovery process in the North? The long wave view suggests that the recovery process in the industrialized countries should not be impeded by a lack of capital; yet it is also clear that it is necessary for the Third World countries to have sufficient purchasing power to engage in trade with the industrialized countries. World economic recovery, however, cannot be generated by a transfer of funds to the Third World alone.

4. Innovation diffuses from core to periphery

One of the findings of the innovation literature is that innovations tend to spread from their center of origin – which is usually in the most advanced economies -- towards the peripheries of the industrialized world. This process occurs within countries and therefore has relevance for regional economic policy within a country; it also occurs within larger entities. Thus innovations have spread from the United States to Western Europe, and from Western Europe to Southern Europe and North Africa, but also from Japan to other countries in East Asia, and so on. Through the adoption of modern technologies, the NICs have in fact entered the circle of industrialized countries. It is likely that a new long wave upswing phase will see the arrival of a new set of NICs.

(II) LEADERS AND FOLLOWERS

1. Early Entrants and Latecomers

The diffusion of industrialization over countries has followed a particular pattern. The Industrial Revolution spread from Britain to the rest of the western world, but geographical proximity to Britain proved to be no guarantee for quick adoption of the new technologies, witness the late industrialization of the Netherlands, vis-a-vis the early industrial development in Switzerland, in timing a close second to Britain.

In the economic-historical literature it is common to speak of the four These were the early industrializers, countries whose 'take-off' occurred before the depression of the 1870s. To a large extent they represented the industrialized world of the 19th century, together accounting for almost 80 percent of world manufacturing output in 1870 and still over 70 percent in 1913 (Table 1). The other early entrants were two small European countries -- Switzerland and Belgium.

In Table 2 I have listed countries in the order in which they industrialized, taking Rostowian take-off periods as the beginning of industrial development. I realize that such an order cannot be established unequivocally.

Table 1. States in World Manufacturing Output

Period	U.S.A.	United Kingdom	Germany	France	Russia	Others
1870	23.3	31.8	13.2	10.3	3.7	17.7
1881-1885	28.6	26.6	13.9	8.6	3.4	18.9
1896-1900	30.1	19.5	16.6	7.1	5.0	21.7
1906-1910	35.3	14.7	15.9	6.4	5.6	22.7
1913	35.8	14.0	15.7	6.4	5.3	22.6

Source: Folke Hilgerdt, *Industrialization and Foreign Trade*, League of Nations, 1945, p.13.

Industrialization has often come in spurts, and the question then is which start was the true take-off. For some countries historians disagree on the timing, a result of the (necessarily) qualitative nature of the concept of is considered to have fallen between 1868 and 1980 by Rostow himself. Other authors, however, have noted a considerable slowdown in Swedish economic development after 1875, which was followed by a new outburst of growth only after 1892. Other European countries had similar experiences. They all experienced railroadization between 1840 and 1870 (a development often seen as the single best masure of take-off), but then suffered from the Great Depression of 1873-1895 before growth accelerated again towards the end of the century.

The important lesson of Table 2 is that take-offs are most likely to take place during long-wave expansion phases. In Europe the growth spurts to which I referred above, coincided precisely with long expansions. Checking the countries listed in Table 2 we see that for only a few of them take-off occurred during a downswing period: France and Belgium, and Brazil, Argentina and Turkey. However, one has to add then that the first long-wave downswing may have been only a downswing in prices, not in industrial production growth. Corton textils was followed by railroadization without a long depression in between. France and Belgium did develop on the strength of the same revolution Great Britain took off on. In the case of Turkey one should realize that much of the Turkish take-off occurred during an international economic upswing.

It is far from surprising that country take-offs should coincide with international long-wave expansions, for most countries depended to a greater or lesser extent on export expansion for their take-offs. The domestic markets often were too small a basis, especially for the smaller countries. This was true in the 19th century, this is equally true today. For now it means that the circle of industrialized countries will only be enlarged if there is to be a fifth long-wave expansion, during which other less developed countries can try to copy the success of the present NICs, whose names can be found at the bottom of Table 2.

Table 2 of course represents a highly simplified picture of industrialization. It does not indicate which path of development will follow once the first, and critical, jump has been made. Each industrialized country has followed its own course -- the paths of Great Britain and Switzerland, to name just two countries with comparable starts, have been widely different. There are no standard models of development, although it is tempting to look for common features in the patterns which emerged after take-off.

2. After a country has taken off, it will be less affected by the next long wave downswing

There is one possible relation between industrial development and long waves I should like to point at. Assuming that take-offs are indeed most likely during a long-wave upswing, we may also assume that a country which has just taken off, will be less affected by an ensuing long-wave downswing. The growth of its still young industries may carry a country through depression, which is first of all an international phenomenon. Only when a country has adopted the world pool of technologies and caught up with more advanced nations, will it settle in the international wave-like rhythm of growth. Thus Great Britain never suffered from a 'first long-wave downturn', the United States grew through the depression of the 1870s and 1880s, the Skandinavian economies were expanding despite the Great Depression of the 1930s, and NICs such as South-Korea and Taiwan are among the fastest growers of the 1970s. But Britain did not escape slowdown after 1872, and the US suffered its greatest setback after 1929. In our times the older countries have done much worse than the latecomers. We are somewhat hesitant ourselves about the merits of this hypothesis. Yet we feel that the way in which a country is affected by an international depression and its age as an industrialized nation are not unrelated.

3. Location in space does not provide a clue towards explaining which countries will be the next to take off

Table 2 provides no guidance as to which geographical area should industrialize when. The very different economic histories of the European nations illustrate that diffusion of industrialization does not take place smoothly over space. In Rostowian terms the actual hopping around process should be explained by pointing at the different preconditions for take-offs, as they existed in the different nations. These conditions, rather than location in space, should provide clues for which group of nations will constitute a next bunch of entrants.

Table 2. Long Waves and Take-off Dates

1st long wave upswing 1782-1825	Great Britain	1783-1830
	Switzerland	1798-1835
1st long wave downswing 1825-1845	France	1830-1870
	Belgium	1833-1860
2nd long wave upswing 1845-1872	Germany	1840-1870
	United States	1843-1870
2nd long wave downswing 1872-1892		
3rd long wave upswing 1892-1929	Japan	1885-1905
	Russia-USSR	1890-1905
	Sweden	1892-1913
	Norway	1892-1913
	Denmark	1892-1913
	The Netherlands	1895-1913
	Italy	1895-1913
	Canada	1896-1914
	Australia	1901-1920
	New Zealand	
	Austria	1904-1912
3rd long wave downswing 1929-1948	Argentina	1933-1950
	Brazil	1933-1950
	Turkey	1933-1961
4th long wave upswing 1948-1973	Mexico	1940-1960
	India	1952-1963
	China	1952-1967
	Taiwan	1953-1960
	Iran	1955-1965
	Thailand	1960s
	South-Korea	1961-1968

Sources for take-off dates:

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COMMENT ON POINT 1: THEORIES OF THE LONG WAVE

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The theoretical hypothesis which presupposes the existence of "long cycles" presumably possesses certain analytical merits. It permits, in particular, to discern more distinctly certain features in the development of technical progress and economic growth over comparatively long periods of time. At the same time, certain theoretical schemes of "long cycles" tend excessively to universalise elementary techno-economic processes and overlook the concrete historical forms of their development. The volume and quality (in particular, comparability) of statistical information accumulated to this day inhibit a rigorous and exhaustive verification of the hypothetical role of "long cycles" in various spheres of economic activity. And, for confronting researchers, there is also the problem of overinterpretation.

One approach to long cycle studies takes into account the fact that the developed market economy is marked by various types of fluctuational movements. Marx showed that, as capitalist machine industry emerges on the historical scene, various fluctuations come to be dominated by a regular alternation of recessions and upswings on a macro-economic scale (and, since the latter part of the last century, also within the framework of several capitalist countries). This process was later called a regular "business cycle".

The cyclical crises* already have a century-and-a-half history. In the sixties and early seventies some economists doubted whether these uniformities retain their validity in the second half of this century (see, e.g., *Is Business Cycle Obsolete*? New York: Wiley, 1969). However, today such doubts are expressed more rarely, owing, partly, to the recessions that occurred in the mid-seventies and early eighties.

*Here and elsewhere the terms "cycle" and "cyclical" are used to describe a regular business cycle.

The two most recent comparatively acute, and long two latest recessions and the slack cyclical upswing that separated them have again drawn the economists' attention to the possible impact of the low-frequency oscillatory component. The model of a regular business cycle can serve, in our view, as the most "reliable starting point for a most general conceptual framework of low-frequency fluctuations.

Deviations are being accumulated in the course of business expansion which ineluctably cause unfavorable changes in the movement of the size and rate of profit. At a certain stage in this process the changed relationship between current expenditures and prices reduces the output in several industries. All conflicts of capitalist production manifest themselves in regular economic recessions, but not all of them can be resolved, albeit temporarily, in each recession. In the course of a cyclical recession, the "clearing out" of conditions for a new wave of capital accumulation can rarely be sufficiently complete, especially in a comparatively shallow recession. Conditions are being periodically shaped for a cumulative ("transcyclical") development of certain processes restraining growth in the rate of profit. These transcyclical processes are usually manifested in various spheres, but they are always directly connected with specific long-term regularities of capital accumulation.

Even when we deal with the unevenness of technical progress and innovation "spurts", their effect on the fluctuational movements of economic activity are, to a decisive extent, dependent on the economic relations. For instance, in a capitalist economy, the profitability of a transition to a massive introducton of some innovations is determined by the current economic situation especially by market conditions, interest rates, business expectations, etc.** At the same time, the transcyclical accumulation of unfavorable conditions manifests itself in the "feedback" -- that is the consequences of a comparatively more intensive and long economic growth following upon the preceding, rising wave of low-frequency fluctuations. It becomes clear, for example, that, at the given level of technical and economic development, a situation may arise under which the market demand has been "saturated" by the production of major industries, while the spasmodic expansion of the consumption of natural resources runs against its limits.*** In recent years, such oscillatory contours have also involved direct and reverse connections between economic growth and increasingly acute ecological problems.

Thus, the crisis prepared by the cumulative transcyclical movement of these processes is a the crisis of the entire structure of established socio-economic relations. It can be overcome by restructuring economic forms of resource allocation and management, a certain redistribution of functions between private business and the state, and changes in the system of the international division of labor and in the performance of the national economies. These processes have always required a more or less prolonged time and have been expressed in forms that are exceedingly painful for the bulk of the population.

**It is quite probable, for example, that the slowed growth rate of wages in the seventies and early eighties (or even their downward drop), as well as the sharp increase in the interest rate have narrowed down the possibilities of technical progress and limited the dissemination of capital-intensive innovations.

***The emergent indications of partial saturation or limits of supply of some raw materials do not and cannot mean, of course, that the individuals' requirements in some commodities have been fully met, or that some natural resources have been exhausted.

The general worsening of the overall economic growth conditions registers directly on the scale and forms of the investment process: growth rate of aggregate investments is slows, and in some cases a tendency is felt for a decreased share of investments in the gross national product. The changes that occur in the sphere of capital accumulation are as a rule vividly manifested in the form of a gradual growth in the investment risk. A sector of the economy marked by an intensive accumulation of non-residential structures and business equipment may shrink from one cyclical upswing to another. There is a shallow decline in the risk discount multiplier and in the "usual" discount ratio (parameters affecting investment decisions), that accompanies transition to the cyclical upswing. All this significantly weakens the "latent" energy of cyclical upswings and prepares conditions for longer economic recessions. An analysis of the empirical material that encompasses large stretches of time can show that real accumulation belongs to those spheres in which low-frequency fluctuations perhaps stand out in especially bold relief. At the same time, the slowing down of the economic growth rates is seen during transcyclical growth in the number of unemployed and a gradual increase in the average duration of unemployment.

In the prewar period many authors believed that "long waves" were most clearly seen in the movement of prices and interest rates, and, in fact, they deduced the decreasing phase of these waves from a long drop in prices. The experience of postwar years has shown that such notions (at least in their earlier form, which implied a drop in the absolute level of prices) have not stood the test of time. On the other hand, some features of the transcyclical accumulation of unfavorable conditions can be traced here, too.

Thus, the relevant estimates can show that the decreasing phase of low-frequency fluctuations is, more often than not, characterised by the transcyclical growth in the dispersion of relative prices and sharp leaps in interest rates. In this century one could also observe a fastly growing amplitude of exchange-rate fluctuations during these phases. A gradual "shaking" of the structure regulating commodity-money circulation and capital movements further intensifies economic instability.

The stagflational forms taken on by these processes today make the distribution of incomes and wealth in capitalist society more uneven and at the same time intensify socio-political tensions.

IMPLICATIONS FOR NATIONAL AND REGIONAL ECONOMIC POLICY

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TOPIC 1: THEORIES OF THE LONG WAVE

What are the basic alternative theories of the long wave? To what extent are they competing or complementary? What is the most meaningful taxonomy of long-wave theories?

THE GOAL OF THEORY BUILDING

The proper goal of long wave theory building is the integration of the various hypotheses and theories that have emerged in recent years. The question facing long wave theorists should not "which theory is correct (to the exclusion of all others)?" but "how do the mechanisms described by the theories interact, amplify one another, and contribute to the long wave?"

How, then, can long wave theories be classified? We believe the three most important categories in a taxonomy of long wave theories are:

1. Endogenous vs. Exogenous explanation
2. Structural vs. Correlative
3. Disequalibrium/dynamic vs. Equilibrium/static

The most important taxonomic distinction to be made is whether the theory provides an endogenous explanation of the long wave. An endogenous theory explains the long wave as the result of the interactions of components of the system. An endogenous theory explains how the long wave can arise without exogenous driving forces. An endogenous theory will explain how the small,

random shocks that continuously bombard the economy, such as weather fluctuations, can trigger the latent long wave behavior of the system.

In contrast, an exogenous theory is one in which the long wave is the result of a fluctuation in a variable which is itself outside the boundary of the theory, and therefore unexplained. The nineteenth century sunspot theory of the trade cycle provides an example. An exogenous theory is unsatisfying as it really begs the question: it does not explain why the external variable fluctuates with the appropriate period. An exogenous theory ignores the effect of feedback from the system to the driving variabls. An exogenous theory cannot be used to assess policies that might feed back and affect the driving variable. Exogenous theories tend to be monocausal. They tend to emphasize one half of a feedback loop which, if fully taken into account, would help explain the behavior of the exogenous variable as an endogenous reaction to the rest of the system.

A second important taxonomic distinction is the structural and behavioral realism of the theory. A long wave theory, indeed any theory of economic dynamics, should properly portray the physical structure of the system and the behavioral decision rules used by the actors. By structure is meant the stock and flow relationships which define the accumulation and movement of people, capital, goods, and so on. A good theory will distinguish physical stocks of labor, capital, materials, technology, etc., from parallel stocks of money, net worth, orders, and so on.

A good theory will portray the decision rules used by the actors in the system. Economic decisions are made in an environment of uncertainty, with limited, often biased and distorted information, under pressure of time, by human beings with limited information processing capabilities and imperfect mental models of the system. A theory of the long wave, and of economic dynamics in general, must not presume the actors are able to find the global optimum of the system, have perfect information, perfect knowledge of the system structure, or the ability to anticipate infallibly the consequences of current actions.

Likewise, a good theory will not rely on historical correlations between variables. Theories based on historical correlations are only valid if the underlying structural relationships continue to hold. It is obvious that correlative theories are of little use in evaluating policies that may carry the system to a new operating region. A proper theory must generate and explain both the correlations that are observed and also the changes in the correlations that may arise over the course of a long wave. A good theory will explain the so-called "structural changes" that alter historical correlations.

The third important distinction is the dynamic nature of the theory. The long wave is an inherently disequilibrium phenomenon. A proper theory should portray the processes by which the system adjusts to shocks. Theories of the long wave, and of economic dynamics in general, must not presume that equilibrium exists or is stable. The process of equilibration should be modeled. How do actors perceive and react to imbalances? What constraints, delays, and misperceptions may prevent a swift and smooth adjustment to equilibrium?

The development of an endogenous structural theory demands a broad scope that crosses disciplinary boundaries. Developing an endogenous theory requires an eclectic method, both to model the interactions and to verify the results empirically.

THE NATIONAL MODEL

Since 1975 the System Dynamics National Model has been the vehicle for the development of an endogenous structural theory of the long wave. The National Model also generates other important modes of behavior including the four-to-seven year business cycle, an intermediate cycle of approximately fifteen to twenty-five years, and monetary inflation.

The mechanisms responsible for the business and intermediate cycles have been identified and are distinct (see Topic 2). The business cycle is primarily the result of inventory and employment interactions. The intermediate cycle is primarily the result of attempts to balance the mix of capital and labor as factors of production. The difference in period arises from the differences in the relatively short time required to adjust inventories and change employment compared to the longer time required to acquire and depreciate capital and alter the mix of factors.

The long wave arises through different mechanisms. There seem to be several important channels which contribute to the genesis of the long wave. The most important of these are discussed below.

Self Ordering

The National Model distinguishes producers of capital plant, equipment, basic materials such as steel from other firms in the private sector. The capital producers differ from oher sectors due to the existence of "self ordering". In order to expand capacity, producers of capital plant and equipment must order additional plant and equipment from each other. In the aggregate, the capital-producing sector acquires capital from itself, hence self ordering.

Self ordering creates a number of positive feedback loops: if the demand for plant and equipment expands, the capital sector must expand capacity. To do so, more orders for plant and equipment are placed, further swelling the demand for capital and reinforcing the pressure to expand. In addition to this accelerator mechanism, a variety of disequilibrium effects arise, creating a number of additional positive feedback loops which contribute to the strength of self ordering:

1. Rising orders deplete the inventories and swell the backlogs of capital-sector firms, leading to further pressure to expand and still more orders.
2. Rising backlogs cause average lead times to rise. To ensure an appropriate rate of capital acquisition, firms must order new equipment farther ahead, further swelling the order rate for capital.
3. Rising order rates and backlogs cause an expansion of employment, reducing unemployment and eventually tightening the labor market. Wages then rise, encouraging the substitution of capital for labor throughout the economy and augmenting capital demand still more.
4. Rising demand causes capital prices to rise, raising profitability and the ability to attract investment funds. Existing firms expand, and new firms enter the capital sector, further boosting demand.

5. Rising employment and output swell aggregate income, stimulating aggregate demand. Firms throughout the economy then grow, causing the demand for capital to rise even more.

Though all sectors of the economy are linked to one another to some degree, self ordering is strongest in the industries that produce capital plant and equipment, basic industries such as steel, and other heavy industry. Like the other sectors of the economy, these industries can produce the business and intermediate cycles, and in the absence of self ordering would exhibit periodicities of roughly four and twenty years. The net effect of the positive feedback loops created by self ordering, however, is to destabilize the mechanism that creates the intermediate cycle, stretching out the period and increasing the amplitude.

Self ordering causes the capital sector to overexpand in response to an increase in orders. For example, at the end of a long wave downturn the capital stock of the economy is old and inadequate. To provide for long-run replacement and growth *and* to rebuild the capital stock to appropriate levels, the capital sector must expand beyond the long run requirements. Once a capital expansion gets under way, the self ordering loops amplify and sustain it until production catches up to orders, excess capital is built up, and orders begin to fall.

At that point, the self ordering loops reverse: a reduction in orders further reduces investment, leading to a contraction in the capital sector's output, followed by declining employment, wages, aggregate demand, and output. Capital production must remain below the level required for replacement and long-run growth until the excess physical and financial capital is depreciated -- a process that may take a decade or more due to the long lifetimes of plant and equipment. Once the capital stock is worn out, investment rises, triggering the next upswing.

The positive loops created by self ordering operate through many channels, including capital demand, growth expectations, inventories and backlogs, prices, labor markets, financial markets real interest rates, and aggregate demand. The net effect is to significantly amplify the strength of the basic self ordering loop. Though all of these channels are portrayed in the National Model, simple models that include only the most basic self ordering feedbacks can generate a robust long wave. Self ordering is therefore a sufficient cause of long waves.

Debt/Price Dynamics

Self ordering, though it may be sufficient to generate the long wave, is not the only mechanism at work. Another major mechanism which we believe contributes to the long wave lies in the dynamics of debt and aggregate prices.

At the end of a long wave downturn, debt levels and aggregate prices are relatively low, the result of liquidation and price cutting in the face of unemployment and idle capacity. As the expansion phase gets underway, firms, particularly in the capital sectors, expand their debt levels in order to finance the expansion. Debt relative to GNP rises, and as the money supply expands, so too do aggregate prices. Expansion of debt is "justified" because vigorous growth, high rates of capacity utilization, and high profitability all encourage expansion of external financing. Simulations show, consistent with historical experience, that real interest rates are low or negative during the expansion phase, encouraging expansion.

Towards the later years of the expansion, investment in capital begins to soften as excess capacity develops. The upward momentum of prices and money growth may then trigger a continuing expansion of debt through speculation in land, stocks, collectibles, or other assets. Near the long wave peak, overcapacity develops and investment falls, depressing employment and aggregate demand. With declining income, debt service ability falls, and bankruptcies increase. The growing debt burden depresses aggregate demand and prices soften, further squeezing debt service ability and forcing additional liquidations. Simulations show that near the peak and during the downturn, real interest rates rise and remain at high levels, even as nominal rates fall.

During the long wave downturn, debt is liquidated and prices typically fall. In such a debt/deflation spiral, defaults and liquidations reduce the stock of money, squeezing nominal incomes and wealth, forcing further cutbacks in aggregate demand and further price cuts. These then further reduce the debt service ability of firms and households, leading to still more defaults and liquidation. In the extreme, the debt/deflation spiral can cause the collapse of the banking system and international trade, as occurred in the 1930s, and as it threatens to do so today. Whether the liquidation is orderly or whether it takes the form of bankruptcies and defaults, possibly leading to a panic, cannot be predicted in advance. The greater the degree of speculation during the expansion, the more likely is a panic during the downturn.

Analysis of the National Model shows the debt/price dynamics to be powerful contributors to the long wave dynamics. These positive feedback loops further amplify the self ordering loops, contributing to the persistent nature of the long wave. More work needs to be done to identify effective policies to avert a debt/deflation spiral. The interactions of the price changes induced by the long wave with the inflation caused by monetization of government deficits should also be examined.

Technology and Innovation

The National Model has demonstrated that the long wave can arise even when the level of technology is constant and the rate of innovation zero. Nevertheless, interactions between the long wave and innovation seem to be quite important. We believe that the long wave influences innovation and technology. Simple models have shown that the long wave can generate a fifty year cycle in basic innovation even when those innovations do not feed back to affect the economy and the long wave. The bunching of innovations can thus be explained as the result of entrainment of the innovation process by the long wave.

The long wave creates a shifting historical context for the implementation of new inventions. The long wave is characterized by the buildup, overexpansion, and relative decline of the capital-producing sectors of the economy. Midway into a capital expansion, opportunities become poor for applying new inventions that require new types of capital. The nation is already committed to a particular mix of technologies. The environment greatly favors improvement innovations over basic innovations. During a long-wave downturn, basic innovation opportunities gradually improve as old capital embodying the technologies of the preceding buildup depreciates. Near the trough of the wave, there are great opportunities for creating new capital embodying radical new technologies. The old capital base is obsolete, bureaucracies that thwarted basic innovation have weakened, many companies committed to producing old

types of capital are bankrupt, and traditional methods are no longer sacrosanct.

Thus the long wave theory emerging from the National Model suggests that basic innovation will be depressed during the long wave expansion and stimulated during the depression periods. Note that the peak in innovation under this hypothesis would occur about when the capital stock reaches its minimum. The low point for the capital stock may be as long as a decade after the peak in output, due to the long lifetime of capital and infrastructure. Improvement innovations, in contrast, will be favored during the upswing of the cycle, after the new basic technologies have been introduced.

Though innovation is not necessary to explain the long wave, there is little doubt that innovation has a strong influence on the technologies that characterize each long wave. Each long wave seems to be centered on a particular ensemble of basic technologies, including particular forms of energy, transport, communications, and materials. These ensembles evolve synergistically and, like species in an ecosystem, compete against other candidates for a limited number of available niches.

The impact of technology and innovation on the long wave itself, on its strength, period, and character, remains less certain. Much work needs to be done to examine how innovation might feed back and affect the other mechanisms that create the long wave. Can fluctuations in innovation amplify the long wave? Can policies directed at stimulating innovation shorten the depression period or reduce the amplitude of the long wave? These questions remain, so far, unanswered. The proper framework for addressing them is an endogenous theory of innovation and technological change coupled to the other mechanisms capable of generating the long wave.

Political and Social Values

Substantial evidence exists that political and social values in western nations fluctuate with the period and phasing of the economic long wave. During periods of long wave expansion, material wants are satisifed, and social concerns turn to civil liberties, income distribution, and equity. During the later phases of the expansion, foreign policy concerns predominate. As the expansion gives way to decline, conservatism grows, and social concerns return to material needs. Economic policy takes center stage in legislative agendas. During the downturn, the accumulation of wealth becomes the overiding concern, at the expense of civil rights legislation and equity. The most dramatic example of this cycle is, of course, the rise of fascism in the 1920s and 1930s. The recent conservative turn in many western nations is also consistent with the current long wave downturn.

We believe the variation of political values is the result of entrainment by the economic cycle. It is quite natural to emphasize material needs during depression periods. People find it easier to be charitable and to extend the rights and priveleges of society during good economic times when incomes are rising than in times of economic retrenchment and depression.

As in the case of technology, the effect of social value shifts on the severity and length of the long wave remains an uncharted region. The connection between political values and international conflict may be especially important here, especially in view of the theories that relate war to the long wave. Long wave research should broaden the boundary of analysis to include the effects of

the long wave on international relations, including trade, debt, foreign aid, and conflict.

SELF-SUSTAINING NATURE OF THE LONG WAVE

The business and intermediate cycles generated by the National Model are damped cycles. Small, random shocks trigger somewhat irregular cycles with average periods of about four years and twenty years, respectively. In the absence of such shocks, the cycles slowly die away. The tendency to oscillate is latent in the structure of the economy. The role of random shocks is to trigger the inherent, oscillatory tendencies, just as a rocking chair struck at random will oscillate at a characteristic period determined more by the nature of the rocking chair than by the nature of the shocks.

In contrast, the long wave tends to be a self-sustaining cycle, which, once set in motion, grows in amplitude up to a limit. The cycle then persists with a roughly constant amplitude. The tendency to oscillate arises from attempts to correct imbalances in the capital stock in the face of long delays in acquiring and eliminating capital. The tendency of the cycle to grow derives from the unstable positive feedback loops surrounding self ordering. Various nonlinearities, such as limitations on the labor supply or diminishing returns to capital, constrain the amplitude of the cycle.

Like the shorter cycles, however the long wave generated by the National Model is influenced by random shocks. The randomness causes individual long waves to differ. Randomness causes the period of the cycle, its amplitude, and particularly the severity of the downturn period to vary from cycle to cycle. Such variability is consistent with history. The Great Depression of the 1930s represents one extreme: a single, sharp downturn followed by a long depression. In contrast, there was no single cataclysmic collapse during the long wave downturn of the 1870s through 1890s. Between 1873 and 1897 there were three great depressions in the US, each of which was one quarter to one half as severe as the Great Depression of the 1930s. The variability of the long wave from cycle to cycle implies it is hard, if not impossible, to predict the exact course of the economy through the long wave transition. Nevertheless, like the rocking chair struck at random, the fundamental character of the long wave is determined by the endogenous structure of the economy and not by the random shocks.

SUMMARY

The long wave is a complex phenomenon. It presents a different aspect from each angle. Yet it is a systematic phenomenon with identifiable causes. The theories and hypotheses that have emerged in the past decade should not be viewed as competitors. Most likely all are correct in the sense that they all identify a piece of the long wave puzzle. The goal for theory building in the future should be the integration of the various theories into a "grand unification theory" of long-term economic dynamics. An open-minded, eclectic, yet methodologically rigorous approach is required. We believe that system simulation offers one such methodology.

TOPIC 2: IDENTIFYING LONG WAVES

To what extent can the long wave be clearly distinguished empirically from business and Kuznet's cycles? What are the specific problems and ambiguities in attempting to clearly identify historical long waves? To what extent can the causal mechanisms underlying different cycles be distinguished? Is it possible for a single, all-encompassing model to represent the diverse mechanisms underlying the different cycles?

THE INTERDEPENDENCE OF EMPIRICAL VERIFICATION AND THEORY

In studying the long wave, as in studying any phenomenon, it is impossible to divorce the interpretation of data from theory. Reliably distinguishing different cycles in available historical statistics is difficult if not impossible unless one has a well developed structural theory of the causes of the long wave. At the very least, one's basic theoretical ideas define what variables one examines and what patterns in those variables seem significant. Morgenstern's classic paper "Measurement Without Theory" argued persuasively that meaningful measurement can rarely be made in the absence of a theoretical framework. Moreover, to the extent that a well developed theory exists, empirical observation becomes more focused and potent. One of the primary reasons the long wave has had relatively little impact in the field of economics is the absence of a persuasive theory of its causes (e.g., Gordon 1981). The diverse empirical data that have been presented as evidence for the long wave will remain of minimal scientific value until such theories are developed and convincingly brought into context with the data. Likewise, policy prescriptions based on the long wave will not be taken seriously until persuasive theories are developed.

The idea that theory is always at least implicit in data analysis contrasts sharply with the view that statistical techniques should be used to "let the data do the talking". For example, spectral analysis and econometric tests are often proposed as methods to detect cycles or test hypotheses independent of prior assumptions or theories. Such a view of statistical techniques is not correct, either philosophically or practically.

The practical problems are obvious. There have been at most four cycles of the long wave. Many more would be required to generate statistically significant estimates of dominant periods, to establish leading and lagging indicators, and to estimate the means and variances of variables over the cycle. However, the failure to identify a significant cycle of fifty years obviously does not show such a cycle does not exist. Worse, there are only a handful of economic time series for which measurements have been made over the past two hundred years. Moreover, these data are not necessarily the most relevant for testing hypothesized causes of the long wave. For example, one major class of theories of the long wave involves capital over-expansion. The most useful data to test this theory would be long-term time series for production, capital stock, employment, price, return on investment, capacity utilization and similar variables for the capital producing sector of an economy. Such data are difficult to assemble even for the post World War II period, because national income accounts and other available data are not aggregated along the lines most useful for the theory. Data for the entire industrial era are even less

available.

The long-term time series that do exist are generally aggregate figures, such as the wholesale and consumer price indices, interest rates, and GNP. Such data provide only weak evidence for the long wave, as one would expect, given the diversity of behavior modes that influence historical change. Many researchers have turned to other empirical sources to corroborate specific long wave mechanisms. Thus, innovation theories of the long wave have benefited from numerous historical studies of basic innovation; studies of value change have drawn on content analysis of political tracts.

Yet even if adequate data were available, purely empirical analysis would not be sufficient to identify the long wave and distinguish it from other modes of behavior. One may fail to locate a strong fifty year cycle in a given time series even though such a cycle in fact exists in the real economy. For example, historical data for US consumer prices from 1800 suggest a strong fifty year cycle with peaks exacerbated by the wars of 1812, 1860-1865, and 1915-1918. Yet, the fifty year cycle has been swamped in the past twenty years by accelerating inflation caused by government deficit financing. Unless one has a prior theory to aid in disentangling such dynamics, statistical techniques such as spectral analysis can be misleading.

Similar problems attend the use of correlative techniques such as econometric estimation. There are many facets to the long wave: it affects a wide range of economic variables, innovation, technology, and even political values. There seem to be several distinct mechanisms that are sufficient to create the long wave or which can amplify the long wave. These mechanisms may have the ability to independently generate oscillations with periods of roughly fifty years. In the same way that individual firms in the economy oscillate in phase to create the business cycle, so the various mechanisms behind the long wave become entrained into a single cycle. Entrainment of various mechanisms implies that it is difficult to sort out cause and effect from empirical data. As Phelps-Brown (1972) puts it "running regressions between time series is only likely to deceive". Even where data are adequate, the correlative techniques fail to identify the causes of so-called "structural changes" which alter the correlations. Such "structural changes" may in fact be caused by the long wave. The development of stagflation in the 1970s is a prime example.

THE CHALLENGE OF IDENTIFYING LONG WAVES

The fact that meaningful empirical verification of long waves requires a theoretical context is both encouraging and discouraging. It means that the task of historical identification is much more demanding than statistical analysis alone. However, it also suggests the possibility for much greater payoffs through integrating theory development and historical analysis. But if a purely statistical approach to empirical verification of long waves is not possible, how can long waves be identified? What is the role of formal statistical techniques?

To verify the existence of the long wave it is necessary (1) to develop a model or theory which generates the long wave and distinguishes it from other modes of behavior such as the business and Kuznets cycles, and (2) to develop confidence that the model accurately reflects reality, both in its structure and behavior.

A proper model of the long wave will have several key characteristics. It will provide an endogenous explanation for the long wave and other relevant modes of economic behavior. There should be few if any exogenous variables and certainly no exogenous variables with cyclic characteristics. The model should be a structural theory of the economy with a realistic portrayal of decision-making. The theory should explain how the decisions of individuals, firms, and governments interact to produce the long wave and other dynamics. It should generate the macrobehavior of the system from assumptions about the microstructure, and not from correlations of economic aggregates.

Since 1975 the development of an endogenous structural theory of economic dynamics has been a major goal of the System Dynamics National Model project. The National Model has been used to investigate a number of economic dynamics including the business cycle, inflation, the energy transition, and the long wave.

Early work showed the economy capable of generating several oscillatory modes. The characteristic period of the oscillations depends on the length of the delays and adjustments involved in each mode. The four-to-seven year business cycle was found to be caused by interactions between inventory management and employment policies. The average period of about four years is the result of the fairly short time required to acquire labor, to build up inventories, and to form expectations of future demand. The Model also generated a fifteen-to-twenty-five year cycle similar to the construction or Kuznets cycle. The intermediate cycle arises from the attempts of firms to balance the mix of capital and labor in production; the roughly twenty year period is due to the delays in acquiring and disposing of capital plant and equipment. The long lead time and lifetime of capital compared to the delays in acquiring and discharging labor account for the long period of the cycle relative to the business cycle. The long wave arises through different mechanisms. There seem to be several important channels which contribute to the genesis of the long wave. These are discussed under Topic 1 and include capital self-ordering and debt/price dynamics.

The identification of these cyclic modes in a model is a relatively straightforward task. The mechanisms responsible for each cycle can be isolated and their contribution to each particular mode identified through controlled experiments on a model. A variety of analytical techniques to establish the contribution of a variable or causal link to any given mode are available to complement the experimental approach.

Once the modes generated by a model are identified and the mechanisms responsible for each understood, how can the existence of these modes in the real economy be verified? It is here that formal statistical techniques can be most useful. A structural model should generate the same type of data as the real system. The output of a model should have the same statistical character, generate the same spectra, correlations, and "structural changes" as the real system. Thus the proper role for statistical techniques in the identification of long waves is to test whether theories of the long wave can endogenously produce data with the same characteristics as the real system.

Synthetic data experiments are most useful here. For example, the National Model generates three distinct cyclical modes: the business cycle, the intermediate cycle, and the long wave. To test a model against the empirical data, one should examine the spectra of the model-generated data to see how well they correspond to the actual spectra. If a model generates data with the same statistical properties as the actual system, and if the mechanisms responsible for model behavior are understood and accepted, then the model

provides strong evidence for the existence of the modes in the real system.

Similarly, one should not attempt to identify the long wave or other cyclical modes by examining correlations between the independent and dependent variables of model equations. Rather, one should see if model-generated data reveal the same correlations (or lack of correlations!) as the actual data. Likewise, model-generated data should show how, over the course of the long wave, historical correlations shift. The shifting relationship between inflation and unemployment as expressed in the Phillips Curve provides a good example. The National Model does not contain an equation that directly relates inflation to unemployment. Yet the Model generates the same type of correlation between inflation and unemployment seen in the actual data. Further, the Model shows how that correlation shifts as the economy moves through the expansion phase of the long wave and into the downturn.

Naturally, one would not expect a model to reproduce the exact path of economic variables over time. Peculiarities of historical circumstance, local variations, and other sources of noise will cause a model to differ from history on a point-by-point basis, in the same way and for the same reasons that each long wave is different. The important comparison is between the statistical properties of the actual and model-generated data.

A second major type of empirical corroboration involves explaining a complex set of conditions that arise simultaneously as the economy enters a particular stage of the long wave. Such a set of conditions might be called a syndrome, analogous to the use of the term in medicine. For example, the National Model generates a set of conditions at the peak of the long wave that have emerged in advanced economies in the past 10 to 20 years, including:

Increasing capital intensity

Declining capacity utilization

Rising unemployment

Increasing severity of business cycles

Deepening depression of capital and related basic industries

Slowing inflation

High real interest rates

Declining return on investment.

These conditions are often viewed as unrelated or the result of exogenous influences such as OPEC, foreign competition, and so on. The National Model shows them to be a related set of symptoms arising from the mechanisms that create the long wave. The fact that a single dynamic theory internally generates such a large number of the conditions observed in reality is a powerful corroboration of the long wave theory. The interrelationships amongs a complex set of variables can be understood in terms of a single unifying theory. Historical analysis into conditions during similar phases of past long waves should be performed to further develop confidence in a model's ability to generate realistic economic behavior. Such analysis, relying as it must on the tenor of the times as expressed in legislative agendas, the business and popular press, and social action, will be primarily qualitative. The development of such qualitative corroboration would provide a powerful complement to the formal analysis of model behavior.

SUMMARY

A broad spectrum of data has been developed which suggests the existence of the long wave. Yet the scarcity of standard economic variables over a suitable range limits the possibilities for identifying long waves through empirical means alone. Acceptance of the long wave can only proceed as a causal theory of the long wave is developed. Theory and empirical work must now walk hand in hand. The goal of long wave theory should be the development of an endogenous structural explanation for the long wave. The mechanisms responsible for the long wave must be articulated and distinguished from those responsible for other modes of behavior. The goal of empirical work should be the comparison of the actual data with the data generated by the theories. Only when a theory of the long wave can generate data with the same statistical character as the real data will the long wave gain credence as a phenomenon worthy of scientific study or as a basis for economic policy.

TOPIC 3: THEORY TESTING AND INTEGRATION

What is the range of appropriate tests for alternative theories of the long wave? Are conventional econometric mthods appropriate? What can computer simulation contribute to testing theories of the long wave? Is it possible to develop valid tests given the paucity of time series data? How close are we to an integrated theory of the long wave? What specific methodologies exist to meaningfully integrate theories and test their relative explanatory power?

THE NEED FOR AN INTEGRATED THEORY

Research over the past decade has shown that there are many facets to the long wave. A growing body of theory and evidence suggests that the long wave affects a wide range of economic variables innovation, technology, and even political values. The long wave is clearly not a monocausal phenomenon.

Yet up till the present, the majority of long wave theories have stressed a single cause or a small set of causes. Each theory tends to focus on one part of the social, technical, and economic system without justifying why a particular mechanism is more important than others. The goal of theory building must now be the integration of the various theories that have emerged in the past decade. The mechanisms proposed in each theory must be evaluated in a common framework, their interactions analyzed, and their relative contributions to the long wave syndrome established.

An integrated theory of the long wave will have several key characteristics. It should be a formal model so that all assumptions are made explicit and so the conclusions can be reproduced, tested, and extended by others. It should be an endogenous explanation of the long wave, generating the long wave through the interactions of individuals, firms, and governments. It should be a structural, causal theory, not a correlative one. It should realistically portray the decision-making capabilities and decision rules of individuals and organizations. It should be a dynamic theory, and must not presume the economy is in a state of equilibrium. Finally, it should generate other important modes of economic behavior and distinguish them from the long wave.

A STRATEGY FOR THEORY INTEGRATION

The major theories of the economic long are not mutually exclusive. Consider, for example, the capital overexplansion theory developed at MIT and Mensch's depression-trigger theory of basic innovations. The MIT theory asserts that the long wave decline arises from overbuilding of capital. Under this theory, a sustained upturn can only come when the imbalances created by excess physical capital and debt are corrected. Mensch's theory asserts that depressions bring forth new basic innovations which make possible a new expansion. Both theories may be correct insofar as they identify mechanisms that operate in real life. Both can be integrated into a broader theory, which could serve as a basis for assessing their relative capabilities to explain past long waves and identifying policies to influence future behavior (see below).

The system dynamics methodology originally developed at MIT can play a vital role in integrating diverse theories, testing their explanatory power, and developing more effective policies. System dynamics provides a general framework for translating verbal theories into formal dynamic models, a set of guidelines for formulating models that realistically represent the physical structure and decision-making rules of systems, and a set of computer-simulation procedures for testing the internal consistency and realism of those models. System dynamics is especially suited for testing well developed qualitative theories. The method is not limited by available quantitative data. The ability to portray "soft" variables is especially important in studying the long wave because of the diverse manifestations of the phenomenon and the paucity of long-term economic, technical, and social data. Although the methodology is still evolving, particularly in the areas of behavior analysis and validation of complex nonlinear systems, it appears to be the most advanced tool for the task of testing alternative long wave theories.

There are two primary ways in which system dynamics can aid the development of an integrated theory of the long wave.

The National Model

The National Model project at MIT has been the vehicle for the development of an endogenous structural theory of the long wave. The Model provides a rich, detailed description of the microstructure of the economy. It generates a wide range of economic dynamics including the long wave, the business cycle, an approximately twenty year intermediate (Kuznets) cycle, and inflation. It has been used to examine energy-economy interactions over the long term.

The National Model comes closest, at present, to an integrated theory of the long wave. The long wave in the Model arises through a variety of distinct mechanisms (see Topic 1). The Model shows how these mechanisms interact and amplify one another. The Model has been used to identify a wide range of distinct feedback channels which contribute to the long wave. For example, one of the important causes of the long wave is capital self ordering. Self ordering stems from the fact that the capital plant and equipment sector of the economy, in the aggregate, orders and acquires capital from itself. Thus an increase in orders for capital is amplified by the needs of the capital sector itself, leading eventually to capital overexpansion. But the Model has shown how self ordering creates a variety of additional positive feedback loops which further amplify the basic self ordering mechanism. These include the response of firms to rising lead times the buildup of growth expectations, and the behavior of labor markets prices, credit markets, and aggregate demand.

Thus the National Model has already resulted in an integrated theory of the long wave in the sense that the Model identifies numerous specific feedback structures which contribute to the cycle. Through controlled simulation experiments and analysis of the Model, the contribution of each mechanism to the overall behavior can be evaluated.

However, though the National Model is quite large, it does not yet contain all the causal mechanisms that have been advanced as theories of the long wave. In particular, there is as yet no structural representaton of the innovation process or technological growth. Elaboration of the Model to examine these hypotheses is planned. Nevertheless, the Model at its present stage of development allows testing of a wide range of theories of the long wave and provides a powerful basis for identifying alternative patterns of behavior in real economies.

The Role of Small Models

The advantages of the National Model are its wide boundary and the rich detail in which economic behavior is represented. However, the complexity of the Model makes it difficult to explain and explore the individual mechanisms that contribute to the long wave. There is a need for a portfolio of simple models to aid in identifying and understanding particular mechanisms behind the long wave. Such models will be especially important in the communication of the long wave theory to the broader community of economists

Several such models have already been developed. Sterman (1983) develops a simple model which shows how capital self ordering can cause the long wave. The model shows how the long wave arises from the interactions of the investment decisions of firms in the capital producing sector. More importantly, it shows, through a variety of simulation tests, that the decision rules of individual firms are rational and appropriate. The demonstration that the long wave can arise even when individual actors are behaving rationally is crucial if the long wave is to be accepted as the consequence of commonplace, everyday decisions and not as an artifact or aberration.

Simple models can also help establish the relative importance of various theories of the long wave. For example, the Sterman model shows self ordering is a sufficient cause of the long wave. In particlar, the model shows the long wave can arise with technology held completely constant. Yet many theories focus on innovation and technology as key causes of the long wave, and data on

basic innovations show a clear long wave pattern. Work in progress has shown that it is possible to integrate the self ordering theory with Mensch's depression trigger theory. A simple structure to portray the process of invention and innovation, as described by Mensch, was incorporated into the model. The results show that the long wave generated by self ordering can cause long cycles in the rate of basic innovation even when the invention rate is constant. Thus a straightforward experiment demonstrates that the ecnomic cycle can entrain the process of innovation, confirming the earlier hypothesis of Forrester (1977) and Graham and Senge (1980). The next step is to test whether the long wave in innovation can feedback and amplify the long wave.

BUILDING CONFIDENCE IN AN INTEGERATED THEORY

The development of an integrated theory that meets the requirements described above is not easy. The process of building confidence in such a theory and in the mechanisms responsible for its behavior is complex, time consuming, and inherently subjective, as is building confidence in any scientific theory (Forrester and Senge, 1981; Bell and Senge, 1981). As the long wave is a many-faceted phenomenon, so the testing procedure must be open minded and eclectic.

There are several classes of tests to which a model of the long wave must be subjected. These tests are much broader than the usual statistical tests of goodness of fit. One class of tests concerns the adequacy of model structure. As a theory of human behavior, the microstructure of a model should be compared to available information on decision-making. Such information will be primarily qualitative, but a model which fails to account for the information processing capabilities and decision rules of individuals is not a good theory. Such tests can draw on direct observation as well as a large and growing literature on cognitive capabilities and heuristics, organizational structure, and behavioral economies.

Another class of tests concerns the robustness of the behavior. A model of the long wave should be subjected to a series of "extreme conditions tests". A good theory will be robust in the sense that the behavior of every decision rule and of the model as a whole must make sense even in extreme, ahistorical conditions. The determination of robustness is primarily a matter of experimentation and logical analysis. A model that fails extreme conditions tests cannot be trusted for policy analysis or projections of future conditions that may carry the system into a new operating regime.

Still another class of tests addresses the adequacy of the behavior of a model. It is here that the statistical techniques can be most useful. Testing the adequacy of behavior is more than comparing the behavior of a model against history on a point-by-point basis. There is little reason to expect a close match between model and data on a point-by-point basis. Social systems are subject to a great deal of noise which has a strong influence on the exact path of the system through time. The business cycle, for example, is a damped mode which requires the continuous bombardment of small random shocks to stay alive. The exact path of such a mode is inherently unpredictable, though its average period, amplitude, phase relationships, and so on are rather stable. A good model should generate data with the same statistical character as the real data. The role of statistical tests is to examine the ability of a model to generate, for example, the same spectra, correlations, and phase relationships as the real data (see Topic 2).

SUMMARY

The difficulties in the development and testing of an integrated theory of the long wave are great. Yet the likely results justify the investment. These results include consensus concerning the existence of the long wave, the primary mechanisms responsible for the long wave, and the response of the economy to various policies. The tools exist and need only be applied in a spirit of cooperation.

TOPIC 4: POSSIBILITIES FOR INFLUENCING LONG-WAVE BEHAVIOR

To what extent can the long wave be influenced by economic policy? What fundamental parameters and structures seem most important for determining the period of the long wave? How do the policy options that can potentially influence long-wave behavior vary from the expansion phase to the downturn phase? If advanced economies are in the downturn phase of the long wave, what meaningful policy options currently exist and how can they be brought to the attention of policy makers? In what ways are the appropriate policies for a long-wave decline different from the policies currently being implemented in the Western industrial economies? What policies are the most dangerous ones, which should therefore be avoided during a long-wave downturn?

A discussion of influencing long-wave behavior in the next few years should start by identifying present economic circumstances and the current state of analytical mthods. Where are we in the economic long wave? What is the present condition of national economies? What are the dynamic considerations when one tries to intervene in an oscillatory mode of a system? Is knowledge of the long wave syndrome now sufficient to prescribe action? What are the hazards in taking action on the basis of partial or incorrect interpretations of the long wave? How can effective policies be identified? What are promising directions to explore in coping with pressures from the economic long wave?

PRESENT POSITION IN THE LONG WAVE

We believe that the long wave is an economic process that is endogenously generated within industrial economies. The long wave is a complicated syndrome of interrelated forces and symptoms that cause a massive fluctuation of physical capital accompanied by changes in debt, prices, unemployment, and interest rates. The last expansion phase spanned the three decades from 1945 to the mid 1970s. The peak has been reached and passed in the last decade. We are now entering the downturn phase. Major stresses of the downturn are now becoming visible, but the stresses have not yet become great enough to correct the economic imbalances. The next ten to fifteen years will be one of the recurring "Great Depressions" that occur at intervals of forty to sixty

years. In the depressions, old capital plant is worn out and depreciated, distortions in relative prices are realigned, debt is paid off or defaulted, and a new pattern of living and a new technological infrastructure emerges. Our challenge is to adopt policies that will make the transition smoother.

ECONOMIC CONDITIONS AT THE BEGINNING OF A DOWNTURN

At the beginning of a major long-wave downturn, industrial economies are in the strongest condition they have ever been, and at the same time they are so highly stressed and imbalanced that in the past the strengths have not been harnessed effectively. The problems lies not in the real, physical aspects of an economy, but instead in the financial, attitudinal, and institutional aspects.

At present, as we pass the peak following a long-wave expansion, all productive capabilities are at the highest level they have ever been. More than ample capital plant exists; in fact, most industries have excess capacity. Labor is more available than at any time in the last three decades. Productivity is the highest it has ever been, even though it may no longer be rising as rapidly as before. More housing is in place than ever before. The stock of consumer durables is at its all-time peak. The industrial economies are in the best physical condition that they have ever achieved. Based on the state of the real economies, as distinguished from the nominal and financial economies, the time following a peak in the long wave should be our closest approximation to a golden age. This is the time toward wich civilizations have been striving. We lose sight of the fact that the process of building capital plant and building consumer durables and housing should not itself be our goal; instead, the goal should be a high standard of living made possible by having the capital plant and goods and housing in existence. They are now in existence. So, what keeps us from taking advantage of the near utopia that has been achieved?

During the expansion phase, economic systems have developed severe imbalances. The situation is like the physical stresses that build up at a geological fault before an earthquake. The depression periods are like the earthquakes that release the stresses and bring the system back into internal balance. But can we not understand the nature of the economic stresses well enough to find ways to reestablish balance without an economic cataclysm?

At the end of a capital-investment boom, capital plant in the economy has been overbuilt. The excesses can reach thirty percent or more of the total capital plant. Eventually, the excess is perceived, and new construction declines drastically. Severa imbalances arise from the over-expansion of capital plant.

First, the capital-producing sectors have temporarily completed their mission of building up the economy and their full capacity is no longer needed; the result is unemployment radiating from the capital-producing sectors.

Second, the existing plant itself represents an oversupply of production capacity for consumer goods and services with a resulting downward pressure on prices and revenues. The expansion of capital plant had been accompanied by accumulation of debts to pay for the plant; and falling revenues erode the ability to meet interest and debt repayment.

Third, real interest rates rise because prices fal relative to nominal interest rates; and debts become more burdensome. Prior to the peak in the long wave, real interest rates tend to be low or negative, especially when measured by comparing nominal interest rates with the inflation rate of physical

assets such as land. The result is such an imbalance in relative prices that, in the United States, farm land prices have risen some three times more than wages and consumer prices. The same tends to be true for the price of housing. Physical asset prices have been driven up because physical assets were seen as a hedge against inflation. Now, the deflationary pressures emerging, such high asset prices become unsustainable, and foreclosures begin on mortages that were contracted at the peak prices.

Fourth, the period of economic expansion was a time of apparent excess demand. Prices could be raised to cover costs, so that managerial discipline relaxed and institutions became inefficient and developed excessive overhead. Now in times of economic stress, the excess white-collar employment is being corrected at the very time that alternative jobs are no longer being offered.

DYNAMIC CONSIDERATIONS

We see the economic long wave as endogenously generated, and furthermore as an unstable mode of behavior. By unstable, we mean that the long wqve fluctuation tends to increase in amplitude until it is limited by nonlinearities in the system. An unstable, growing mode is especially persistent and difficult to deal with. One characteristic of persistent mode is the long transient response that will follow a policy change before the system settles to its new pattern of behavior. The transient can easily last for most of a full cycle, and, for the long wave, this can mean several decades. Another way of describing the slow response is in terms of the system states that must be brought to a new relationship to one another. Those system states have reached their current values as a result of a decades-long process of gradual accumulation. Realigning those system states is inherently slow. The relevant system states for this discussion include the capital plant in the production sectors, the labor in the capital-producing sectors, and the debts that have been built up in the expansion process. These are out of balance with the other parts of the economic system, yet can be changed only slowly or by catastrophic, uncontrollable means.

We should not expect a quick and painless recovery from the long wave pressures. On the other hand, there is every reason to believe that policy choices exist that can influence the degree of difficulty that will be encountered.

IS KNOWLEDGE SUFFICIENT TO CHOOSE CORRECTIVE POLICIES?

As this is being written in May 1983, it seems that not enough is now known about the economic long wave to justify unequivocal recommendations of corrective action. There are diverse and unresolved hypotheses as to the cause of the long wave. Until a comprehensive theory of how the long wave is generated has been reasonably widely accepted, policy recommendations run the risk of making matters worse rather than better.

But the situation is changing rapidly. The System Dynamics National Model endogenously generates an economic long wave that combines and unifies many of the long wave theories that have been proposed. Furthermore, the behavior of the National Model agrees with and explains a wide range of symptoms and behavior that are now being experienced in the world's

economies. The National Model has only recently reached this point of development. Interpretations of behavior are taking shape rapidly but are not yet complete. In a few months there should be a much better understanding of the forces involved in the long wave. Even more important, persuasive explanations should emerge for identifying which policy changes would have low leverage and be of little value, which would be counterproductive, and which could have a favorable influence.

HAZARDS IN CHOOSING POLICIES

The history of choosing economic policies by intuition, debate, and political compromise is not encouraging. Failures in economic policy-making arise not from bad luck, but instead from the very complexity of economic systems and from the inability of the human mind to solve the behavior of high-order nonlinear dynamic systems. Several kinds of hazards lie in the path of choosing economic policies.

First, a very high percentage of the policies in any system, perhaps as high as 98 percent, have very low leverage for affecting behavior. Worse, symptoms of difficulty usually point to those policies with low leverage. An overwhelming fraction of political and managerial effort goes into debating policies that matter very little. From such concentration on unimportant policies arises much of the public frustration with governmental ineffectiveness. Examples are evident as we look at various countries in the present economic climate. Many different policies are debated and tried, and governments and managers rise and fall, yet unemployment, inflation, declining industries, and foreign exchange imbalances continue. Among ineffective alternatives, the choice matters very little.

Second, a policy change often leads to a reversal of desirability between the short run and the long run. A policy that is good for the short run is likely to produce undesirable consequences in the long run, and vice versa. Many people do not reocognize the likelihood of such a reversal. Furthermore, the short run can usually be perceived more clearly than the long run and seems more persuasive, so the tendency is to choose immediate advantage, with the result that unfavorable forces accumulate and eventually become dominant. In many ways, our present economic dilemma is the legacy from several decades of maximizing the near term at the expense of the more distant future. That future has now arrived.

Third, not only are there few high leverage policies, but the nature of those policies is usually not correctly perceived. Often, the high-leverage policies go unrecognized, are not even debated, and are not used in the search for better economic conditions. Even worse, when high-leverage policies are used, they are often pushed in the wrong direction. An example is found in the attempts of governments, even now, to encourage more capital investment at a time when the primary cause of economic difficulty is excess physical plant.

Fourth, there is a tendency to overreaction. Symptoms of trouble build up without restraint until they become politically overpowering. Then, at about the time that those trends would have ended anyway, great counterpressure is brought to bear with the result that the reversal is accentuated and the opposite extreme is intensified. We may be seeing such an overreaction with respect to inflation. The long-wave process creates inflation at the end of the expansion phase, with a self-correcting, internally-generated reversal into

deflation as the depression phase unfolds. But the anguish of inflation at the end of this last expansion generated strong political pressures in some countries to counteract inflation at the very time that the normal internal processes of the economy were beginning to move into deflation. As a result, the disruptive effects of deflation in prices and wages at a time when people are trying to repay large debts may have been made more serious.

ARRIVING AT CORRECTIVE POLICIES

We propose to use the National Model to arrive at those high-leverage policies that can be brought to bear on the current downturn in the economic long wave. The Model now represents a good basic theory of how the long wave is generated. Some additional work is needed to consolidate the insights that have been accumulating, to bring into perspective within the Model the various partial theories of the long wave that have been proposed by the many people working in the field, and to identify the principal causal mechanisms in contrast to more minor accentuating mechanisms.

From a consolidated understanding of the long-wave mechanisms will come the ability to identify the influence of various policies, and the direction in which each should be moved. Work to date suggests some of the direction in which to look, but without yet the clarity or persuasiveness that would justify specific recommendations.

POSSIBLE DIRECTIONS

It should be possible to deal with a downturn in the economic long wave at two different levels -- to alleviate the impact of the dislocations, and to reduce the severity of downturn.

With respect to alleviating dislocations, there first needs to be a public and political recognition of the economic processes that are at work. If the long-wave syndrome of interlocked symptoms is understood, actions suggest themselves that are quite different from those that might result from different interpretations. For example, if economic difficulties are interpreted as indicating only a severe but ordinary short-term business-cycle recession, then an inappropriate short-term focus might be adopted. The short-term response would lead to assisting the unemployed in waiting for their jobs to reopen; but if jobs in the capital-producing sectors are not going to return for one or two decades, such action traps a generation of people as wards of the government rather than helping them move into other opportunities for contributing to the well-being of society. On the other hand, if current economic difficulties are interpreted as permanent, and there are indications that such an interpretation is beginning in some quarters, then dispair may lead to social breakdown and political pressures severe enough to increase the risk of another major war.

At the least, a clear public understanding of the long wave should help in dispassionately interpreting current events. It would be understood that difficult circumstances should not be blamed on any single segment of society. The problems were not caused by labor, or management, or government, or by a particular political party, or by the banks, or by foreign governments. Instead, difficult circumstances would be seen as a consequence of the actions

that everyone supported at the time they were taken. When the overexpansion was under way, everyone wanted more credit, more economic growth, more office buildings, more factories, more government expenditure, lower interest rates, and more education leading to more white-collar jobs. Furthermore, if the long-wave downturn is correctly perceived, there will be an understanding that the period of turmoil and readjustment has always been and will be of limited duration, and that the most constructive course of action is to alleviate immediate personal hardship while working for the brighter tomorrow that is sure to come.

Beyond making the best of a difficulty situation, there is good reason to believe that wise policy choices can alter the course of events, probably not to a smiooth and stress-free utopia but certainly to a less traumatic transition than if counterproductive policies are inadvertantly adopted. And the danger is great that counterproductive policies will be forced by political pressures if the true nature of the dynamics of the long wave are not correctly perceived.

Desirable policies must start from a recognition of present imbalances, and the probability that past trends may suddenly reverse to opposite and equally undesirable extremes. Unemployment in many present capital-producing sectors is probably permanent. Little new capital plant wil be needed in the next fifteen years, and, when it is time to rebuild, the technological mix will have changed so that the nature of capital plant will be different, industries will have moved to different locations,and the skills required will be different. As another example, the basis for paying back debt is being undermined, and better ways than inflation or default should be sought for bringing debt back into balance with prices, revenues, and production.

Reversal of past inflationary trends is entirely possible. Some countries are now pleased that inflation is declining, but severe deflation is becoming a growing threat. Our work suggests that one can have a physical depression, that is, high unemployment and unusued factory capacity, with either deflation or runaway inflation. Under present ecnomic circumstances the middle ground of constant prices tends to be an unstable equilibrium -- a ridge from which there is a strong tendency to slide in one direction or the other. A promising direction of search is for a combination of fiscal, monetary, and banking policies that can sustain public purchasing power and prices without allowing further debt accumulation or inflationary money creation for speculative investments.

Promising opportunities for policies to alleviate the severity of the long-wave downturn are beginning to emerge. Further consolidation of the theory of how the long wave functions should reveal still more possibilities. The immediate future promises rapid development of better insights in time to improve economic prospects for the next decade.

TOPIC 5: NATIONAL AND REGIONAL ASPECTS OF THE LONG WAVE

"To what extent are different nations, different regions, or the Third World affected by long wave? To what extent do they have different policy alternatives available to them? Insofar as the transition to new industries may occur during a long-wave downturn, what forms of government intervention are appropriate to diminish the negative consequences for regions heavily reliant on declining industries?

IMPACT OF THE LONG WAVE

We believe the long wave is endogenously generated within industrial economies. Every industrialized nation has the potential to generate the long wave. A variety of distinct causal mechanisms contribute to the genesis of the wave. Prominent among these mechanisms is capital self ordering, which results in the buildup of excess physical capacity during the expansion phase of the long wave. Another is the interaction of prices and debt, which causes prices to fluctuate over the long wave. Simulations of the National Model show that the existence of the long wave is not affected by variations in most of the technical, demograhic, or institutional characteristics of the economy.

While each nation has its own individual characteristics, in terms of the basic causes of the long wave, the developed nations are more smilar to each other than they are different. Capital goods have approximately the same lifetime and relation to workforce. Nations share much the same science and technology. People have about the same lifetime and career length, and so on. Even if the industrailized natons were totally isolated from one another, one would expect their long waves to be similar in period and amplitude. Individual characteristics and historical circumstance, varying frm nation to nation, would, however cause the timing and exact course of events to differ. One nation might be at the peak while another was at the trough, and still another part way into the expansion.

But nations are not isolated from one another. Foreign trade and financial flows, migration, military and political affairs, and even flows of news and information couple nations together. Individual long waves become entrained into a single long wave, each nation experiencing a variation on a global theme. If one's trading partners are suffering from overcapacity and slack demand, exports will suffer and capacity utilization and employment at home will drop. Foreign trade in effect ensures that excess capacity occurs in all economies at about the same time. For example, Japan and Europe have been hard-hit by US economic troubles because of the lower-than-expected US demand for automobiles, steel, and other imports. Thus the US has exported some of its overcapacity.

Most theories of the long wave suggest that a Third World country without a substantial capital infrastructure would not internally generate a long wave. But strong linkages of the Third World to the industrialized nations, through debt, trade, aid, and so on, ensure that these nations will also be entrained in the long wave. Few countries will be immune from the economic difficulties of the next ten years.

Not all nations or industries will be equally hard hit. Nations that rely heavily on production of capital goods will be the most seriously affected. And nations whose major industries will be diminished by technological change will also experience more problems than most. The steel industry will never regain its former role in the economy because goods such as cars and bridges now have a lower steel content. Likewise, farmbelt unemployment in the 1930s, already depressed by low prices, was exacerbated by mechanization. The reverse is also true: industries whose product demand is increased by technology will do better than most. In physical terms, American Telephone and Telegraph grew steadily all through the 1930s. Today, some computer companies may do the same.

GUIDELINES FOR POLICY DESIGN

Most policies designed to mitigate economic hardship evolved as weapons to fight the short-term business cycle. With an average period of three to seven years, the business cycle receives the most attention because it is the most visible of the basic dynamics generated by modern economies. But the long wave is a behavior mode entirely different than the business cycle. The time horizons and magnitudes involved are much greater. Most importantly, the causes of the long wave are distinct frmm the causes of the business cycle. Effective policies to cope with the long wave should be expected to be quite different from policies that have evolved to deal with the businss cycle.

In a businss cycle downturn, workers who are layed off can expect to return to the same job and factory in a few months. Unemployment insurance is a useful buffer to tide these workers over until business picks up again. But in a long wave downturn, many jobs, especially those in the capital producing sector, will never return. Unemployment insurance is then insufficient. Retraining and relocation programs may help, but when jobs are scarce throughout the economy, they may simply shuffle people around without substantially increasing employment.

Likewise, stimulating an economy that is underperforming by boosting exports may mitigate the effects of a business cycle recession. But in a long wave downturn, the attempt of every nation to boost exports and restrict imports can lead to protectionism and a trade war which could substantially amplify and prolong the downturn in a perverse "tragedy of the commons". Financing the imports of third-world nations during a business cycle recession is a legitimate financial tool, borrowing against revenues that will return when business picks up again. But as a tool to mitigate a long wave downturn, foreign loans easily become de facto subsidies. Such loans can easily be used to offset a weak economy and finance current consumption, thus maintaining imports, instead of fostering investment in sustainable sources of income and employment.

The developed nations cannot depend on foreign trade as a policy tool to blunt the impact of the long wave. The third world should not follow policies that hinge on the economic health and good will of their trading partners – both will be in increasingly short supply. We believe it is possible to design policies that can not only work well for one nation, but can work well for all nations. Indeed, in the end, these are the only policies that can work.

For example, we believe that the long wave peak and downturn are times of excess physical production capacity. Effective policies will create and sustain pressures to gradually reduce the excess capacity and stimulate the economy will be counterproductive. For example, in a time of excess physical capacity, an across the board investment tax credit will either by ineffective or worsen the overcapacity.

Simulations of the National Model suggest the following components of a strategy to mitigate the effects of the long wave downturn. The results are preliminary and more work is needed.

Appreciation of Time Delays

An important component of effective policy for the long wave downturn is a proper appreciation of the delays involved. The long wave downturn is a time of excess capacity. Economic health cannot return until that excess is eliminated. A decade or more may be required to eliminate the global excess due to the long life of capital. Governments and central banks must be prepared for an extended period of financial stress. Lenders must be prepared for much higher fractions of nonperforming assets for much longer periods. For example, though world output in the previous long wave downturn peaked in 1929, defaults on international loans did not peak until 1935. In 1929, the consensus was that there would not be a major international lending crisis. Public and government awareness of the time required to correct the problem can help prevent panic, maintain morale, and foster programs aimed at causes rather than symptoms.

Maintaining the Financial Systems

The financial systems of many countries are overextended and increasingly disaster-prone. Long wave downturns have often triggered financial panics in the past. Vigorous action now by each country to stablize its financial system should be beneficial over the next few years.

Preventing Deflation

During the 1930s, US legislators attempted to prevent deflation by enacting price controls. Such controls were generally ineffective. Some economic historians believe that the deflation could have been retarded by vigorous action by the central bank. Others believe that fiscal policy represents greater leverage. Model simulations suggest that monetary and fiscal policy may play an important role in controlling the inflation-deflation process and the amplitude of long waves.

Discouraging Saving

With an excess of physical capital, long wave peaks and downturns have been marked by little new physical investment and frequent bouts of speculative investment. During a long wave downturn, there is little need for saving in the aggregate. In fact, simulations suggest that attempts to save during the long wave downturn are an important factor in the collapse of aggregate demand. This leads one to question the recent changes in US tax and pension laws designed to encourage saving.

Avoiding Subsidies

Rather than attempt to subsidize industries with excess capacity, government policy should attempt to sustain the pressures that will shift resources from the redundant industries to the production of needed goods and services. Subsidies to boost demand in the old product lines of failing industries should be avoided, as they merely prolong the misallocation of resources. If political pressure mandates action, then subsidies for conversion to new products, retraining, or public works such as energy conservation are preferable to price supports and other costly and counterproductive attempts to return to the 1960s.

SUMMARY

The discussion above suggests two conclusions: First, the long wave is a separate mode of behavior from the business cycle. Extreme caution is required in applying policies adopted during gentler times to the long wave downturn. Second, the policy implications that emerge from consideration of the long wave are sometimes quite different from the conventional wisdom. If advocacy of such policies is to be effective, a formal model may be necessary. Through a formal model the complex interactions among capital, employment, prices, and debt can be integrated with sufficient clarity, consistency, and persuasiveness to provide a basis for consensus.

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COMMENTS ON TOPICS 1, 4 AND 5*

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TOPIC 1: THEORIES OF THE LONG WAVE

> "Economists set themselves too easy a task if in tempestuous seasons they can only tell us that when the storm is long past the ocean is flat again." (J.M. Keynes, "Tract on Monetary Reform", 1923.)

Long wave theories originally developed from a combination of casual, empirical observation and attempts at statistical analysis. Many authors before the First World War had pointed to an apparent tendency for certain long-run statistical indicators of the economy to show a long wave pattern [1]. In particular this applied to prices and interest rates but trade statistics and production statistics were also cited by these early authors. Some historians simply adopted the long-wave ideas as a convenient form of historical periodisation.

At one level the debate on long-waves has simply been a prolonged controversy about these statistics. One school of critics has simply and consistently maintained that the statistical evidence is inadequate to support any well-founded belief in the existence of the phenomenon [2]. On this level it is extremely unlikely that the debate will ever be finally resolved. The retrospective reconstruction of historical times series is an art rather than a science and it is extremely unlikely that it will ever be achieved to everyone's satisfaction. Even if it were, this would not refute the standpoint that 4 "waves" or

*This note draws heavily on the ideas of my colleagues, Luc Soete and Carlota Perez, to whom I am greatly indebted. They are, however, not responsible for its contents.

"cycles" are too few on which to build any firm foundations, since each one has its own unique features. Nor would it dispose of the controversy about the incidence of wars and civil wars and their influence on the long-term trend of prices, interest rates production, trade and investment. Nevertheless, the refinement of the relevant statistics and the prolonged controversy about statistical techniques has made an important contribution to the wider debate, by compelling the various participants to take some account of the need to relate any theory to the real movements in the world economy.

The wider debate assumes the existence of a long-run phenomenon worthy of some investigation and research. As the minimal level, it takes the agnostic standpoint of Van der Zwan [3] and speaks only of successive major structural crises of adjustment in the economy, without making any specific assumptions about long wave movements or about their periodicity. More commonly it assumes that at least in some countries or in the world economy as a whole, (with national variations) there has been a discernible ebb and flow of economic activity over periods of approximately half a century duration. These fluctuations are believed to be of sufficient interest as to justify a special type of explanation, differing in important respects from conventional short-term or medium-term business cycles analysis (the so-called Juglar cycles).

Interest in this approach has quite naturally increased because of the simple fact that the recession in the world economy in the 1980s had proved to be more serious than any other since the 1930s. This fact would in itself guarantee that some attention would be given to comparisons between these two periods. Simply to understand more thoroughly just why the big post-war boom was so prolonged and growth rates so high, and to understand why this growth gave way to stagnation and depression is in itself, an important task for social science.

Attempts have been made to clarify long wave theories in various ways, for example, according to the theoretical paradigm in economics, characteristic of the authors. One could distinguish a category of monetarist theories (Dupriez), of Marxist theories (van Gelderen, Mandel, etc.), of neo-Keynesian theories, of Schumpeterian theories, and so forth. The difficulty with this type of classification is that there are many hybrid theories and some that do not easily fall into any particular classification, such as Rostow and van Duijn. Nevertheless, classification in terms of theoretical paradigms becomes particularly important, where policy measures are being considered. (See Topics 4 and 5.)

Perhaps the most interesting recent attempt to classify long wave theories was that of Delbeke [4]. He distinguished between theories, according to the emphasis placed on particular factors of production or inputs into the economic process capital, labor, raw materials, and entrepreneurship. Although starting from completely different ideological and theoretical standpoints, Mandel and Forrester, according to Delbeke's analysis, share a common central emphasis on the process of capital accumulation and the role of profitability in this process. The uneven development of the capital goods sector of the economy and of the consumer goods sector respectively, plays an important part in the models of both these theories. Both stress the long-term nature of this process in which the capital goods sector is driven to over-expand its capacity in order to satisfy both its own requirements for expanded reproduction and those of the other sectors of the economy. The ultimate emergence of surplus capacity and the erosion of profitability in the capital goods sector is an important phenomenon for both Forrester and Mandel in the transition of the long waves from boom to recession and depression. Keynes

also emphasized this aspect of the problem in his discussion of the collapse of the American boom in the 1920s.

However, after attempting this classification, Delbeke concluded that in reality the various theories were more complementary than might appear at first sight. He pointed out too that such authors as Rostow and van Duijn synthesized several theories in a somewhat eclectic way.

Judging from the evidence of several international seminars held in the last few years, a more meaningful breakdown between various long wave theories might be between the neo-technology theories and the rest. The new technology theories derive from Schumpeter's original interpretation of Kondratiev cycles [5] in which he emphasized technical and social innovation as the engine of growth. According to his theory, the process of economic growth is not simply accompanied by the introduction of new products, processes and systems, but is *driven* by the opportunities for more profit and markets associated with such innovations. This strong emphasis on the role of technology is rejected explicitly by such authors as Mandel [6] and Forrester [7], who regard it as a form of "technological determinism", or as an over-estimation of the role of innovative entrepreneurs. Critics of the Schumpeterian approach, from Kuznets [8] to Rosenberg [9] whilst often sympathetic to the idea that the introduction of major new technologies might very well bring about perturbations of various kinds in the economy, have nevertheless insisted that stronger evidence was needed, as well as a more convincing theoretical explanation.

Since the appearance of the work of Gerhard Mensch [10] in 1975, various researchers strongly influenced by Schumpeter have attempted to respond to this challenge. This has stimulated an important debate on the timing of the appearance of various radical innovations and the role of *diffusion* of such innovations in Schumpeter's "swarming" of investment behavior. Most authors now seem to agree that it is the massive investment associated with the widespread diffusion of new technologies which alone could give rise to major fluctuations in the economic system.

Freeman, Clark and Soete [11] in their study of unemployment and technical innovation attempted to demonstrate a link between diffusion of new technologies, the growth of new industries, the pattern of investment and changes in the demand for labor. In the early stages of a new technology the pattern of growth is often rather labor-intensive, because of the task of standardization of components, materials and design, and the absence of any capital goods industry able to supply new types of equipment. As the technology takes off, and the new industries enter the stage of rapid growth, capital-saving innovations may be exceptionally important. As the technology matures, the increment in employment associated with each new vintage of investment tends to diminish, with economies of scale, standardization and an increasing concentration on factor-saving technical changes to offset the pressure on profit margins. In the development of satisfactory theories of any cyclical or wave-like phenomena the key problem relates to the points of inflection: why does boom give way to recession and depression? Why does the economy emerge from a trough to a period of recovery and boom?

In their apporach to the problems of the transition from boom to recession, most neo-Schumpeterian authors, share a common recognition of the role of declining profitability, originally emphasized by Marx, in relation to the ordinary businss cycle and incorporated by Schumpeter as a central feature of his theory. This erosion of profit margins is attributed by neo-Schumpeterians (with varying degress of emphasis) to four main factors:

(1) The increased competition associated with the intensive "swarming" and "band-wagon" process of the high boom period.

(2) The pressure on input costs associated with these same swarming processes and the rapid expansion of the economy generally. Many authors stress labor costs, but material costs and energy costs also figure prominently in some theories.

(3) The tendency to approach saturation levels after a prolonged period of expansion with respect to some markets. Most authors recognize that this is not necessarily a long wave phenomenon and that there is considerable variation between different products. Van Duijn [12] has clarified this point particularly well. Pasinetti introduced the notion of a specific pattern of demand associated with each long wave.

(4) The tendency to approach technical limits and scaling up limits as the potential productivity and other gains of any new technology are more fully exploited. ("Wolff's Law").

In addition to these phenomena, Gerhard Mensch also stresses the tendency for entrepreneurs to move from basic product innovations to product differentiation ("Schein-innovations") and minor improvement innovations.

The explanations advanced by neo-Schumpeterian theorists for the loss of impetus in any major period of expansion appear to offer a plausible explanation of the change in the economic climate from the late 1960s, to the 1980s. Nor are they wholly inconsistent with the theories and explanations advanced by more orthodox economists. The latter, however, place far greater stress on such "exogenous" factors as the 1973 and 1979 OPEC oil price rises, on persistent inflationary pressures within the system and on the monetary policies adopted by governments to combat these pressures.

However, it is when the analysis moves to the trough of the long wave that more substanntial differences emerge.

In an important original contribution to the recent London seminar on "Technical Innovation, Design and Long Cycles in Economic Development", Carlota Perez [13] emphasizes the importance of a good "match" between the technologial "style" or "paradigm" of a long wave and the socio-institutional environment. Depressions, in her analysis, represent periods of mis-match between the emerging new technological paradigms (already quite well advanced in the previous long wave), and the institutional framework. The widespread generalization of the new technological paradigm throughout the economic system is possible only after a period of change and adaptation of many social institutions to the requirements of the new technology. Such institutional change include the education and training system, the structures of firms and management behavior, the prevailing pattern of industrial relations, the capital market and financial system, government institutions and policies, the pattern of public and private investment and the international framework within which international trade takes place, flows of international investment occur and technologies are diffused on a world-wide basis. All of these were relatively well-adapted during the period of high boom in the 1950s and 1960s to the requirements of the rapid adoption of the mass production technological style based on very cheap energy (especially oil), and the Tayloristic assembly line production engineering approach. However, these same institutions which were rather well-adapted to that mature technological style are rather ill-adapted to the requirements of the new technological paradigm, associated with micro-electronics and information technology. It may prove difficult to make this social adaptation, as it was at one time in the 1930s and 1940s, or in

the 1880s and 1890s, when other new technological styles were involved.

Giovanni Dosi [14] has pointed out that there is in any case reason to expect periods of mis-match between the science-technology system, the socio-economic institutions, and the political and legal framework. This arises from the single fact that both science and technology develop at least in part as a result of autonomous internally driven processes which are only indirectly affected by the demands of the economy. This applies of course most of all to fundamental science, but it also applies to radical new technologies. The political and social framework on the other hand, within which enterprises develop and exploit new technologies, responds to somewhat different pressures and because of differing time-lags and the prolonged rigidities sometimes affecting social institutions, there may very well be protracted periods of social turmoil before any degree of correspondence is re-established.

TOPICS 4 AND 5

Within such a framework of analysis it is possible to begin to map out tentative policy objectives for countries at the trough of a long wave. Carlota Perez [15] points out that Schumpeter himself did not develop such an analysis; despite his frequent emphasis on the importance of organizational innovations and the wider socio-political framework, so far as long cycles are concerned his theory was rather limited to more narrowly economic factors. This meant that he tended to regard depression as a "pathological" and unnecessary deepening of recession and scarcely considered what types of government action were needed to stimulate recovery from depression, although he did rather reluctantly and belatedly admit the need for such intervention. His generally hostile stance to Keynesian economies (as evidence, for example, in his vitriolic review of Keynes ("General Theory") did not predispose him to consider the possibility of neo-Keynesian counter-cyclical policies in a long cycle sense. Indeed he regarded the growth of government intervention and regulation, whether for Keynesian or other reasons, with considerable distaste and although resigned to the prospect of a general drift towards socialization [16] this was not a welcome prospect for him.

Keynes [17] himself, although writing his major work during the Great Depression of the 1930s, did not take up either the notion of Kondratiev Long Waves, nor its Schumpeterian variant. Nevertheless the remedies which he recommended were sufficiently drastic as to cause a major rupture in the theoretical paradigm of neo-classical economies and (later) in the governmental policies and institutions of most capitalist economies. Essentially, he recommended the "Socialization of investment" without public ownership. This meant that the state should assume responsibility for the overall level of activity and employment within the economy, since in his view the unaided private market mechanism, and in particular the rate of interest, could not be relied upon to bring about any sustained economic revival of growth.

Although he himself died in 1946, Keynes was in many ways the architect of the "good match" between social institutions and the new technological paradigms which prevailed in the fast growing industries of this post-war boom. As Carlota Perez has emphasized, the mass production of consumer durables

and vehicles could flourish within a Keynesian system of demand management, which both stimulated the necessary scale of investment directly or indirectly, and permitted the necessary growth of the mass consumer market, including credit systems, for the huge range of new products. The favorable international framework, too, owed much to Keynesian inspiration. The new international financial institutions and the new post-war approach to development and international trade, although falling short of what Keynes himself had hoped for, did nevertheless provide a much more favorable environment for the rapid growth of the world economy.

Quite apart from the monetarist counter-revolution, another problem confronting contemporary Keynesian theory and policy-making relates to its failures to come to terms with the technological element in economic development, both at the national and international level. For Keynesian macroeconomy theory it makes very little difference, which are the fast growing, new industries and which are the declining or stagnant industries. It is aggregate demand which matters and the changing composition of demand and supply is of little significance. In terms of the neo-Schumpeterian theory which has been discussed, however, it matters enormously, *which* are the emerging new technologies and industries because the social institutions which must favor their development and diffusion may be very different.

The conditions which will prove most favorable to the achievement of the full potential of the micro-electronic information revolution can as yet be only dimly discerned. But it is evident that they will involve big changes in management systems, in communication systems, in industrial relations, in the mode of delivery of many services in the pattern of public investment, in the education and training system and much else. None of the dominant theoretical paradigms, be they monetarist, Keynesian or Marxist, have addressed themselves to these questions, although they are among the most important ones from the standpoint of putting the world economy back on to the path of high and sustainable rate of economic growth.

From a neo-Schumpeterian standpoint (although as we have seen, Schumpeter himself was reluctant to pose the issues in this way) the problem is one of government policies which will encourage a new wave of public and private investment, involving the rapid world-wide diffusion of the new technologies. Policies to be avoided are those which inhibit or prevent this diffusion process for example by reinforcing outdated institutions and procedures appropriate to an older technological paradigm. Policies to be researched, developed and applied would be those which enable social institutions to be adapted to achieve the maximum gain from the new technologies with the minimum social costs. The nature of the new technologies is such that the participation of the work-force in the implementation of technical change is likely to become an increasingly important issue in this context. The preservation of hierarchical Tayloristic division of labor and management systems is likely therefore to constitute a particularly important social problem over the next decade or two.

It is still a matter of controversy among neo-Schumpeterians as to what balance of public and private investment will be most conducive to the resumption of high growth. As in the 1930s, there is a very wide spread of political alternatives on offer ranging from privatization of the existing public sector, through an extension of public sector investment in the new technologies, to full-scale socialization.

This raises the question of the relationship between long waves and Marx's "materialist conception of history". In terms of this paradigm, depressions may be seen as a particularly vivid manifestation of the tension between "productive forces" and the "social relations of production" within which these productive forces have been growing and changing. Marx [18] suggested that as it becomes increasingly apparent that the existing "relations of production" had become a "fetter" on the growth of the productive forces, then this would lead to the revolutionary re-consitituion of society at large (or to the common ruin of the contending classes).

During the deep depressions (of the 1880s, 1930s, 1980s), Marxist theorists have been divided on each occasion between those who tended to regard the crisis as the "Final Crisis" of capitalism, from which the only exit was a socialist revolution (the so-called "breakdown" theories) and those who, while regarding the socialist exit as the most desirable, nevertheless recognised that the capitalist system was capable of finding solutions to the problem of renewed growth through a variety of institutional and legal changes which would sometime permit the resumption of growth of the productive forces. Lenin was one of those who always insisted that ideas of an inevitable breakdown were mis-conceived, and that solutions within the framework of an essentially captialist social order were always possible, repugnant though such solutions might appear to socialists. His work on *Imperialism, the Highest Stage of Capitalism* [19] may be regarded (with hindsight) as a study of ways in which the institutional framework of capitalism was modified during the crisis of the 1880s and the 1890s to permit the upswing of growth of the "Belle Epoque" in the period leading to the First World War.

Especially important in the context of later world economic developments, was Lenin's insistence on the extremely uneven development of capitalism and simultaneously the internationalization of capital. An important aspect of long wave theory relates to the opening of "technological gaps" between the leading countries and the rest and the closing or partial closing of these gaps, through the international diffusion of technology, and the efforts of latecomers to overtake the leaders. This means *inter alia* that the statistics of any single nation are an adequate basis for understanding long wave phenomena. Only an international framework is adequate.

Marxist theory and dependency theory have tended to emphasize the extreme difficulty facing peripheral countries as they attempt to break out of the dependency situation. The monopolistic advantages associated with technological leadership, cumulative R and D, static and dynamic economies of scale and unequal distribution of bargaining power are indeed considerable barriers to overcome.

However, there are two factors which may redress the balance for some of the catching up countries. In the first place, as Soete [20] has pointed out, it may be easier for newcomers to a technological paradigm to create new social institutions or to adapt their existing institutions. They may not be hindered to the same extent by the ballast of out-dated capital stock, obsolete organizations, and old ideas. Secondly, the balance of economic and political power is changing in favor of the developing world, so that the international institutional framework could in principle be more favorable to their aspirations.

Soete emphasizes particularly in relation to micro-electronics that the newly industrialising countries may derive benefits from the low capital cost of the new technologies, and their potential for small-scale applications. He also stresses the possibility of removing some of the human skill bottlenecks which have arisen in relation to other technologies in the developing countries.

However, the scale of international indebtedness, the slow-down in the growth of world trade, the severe disequilibrium in international payments associated with technological competition and the increased instability of exchange rates are all phenomena which point to the need for a new international economic framework appropriate to the need of world-wide expansion in the remaining years of the 20th century. The Brandt Reports and many other studies have pointed to the acute social and economic problems of the Third World and the necessity of new initiatives to confront these problems adequately.

The development for such an international framework for expansion may prove to be the most difficult problem confronting the world economy if there is to be a fifth Kondratiev upswing. The technology itself is more international in scope and requirements than anything which has preceded it, but the national boundaries of decision making, the intensified international competition, the growth of protectionism (which has always accompanied the downswing of a Kondratiev), the re-emergence of Cold War attitudes and politics, and the perisistent failure of the North-South dialogues all serve to emphasize the great difficulties of re-establising a new and more favorable international economic and political framework for expansion. Such a framework must in any case take into account to a far greater extent than previous arrangements the importance of rapid international diffusion of technology and the need for cooperation between the various political blocs in the world.

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COMMENTS ON TOPICS 1 AND 2

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TOPIC 1: THEORIES OF THE LONG WAVE

GROWTH MODELS

It may be worthwhile to discriminate between theories of economic development -- which are essentially growth theories -- and theories of fluctuations of economic development. Long wave theories clearly belong to the latter. But the first, the pure growth theories, are not irrelevant in case the exogenous variables of traditional growth models cause long waves of economic development, be it through flucutations of their own or through upper and lower ceilings in their development. If such is the case, all those sources of economic growth (and their change over time) succinctly described by Schumpeter at the end of his career become relevant: physical environment, social organization, politics, technology, "human material" and the "national spirit" (in the sense of prevalent attitudes). And it should be stressed that most of these exogenous factors of economic development themselves again are dependent on economic development (which may give it a Marxist twist. But economic evolution as the prime mover of human history may be a hypothesis which today at least economists are happy to think about).

With respect to Schumpeter's "most familiar" determinants of economic growth it may be generalized that if there are n factors, economic and non-economic, making up for growth only few of them are, at a point in time, important. And what is more, the "important factor" mix may change over time. Looking into this n-factor approach the growth models hypothesis becomes more complicated. The n factors can only influence growth

significantly if they are scarce; the important factors should be different from the others because they are more scarce: highest possible growth rates of economic welfare can obviously only be achieved when the marginal contribution of each of the factors to economic growth is the same. Disequilibria occur when some factors have a higher marginal contribution than the others -- only then is the "important factor" approach promising.

DIALECTIC DEVELOPMENT

Some theories rely, for whatever reason, more or less on the principle of dialectic development. Hegel, and in his wake Marx, believed that human history was moving along an upward trend with fluctuations around it. This process would be finished when, finally, the best conditions of human (and governments') existence were realized. Hegel himself, after receiving a generously paid professorate in Berlin, declared the prussian state to be final and perfect stage of development and thus the dialectic process was finished for his part. Marx also thought that one day -- which he hoped to live through -- after a worldwide upheaval of the surpressed masses communism would set an end to the inherently antagonistic development hitherto experienced.

Of course, neither Hegel nor Marx thought about Kondratieff-waves of economic development. Indeed the falling rate of profits was rather regarded to be a trend phenomenon than a cyclical one. But the dialectical idea itself should spell cycles when translated into economics; this is reflected in the crisis of capitalist development as seen by Marx.

Other theories of the long wave are either tailor-made or they can be made to fit into the long wave explanation. As concerns the latter one may quote Hayek with his analysis of the central role of private property rights (and of the family). The Hayek long wave hypothesis would be that in times when property rights (the family) are protected by government growth conditions are good and vice versa in times when this is not the case. This looks like a very interesting variant of long wave theories because evidence strongly confirms -- at least in cross section analysis -- that countries with less property rights perform significantly less well than the others. Examples abound.

SHOCKS AND OVERPRODUCTION

Another set of explanations at first glance seems to be highly mechanical. They suggest that

- exogenous shocks lead to fluctuations of the population and these flucutations echo with diminishing force every generation or so until superimposed by a new shock (August, Lösch),
- a more or less systematic overestimation of future orders by capital goods producers, together with increasing saturation of demand produces long waves (Spiethoff, Forrester).

As regards the latter, systematic maldisposition on the part of entrepreneurs in the capital goods sector (or in any other sector) as a result of a long term rise or decline in unfilled orders is implausible on two grounds: First why do entrepreneurs not learn from experience (are there no feedbacks?), and second, what about the price mechanism -- does it not have compensatory

effects? It can also be argued that overcapacities (and too few capital) are rather a continuous phenomenon in the growth process. Industries or parts of them, come and go. Those going necessarily pass through a stage of overestimation of future demand and of corresponding overcapacities. A long wave theory should rather explain why *all* entrepreneurs in the capital goods sector (incidentally, most of them produce capital goods, consumer goods and primary goods at the same time – why should they err only with regard to capital goods?) make wrong forecasts and why they do not evade on world markets.

MONETARY THEORIES

Some theories may be labelled "monetary". One is related to the Friedman/Schwarz analysis of the monetary history of the United States (especially with concern to the years 1930 and 1931). Though Friedman/Schwarz do not have a long wave concern, "their" hypothesis would say that sudden and unpredictable contractions in the supply of money causes depressions; consequently, the ensuing upswing is due to rectifications of past errors in monetary policy.

Another hypothesis possibly helping to explain long waves which, according to Tinbergen, can be labelled "monetary" is the original Kondratieff idea of gold field discoveries. Two strands of thinking may be identified: one is that movements in the stock of gold lead to movements in the stock of money which again leads to movements in the price level.

The question arises, however, what we mean when dealing with long waves. In our opinion, long waves in the price level are per se of no particular interest -- what matters, after all, is fluctuation in real terms. Only when prices are causing the real world to fluctuate do they matter; and this can hardly be the case with regard to price levels but rather with regard to relative prices. Therefore, the gold discovery hypothesis should be broadened -- which actually can be done -- to incorporate the influence of increased gold stocks on relative prices.

Another problem inherent to this hypothesis is that gold discoveries may turn out to be highly stochastic. It is hard to conceive stochastic events to produce long waves of economic growth (unless the echo principle is considered to be relevant).

The other line of thinking is closer to Kondratieff who maintaned that during a long run development cycle investment activity eventually wanes because borrowed capital becomes scarce and expensive. Gold discoveries can then – just like Pigou's real balance effect -- lead to an increase in savings in the supply of capital via a rise (in the real value) of the money stock. Long run profit expectations thereby rise, investment activity becomes more buoyant and upswing ensues.

INNOVATION

A name very often mentioned is Schumpeter when it comes to explain long run fluctuations of economic development by innovative activities. Quite in line with his conviction of 1912 ("Theorie der wirtschaftlichen Entwicklung"), namely that man makes history, Schumpeter saw the preconditions for an acceleration in economic growth in the cumulative appearance of entrepreneurial pioneers who carry out innovations. In the course of the upswing, the

pioneers are followed by a growing number of imitators; this finally leads to boom like excesses, followed by an enduring decline in economic activity.

Since this approach is not easily converted to a simple "change in investment" hypothesis it is hard to test empirically. How do we measure the importance of an innovation? Are there accidental factors which are also important -- this would serve to refute the innovation hypothesis (Tinbergen).

Incidentally, looking at past development, an important innovation has been e.g., airplane traffic, or nuclear energy or, these days, microprocessors. But were these not -- excepting the latter – economic flops, unable to carry the economies? And microprocessors: will they really serve to cure the employment problems the world is facing today? Lots of people doubt that. In general: the innovation hypothesis does not help much predicting economic performance due to the problem of identifying basic innovations and their "time of departure", and due to the ever present possibility of labor-saving innovations.

SINGULAR EVENTS

Singular events hypotheses are also often discussed as explanations for growth fluctuations. Wars, revolutions, and price shocks are mentioned in this context. It may be doubted, however, whether such events can serve as an explanation of more or less regular patterns -- if these patterns really exist, that is; if not we need not look for explanatory hypotheses. Moreover, singular events may turn out to be endogenous to economic development.

THE ROLE OF RELATIVE PRICES [1]

In the following we introduce the ideas underlying our own work on long waves of economic development.

As distinguished from the explanatory approaches of Kondratieff, Spiethoff, and Schumpeter, long term fluctuations in investment activity can also result from systematic price distortions and rectifications on product and factor markets which directly impinge upon profit expectations. Growth constraining distortions can ensue, for example, from an increase in the degree of monopoly on product and factor markets, or from carrying the protection of economically weak industries, regions, or groups of persons too far. There is no lack of indicators that growth regarding price distortions have developed on the product and factor markets of numerous countries for quite some time. In this regard, particular attention has been focused on the substantial increase in labor costs, on rising protection in international trade, and on the surge of unproductive transfers.

The basic problem of every theory of long swings consists of explaining why the agents in the model react to changes in market signals only with a long lag. Starting from the observation that common interest organizations (organized special interest groups) are common features of economies, the basic idea behind our approach is that institutions -- in contrast to individuals -- react only slowly and sluggishly. It seems to us that this is the actual cause of long run fluctuations in growth.

The hypothesis of institutional sluggishness in reacting to market signals can be justified on various grounds:

-- One cause lies in the life cycle of organizations. If the need for a collective representation of individual interests arises, it takes time -- not least because of the free rider problem -- until the common interests are organized. Further time passes until new organized interest groups have penetrated into the political arena against the resistance of already established interests. Once they have gained their positions, they will defend them as long as possible, even if the original interests have ceased to exist.

-- A further cause for the sliggishness of public and private institutions can be seen in the nature of bureaucracy. Organizations possess an inherent interest to expand their field of activity as far as possible. The older and larger organizations become, the longer and more tenuous the communication channels between the organized and the organizations, be it because the individual no longer counts for much, be it because of "bureausclerosis".

-- Enduring, counterproductive behavior of organizations, particularly of public administration, may also be based on a self-escalating process of societal misinterpretation of market signals, ensuing (counterproductive) intervention, and renewed misinterpretation of ever more ominous market signals.

A diagrammatical representation of the basic structure of this mechanism might clarify our approach (Figure 1). The right hand side of the figure describes that part of the mechanism coming from organizations with an interest in raising product prices or reducing factor prices, or greater transfer payments. The first set will usually be composed of business interests; the second set will contain organizations of employees or pensioners and the like. Adjustment processes occur slowly insofar as they depend on collective decisions, quickly, insofar as they depend on individual behavior. The diagram is restricted to the basic principles of the long term interrelationship. Thus, foreign economic relations, for example, have not been explicitly shown, although they play a role at all the levels mentioned. Also, the existence of feedback effects between all the elements of the scheme can be surmised. The interrelationships between government activity and factor and product markets seem to be of particular importance, because significant retarding elements may be found above all in government influence. This holds, e.g., if firms call for -- and receive -- public assistance when competition pressures rise. On the other hand, labor unions might attempt to pass on increased taxes in collective bargaining agreements.

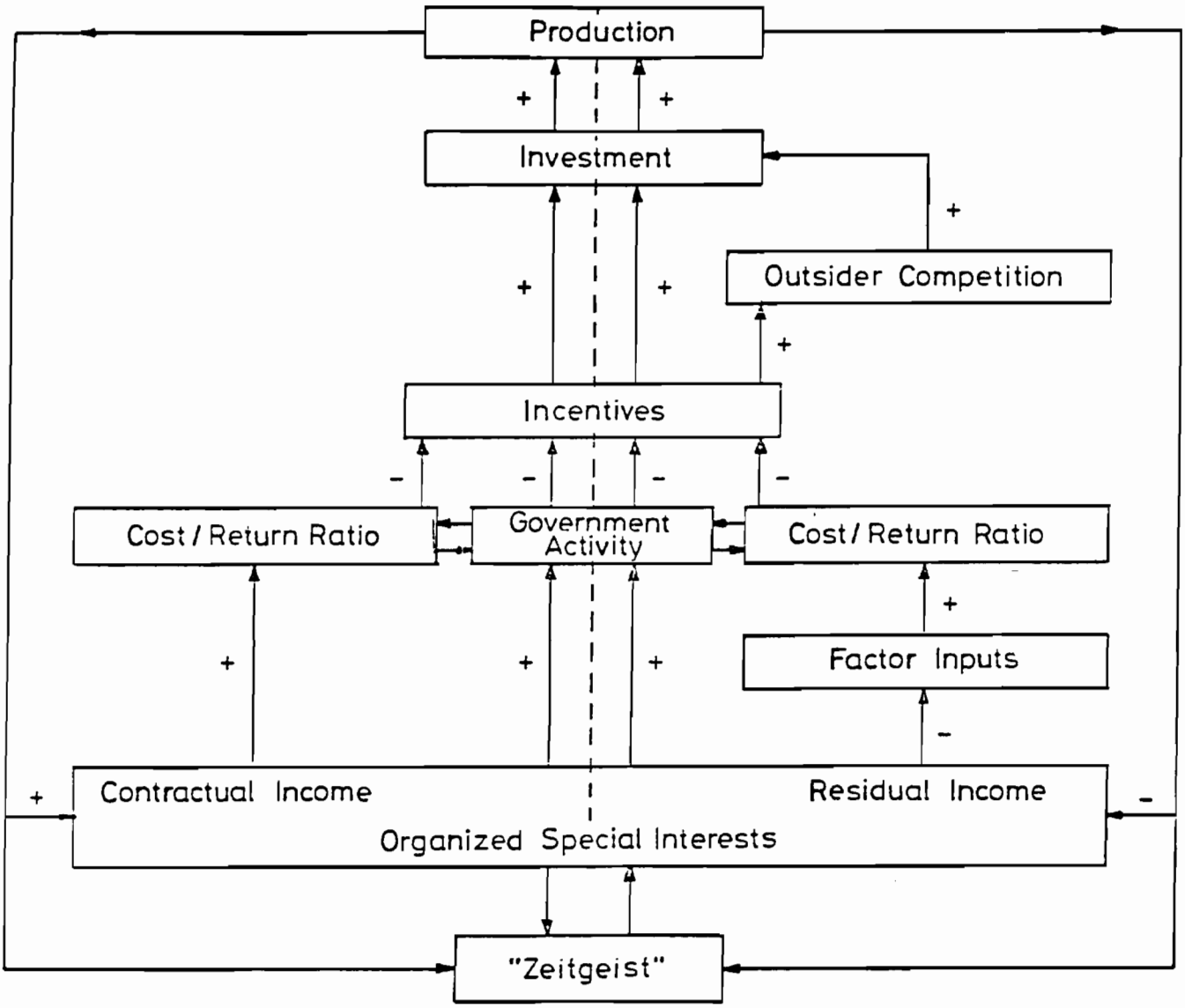

Figure 1. On the Theory of Long Waves in Economic Development

The scheme can be described as follows:

Let a disturbance impinge on the initially existing equilibrium growth path (all public and private organizations that are required in such a situation, or are compatible with it, exist). The disturbance may appear on the level of the "organized particular interests" perhaps because certain interest groups have gradually acquired monopoly power. This will have consequences on factor markets (in the form of persistent upward cost pressure, for example); on product markets (in the form of supply restrictions, for example); or in the field of

governmental activity (in the form of subsidies, for example). In whatever way the tendencies toward monopolization change, from an overal economic point of view, incentives will change:

(a) Insofar as incentives deteriorate -- as in the case of persisting upward cost pressure -- investment activity abates and production declines (relatively). If, on top of that, the government gives in to the demands of organized interests and voters for compensating action -- such as partial or sectoral employment guarantees, subsidization of private activities, or expansion of social services -- it will often aggravate the overall economic decline and intensify the downswing. The longer the contraction continues, the more those interest groups which were the original source of the disturbance lose power. This may result from the progressive circumscription of the interest groups financial resources in the course of the economic decline, or because members more and more lose their trust in and their loyalty to their organizations. Thus, it would appear to be in the organizations' self interest to learn from the experience of the contraction and restrict the struggle over distribution. Changes in societal beliefs -- the "Zeitgeist" -- push in the same direction. These can even end the decline on their own if in the course of revolutionary developments the received social framework is burst assunder. Removal of the original disturbance tends to reduce costs relative to returns for the producers.

(b) To the degree that individual economic agents' profit expectations are raised (in the short run) by cartelization of important product markets, a long run contraction can be initiated as well. The cause for this may be seen in the tendency of cartels to opt for the beaten track internally, and to discriminate aganst outside producers (and individual cartel members) by securing its position domesticaly and abroad. Especially user industries are weakened by cartel prices. These, in turn will combine in order to receive protection against outside competition. The same complaints can be expected from the cartels supplying industries, as their sales decline, as well as from all others who have to finance the protection. Supply reductions spread throughout the economy; the production structure gets frozen in. In the long run, the cumulative group egoism on the entrepreneurial side which drives the economy into the downswing is broken by the always existing, steadily growing danger of outsiders. Since no one wants to be thrown out of business outsider competition leads to a renewed increase in investment and production.

In both cases a new upswing begins. With the increasing duration of the upswing, more and more scarcities appear on product and factor markets, which encourage monopolistic tendencies. The same social and institutional inertia which was effective during the downswing now prevents the interest groups from reacting to their newly acquired power by rapidly changing their behavior, still marked by the last crisis.

In its core, our explanatory approach is endogenous even if exogenous disturbances are not ruled out.

TOPIC 2: IDENTIFICATION OF LONG WAVES

DEFINITIONS

Before considering the problems associated with identification of Kondratieff-like cycles as opposed to Kitchin-, Juglar- or Kuznets-cycles one should discuss which indicator it is that we talk about. Kondratieff was mainly concerned with price movements, others concentrated on sectoral output, or on innovation cycles, or on investment.

Since economics are concerned with the well-being of people the ups and downs of economic activity analyzed should be as comprehensive as possible; in other words, it is economic welfare, usually often mentioned in this respect, seems to be second best to the social product because it does not incorporate labor productivity; a low degree of unemployment may only indicate that there is substantial "hidden" unemployment, i.e., very low levels of marginal labor productivity. Price moements per se do not exhibit anything about welfare or about the development of welfare, and the same holds true for innovation, or sectoral development patterns.

With regard to social product the very nature of the long wave indicates that it is not short run problems of capacity utilization but rather the development of production poential which should be analyzed. This again poses some problems since the capital stock and its development can only be of relevance insofar as the profitable capital stock is concerned. Capital stock statistics only provide for technical information on how much could be produced if prices would not matter. Here again the concept of measuring social products becomes important because it seems to be the best approximation for identifying that part of the capital stock which under present -- or current – conditions is economically efficient. And if the social product is a good proxy one may in fact neglect that it is the capital stock which plays a decisive role. The question of course remains how to identify long run ups and downs of economic activity from short run disequalibria.

IDENTIFICATION [2]

The long run development of the social product can be described by a growth path beset by wave like movements of various frequencies and amplitudes. In order to see whether there are long run cycles which can be made visible to the observer we adopted and, to our belief, improved Kondratieff's procedure. First, detrending the time series data (the exponential trend proved to be superior to the linear trend in terms of statistical fit) made it easier to detect deviations in the pattern of development. Second and simultaneously, smoothening the time series data with 9-year moving averages was thought to serve for depressing any shorter run cyclical movements. Calculating the difference between the moving average and the (hypothetical) trend value as a percentage of the trend value indeed did exhibit a long wave like pattern. Now it may be surmised that every cycle of the long wave has its own peculiarities which makes the average growth performance different from other cycles. Therefore a dummy variable was introduced, first, in the trough exhibited according to the above mentioned procedures one and two. In case this dummy turned out to be statistically significant, differences between

moving averages and the new trend were calculated. If then the trough changed, the dummy variable was shifted along the time horizontal to this newly found lowest point; in most cases the initially discovered trough was thus reinstalled. For all those countries where more than trough existed, another dummy variable was introduced; the procedure then applied was the same as before with the first dummy.

It can be argued that such a procedure leads to misinterpretation of the long wave because

- -- the results of detrending depend on the phase within which observation starts and ends,
- -- beginning and end of cycles should be the inflection points instead of troughs,
- -- detrending plus smoothening procedures produce wave like patterns; the long waves are artificial.

The first two points seem to be well taken. Since one never knows anything conclusive about the economic situation at the start and at the end of the observation period, the peaks and troughs can deviate frm the "real" ones; this argument is all the more relevant the shorter the time series is.

Taking the second argument scholarly one should indeed aim at identifying inflection points of long run development. Empirical research, however, in general is rather crude. The only regular phenomenon in social product time series is that they are too irregular for identifying inflection points. Smoothening does not help that much. Thus, one has to contend with troughs and peaks.

As regards the Slutsky effect it may be added that all other smoothening procedures applied in the case of Germany by and large gave the same results. Moreover, we also tried some spectral and correlation analyses. It turned out that the growth fluctuations observed by the above procedures were most probably not artifically constructed because

(1) the moving average did definitely not induce cycles of about 40 years length, and

(2) the detrending method should not have "approximately enforced such cycles".

The spectral analysis, however, did not come to a positive (or negative) answer regarding the existence of long waves of economic development; the reason given was that one needs constant phases for positive identification as well as longer observation periods. And neither did our theory suggest constant phases nor could this, due to the two world wars in between the data, be expected.

PROBLEMS

Proving causalities and refutation of hypotheses poses some well-known problems, especially in the social sciences. These problems are aggravated when analyzing causes of long waves of economic development. For instance, how can one deal with leads and lags between endogenous and exogenous variables? Since we are concerned with long run behavior, leads can turn out to realy be lags and vice versa.

Also, whereas we normally have means of statistical analysis to indicate the quality of a hypothesized relationship we have almost nothing of that sort with respect to long waves. Even the case of the long wave itself is not easly made, let alone the case of its determinants. Maybe some day data are comprehensive enough to apply some variant of the spectral analysis (allowing, however, for changes in the phases), but we all shall be dead by then.

Problems sometimes cumulate. To give an example: the hypothesis has been advanced that the intensity of distributional conflicts together with inherently sluggish reactions of organized interests leads to long run ups and downs of economic activity. But there are lots of organizations, and lots of conflicts all the time. Choosing wage conflicts since they bear heavily on profit expectations, what is the appropriate measure of these distributional conflicts? Considering that "too high" wage increases negatively affect profits and thus probably expected profits and that "too low" wages work in the opposite direction, the real wage position* should give a good proxy for the intensity of distributional conflicts (other factors being equal). But again the real wage position is not simply exogenous to economic development. We all know, for instance, that productivity depends, among others, on the employment situation (increasing unemployment leads statistically to productivity increases as long as marginal labor or firms exit first). The real wage position under these circumstances indicates possibilities for wage increases in the depression period which, at the given level of employment, do not exist. The good times, on the other hand, after full employment is reached, pose no problems; however before the full employment situation productivity increases are "underestimated" and the possibilities for wage increases are relatively high.

Taken together, causality often has to go a long way -- from real causes to their proxies until measuring problems blur the picture -- before tentative results are obtained. Similar problems apply when trying to take account of government intervention or of the degree of international integration of an economy.

As regards a "single, all-encompassing model" for explaining long cycles, it should not be too difficult to provide it. However, such a model should be

(1) principally endogenous -- that is without the need for initial pump priming like Schumpeter's clusters of innovation or like Mandel's "system shocks", and

(2) based on the ability of individuals to learn from experience; it should also

(3) incorporate the essentials of an economic model.

The last point is to remind us that it is profit expectations of one kind or the other which rules the world and that changes in relative product and factor prices and the reaction to such changes play a significant (though often neglected) role in a nation's development. To be sure, the problems involved in producing such a model increase with these standards.

*The real wage position indicates changes in the distribution of additional macroeconomic income between employees and employers. It is measured by comparing the overall productivity increase (corrected, among others, for terms of trade effects) with real wage increases.

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[2] See also Hans H. Glismann, Horst Rodemer, Frank Wolter: Lange Wellen wirtschaftlichen Wachstums (Replik und Weiterführung). In: Dietmar Petzina, Ger van Roon (Hrsg.), *Konjunktur, Krise, Gesellschaft*, Stuttgard, 1981, p.66.

Recession: Ten More Years to Go?

Cesare Marchetti argues, in his usual provocative manner, that the current recession may well last another ten years, based on his application of Darwinian insights to economic analysis.

That the present recession is a really serious one, and that it has many aspects in common with the recession at the end of the 1920s, more and more people have come to acknowledge. But opinion varies on its likely depth and duration, and the underlying logic is weak. It is this logic that I shall try to buttress and clarify.

The first tangible sign of a recession is that people start losing their jobs beyond the level of two or three percent of the work force; this level is considered physiological, and can be in good part attributed to the mobility of the work force. I recently made a study of the development of the automobile industry and I shall use this example to illustrate how people lose jobs.

A common characteristic between my analyses of economic and social structures is that they are based on physical quantities and not on value. The mental image I have in exploring the time dynamics of these quantities is the Darwinian competition between species, whose mathematical counterpart is Volterra's ecological equations. This image is perfectly captured by the statement of Heraclitus that competition is the father of everything, and the king too. In modern terms it is the creative and regulatory force.

Coming back to cars, I formally assumed that they were an animal species expanding into various niches territorially coinciding with countries, such as the USA, France, or Italy. The expansion of a species in a habitat, whether bacteria or foxes, is best described by a logistic equation. The precision of the fit with the historical data for cars is just amazing. To give one example, the deviation from the fit for the car population in Italy over twenty years was less than one percent, as shown in the diagram.

These logistic equations have only three parameters, or three knobs to turn to fit them to the data. One fixes the position in time of the phenomenon; the second gives the dynamics of the process; and the third is the size of the niche, that is, the maximum number of animals it can support. If the quality of the data is high, as in the case of car populations, and there are no hiccups or uncertainties, then the three parameters can be directly calculated from the data without requiring external information.

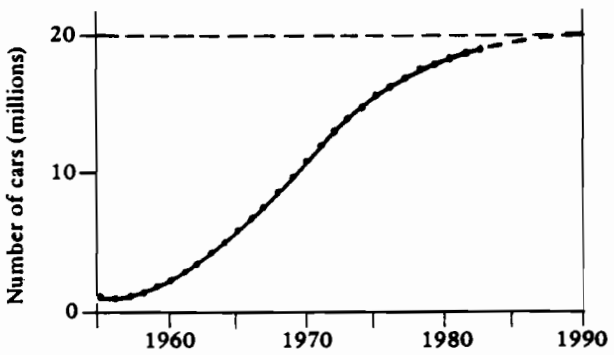
This last fact is extremely important because *it permits us to calculate the final population of objects intrinsically from the dynamics of their market penetration*. And it cuts the Gordian knot of econometric hypotheses, in which the result usually depends on the investigator's opinions or, more often, on those of the sponsor. The justification for the use of such a technique is that it applies to all sorts of competition and expansion behavior. We have in fact a portfolio of about four hundred cases of economic and social behavior analyzed in this way.

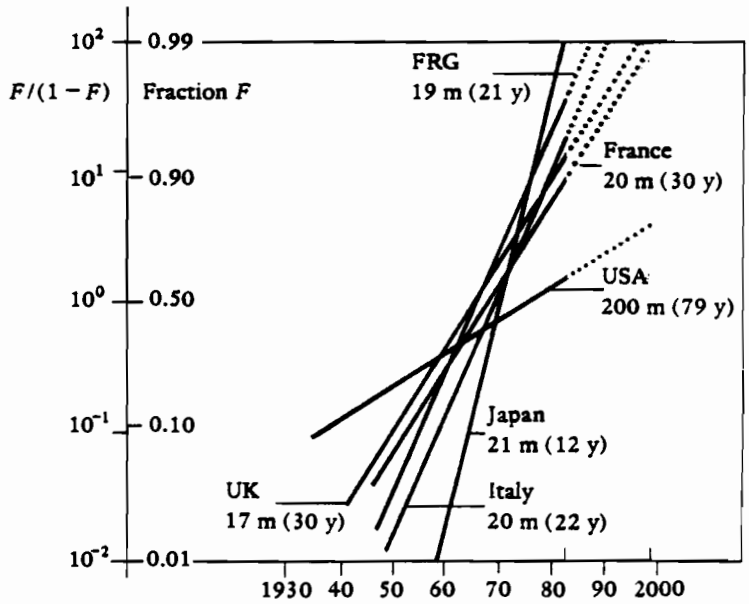
Darwinian Competition

In the case of the car, a saturation level for the car population of each country, which curiously is not directly related to its population or wealth or area or the total length of its roads, can then be determined. Second, and more disturbing, it appears that most of the western countries' car markets are already practically saturated (shown in the diagram below: the ordinates have been chosen so as to make the penetration curves appear as straight lines instead of S-curves for a clearer presentation).

Now, what happens when an industry finds that its market is saturated?

(*Below*) Growth of the car population in Italy. (*Right*) Car populations as percentages of saturation levels. The first figure is the saturation population; the second is the time in years for the population to grow from 10 percent to 90 percent of the saturation level.





First, it will notice that it has excess capacity, since everybody has been operating with a business-as-usual philosophy, expecting expansion to continue for ever. To begin with, the capital burden will increase its weight. Second, production will go to satisfying replacement demand, which is basically a fixed demand. Fixed demand would not be so bad except for the overcapacity and the dynamics of salaries, which push total costs up. The only short-term solution is to increase productivity. But increasing productivity with constant production means shedding jobs. For example, Fiat of Italy maintained its car output even with 70,000 fewer people in its work force in the car division, previously around 200,000.

The really curious fact about market saturation is that it *occurs almost worldwide within a short period*, in spite of the fact that the car market began rapid growth in different countries very randomly. But newer markets grew faster to the extent of overcompensating, as in the case of Japan.

The fact that car populations saturate at the same time all over the world means that the usual safety valve of exporting to compensate for sluggish internal markets does not work any more. Or it works the other way, because competition heats up on the international market with dire consequences for old and established enterprises. In spite of all the institutional barriers that the losers will erect, my Darwinian forecast gives Japan half of all the cars produced in the world in the year 1990.

Not only cars but also many other industries that gave rise to the boom of the 1950s and 1960s have gone through the same development and now find themselves in the same predicament, facing saturated markets and overcapacity, with a consequent need to shed personnel. Companies, like people out of work, become cautious spenders and limit their purchases of services. The wave then spreads; the airlines, for instance, also find themselves overequipped, overstaffed, and moving toward bankruptcy worldwide. They are also starting to shed personnel.

I think the picture is clear enough to go on to the next step – the whys, hows, and whens. Why are so many

Dr. Cesare Marchetti

industries saturating the market at the same time, how can we get out of the doldrums, and when will the vital trade winds start blowing again? The problems of the recession in the 1930s stimulated much theoretical work and, in fact, there is a host of theories – which means that the mechanisms are basically not understood. To aid understanding I shall use the results of system studies I did for completely different purposes, such as the car study, which was originally intended for analyzing the intrinsic dynamic of the spread of an innovation. The surprising result is that at a global level the time for a basic innovation to expand from a 10 percent to a 90 percent share of the potential market is usually about fifty years, whether the innovation is margarine, the vacuum cleaner, or the theory of relativity.

I am pretty convinced that this is linked to a basic human behavior, which seems to show extreme constancy. A brilliant demonstration of this is given in the bottom part of the diagram on the next page, where the blue lines show the market penetration of different primary energy forms. The *rate* of penetration, expressed in the appropriate parameter in the equation, stays constant to within a fraction of one percent over the whole period.

Now, if many industries happen to be in the doldrums together, with similar time constants, this means they started up more or less together, and the question is why. Here a system study I made of invention and innovation in the western world over the last three centuries comes to our aid.

Invention and Innovation Cycles

The final result of the study is also reported in the bottom part of the diagram, where each pair of black lines represents an invention wave and a corresponding innovation wave. The invention wave describes the conception of new products whose success is later sanctioned by the growth of a new industry. The lines themselves represent the cumulative number of inventions (or innovations) at a certain date, expressed as a percentage of the total number in the wave. The curious fact here is that formally the set of innovations grew as if it were a population filling an empty ecological niche – that of the need of innovations by the "system", just to extend the analogy.

The question now arises, what generates the empty niche? Simple: the death of a former species. If the mental model holds, then the innovation waves should be spaced apart by about fifty years. They are. The distance between their center points – when half of the innovations in the waves have been made – is precisely fifty-four years.

Now a picture begins to emerge: dying industries create the vacuum, the niche, that the new species, the new innovations, fill. The spacing between spurts is dictated by the time it takes for market saturation of the various industries, which puts the time into the fifty year bracket. Because the same period has been necessary to mesh into the daily routine of the physicist a basic innovation such as the general theory of relativity, I propose to give this time an anthropological significance.

The internal dynamic of each of the waves, on the other hand, accelerates, doubling speed roughly every century. I have not yet found any clue to this very regular acceleration, nor to that of car market penetration, where the time needed to penetrate successive markets decreases exponentially with

the date of the beginning of rapid market growth.

The present innovation rush will formally start in 1984 – 10 percent of the basic innovations introduced – and end in 2002 – 90 percent introduced. These innovations are the seeds of the next boom, which will start when they are large enough to influence the whole economy. But let's look now in more detail at the timing.

The fifty-four year interval that holds so steadily for such a long time is an obvious reminder of the Kondratieff cycles. I read again his brilliant papers of the 1920s, and I would say that there has not been much said after him that he himself did not say. I arrived at many of the conclusions Kondratieff had reached following my completely different line of thought and profiting from the extra cycle that has occurred since his time. The situation seems to me now so clear conceptually and quantitatively, so well mapped, as to be beyond doubt.

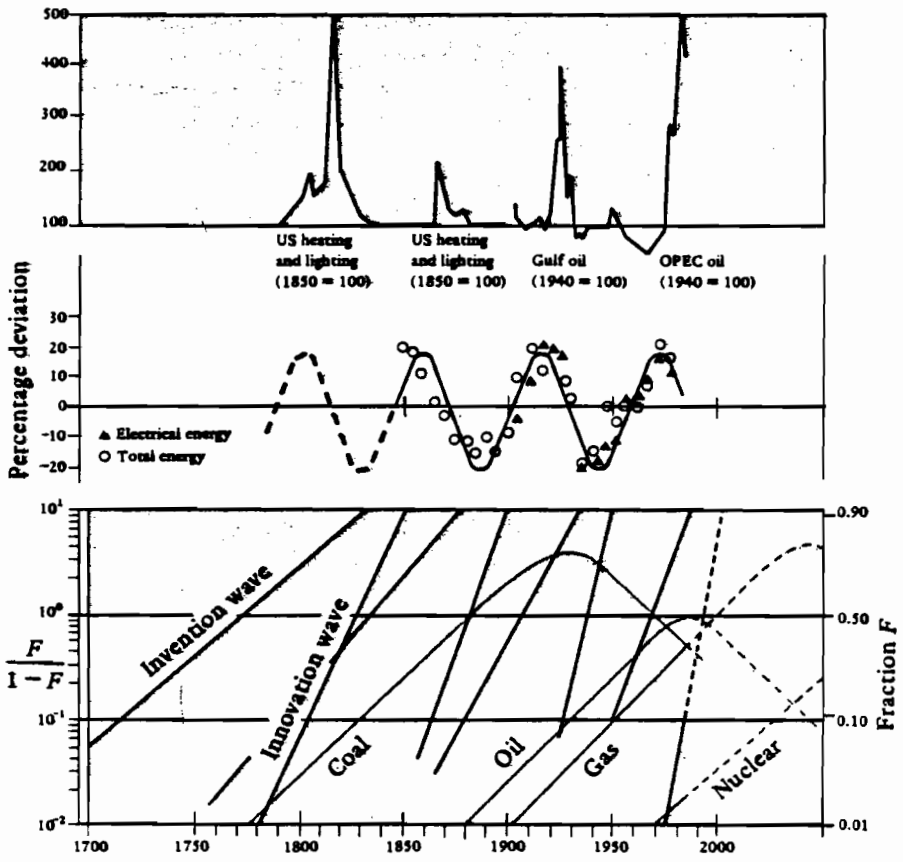
Energy Demand and Energy Substitution

Having to deal, if only indirectly, with economic matters, I have always skipped money as an economic indicator because of its mobility and ambiguity, trying instead to map the processes through their physical manifestations. I have never regretted this choice. To give an example, what about taking the pulse of the economy in physical terms by measuring its demand for energy? The analysis made by Hugh B. Stewart for the US government is shown in the middle part of the diagram, where the oscillations of primary energy demand and electricity consumption about a fundamental exponential growth curve are given as percentage deviations. This metabolic map is in my opinion the best objective measure of what is going on, and the synchroneity of many different features is very striking.

If we look at the upper part of the diagram, energy prices appear basically constant in constant money, with flares about every fifty-four years. These flares occurred, remarkably, four times in coincidence with the peaks of the sinusoid, which basically mark the midpoint of a cycle and the end of the boom period: three times in the past and at the presumed midpoint of the 1980 cycle. Since these peaks have a width of about ten years, the price of energy in general and oil in particular should fall sharply during the next few years – let's say to US$12 per barrel in 1982 dollars.

Financial macro-collapses systematically occur when the sinusoid crosses the zero level; that is, when the speed of fall is maximum. The last time this happened was in 1929; the next is in 1983. *The curve will not start rising again until the 1990s.*

These results give us a fresh and quantitative insight into the cyclic processes of economic activity, and can be used to assess the value of what is being done to deal with the consequences of collapse, and the potential of what could be done.



(*Top part*) Indexed US energy prices. (*Middle part*) Oscillation of US energy demand about its fundamental exponential growth curve. (*Bottom part*) Pairs of invention and innovation waves (black lines) and curves for world primary energy substitution (blue curves).

The Futility of Conventional Measures

The basic cause of weakness, as we saw, is saturation of markets. Can we manage this? Let's take the case of the car. The question boils down to inducing people to own more cars. Apart from the fact that this would only displace the problem by a few years, I am convinced that there is a configurational maximum, the internal logic of which starts to be unveiled.

The first thing governments are called on to do during a recession is to help keep the show running. This is usually done by deficit spending. Deficit spending means that the state takes money from people who have saved it to spread it around for somebody else to spend. This money will never come

back, as is well known. The US government last gave back the principal in 1833. Italy has already spent, in deficit, about 70 percent of all available credit in the nation, which makes reimbursement impossible.

There would be nothing wrong with deficit spending if it were not for two things: the process is self-priming and the recession lasts too long. In other words, the medicine will run out long before the patient is cured. It is perfectly clear that Italy cannot operate over the next ten years as it has done for the last ten, and the USA may reach a similar position only five years from now. And there are ten more years to go before the upturn.

This raises the question of why so much money is available for governments, and for dubious customers in general. On a rough estimate, a trillion dollars in international loans will never be repaid; double this for internal debts. The simplest explanation is that in a phase of boom this money would have gone to industry, but with markets saturating, industries did not really need this much capital. Capital therefore went to customers able to promise to pay high interest rates, even with improbable collateral.

These loans can also be seen as a form of deficit spending. Because the markets were saturating at home, developing countries were given the money to buy goods (otherwise unsaleable) to put a face of proper business formalism on what was actually a give-away in the Marshall Plan style. This mega-lie may strike back destructively on the world banking system when the circular guarantees game is no longer able to hold.

Another form of give-away is to enhance the production of arms, objects to be destroyed, and, *hélas*, to destroy. In this area as well, the temptation is strong and the pressures from the industrial establishment immense. A market of mutually destroying gadgets is ideal as it never saturates. If one adds to that the political necessity of dealing with social dissatisfaction – with an estimate of some 70 million unemployed in western countries in 1988 – the temptation to export the problems via a war becomes strong indeed. The troughs in the diagram have been times of international aggression, culminating, for example, in the Second World War just toward the end of the previous recession (depression) period. The next trough is in the middle 1990s; a war then is something we should certainly find a way to avoid.

How to Lose Least on the Swings

A natural question at this point is how the insights that the analysis gives us into the mechanisms of the recession may help us reach the next boom with a minimum of damage. One point is very clear in the analysis: that the process consists of a transfer of tasks and skills from one class of activities in phase-out configuration to another class in the phase-in stage. The keywords of this transition phase should then be *flexibility* and *adaptability*.

This breaks down into a host of possible initiatives. Instead of giving money (from banks or the state) to the ailing car industry, for instance, it would be much wiser to give the money to the employees themselves, to help them resettle and perhaps start their own businesses. The first procedure can be seen as a freeze, the second as a "fluidifying". Through such a procedure, Olivetti – once a monoculture in the Ivrea area of Italy – has seeded a host of small enterprises which are, in turn, supporting still newer initiatives. The Japanese also follow this policy.

Entrepreneurs will sow the seeds of the upswing during the next twenty years by launching new products – about a hundred according to my estimates. Why not help by giving them money and perhaps even not taxing them? As they will have a lot of technical problems to solve to start their concerns, why not put at their disposal, for nominal fees, the research capabilities of the state? The invention curve of the 1980 wave shows that practically all the inventions going into the next innovation wave have already been made. What's necessary is their development, and this is where state research laboratories, such as the nuclear laboratories, would be appropriate.

During the recession of the 1930s the keynote for state intervention was public works, such as building the European autoroutes. New highways are no longer needed – remember that car markets are saturating – but cities have grown at a hectic pace during the last thirty years, and they tend to be messy beyond description. Improving their comfort and aesthetics is probably one of the most fruitful tasks the public sector can devote itself to this time.

Simple institutional changes could also greatly help. Part-time work, to give one example, would not only keep more people off the breadline but also offer them a lifeline by giving them the chance to move into a new activity. In other words, it increases mobility and creativity.

Deficit spending, as I said, can be seen as a confiscation of money saved and its redistribution for social reasons. In this form it may not last long. But the redistribution could still be obtained by more natural and honest means. In particular by providing services still in great demand, whether babysitting or plumbing or house restoration. The corresponding jobs went out of fashion when the industrial myth proposed nut-fastening as a supreme accomplishment and social liberation. Realizing that the tunnel is very long may revamp such attitudes. Institutions and media could certainly help.

By changing emphasis I am also, perhaps incautiously, stating that Reaganomics, Thatcherism, Mitterandism, etc. are bound to break their promises, together with the monetarists, nervously turning disconnected knobs. My current problem, as a student of the system, is to determine how they could act otherwise, given better knowledge of the cyclical dynamics.

Dr. Marchetti's work on invention and innovation cycles is detailed further in RR-81-29, *Society as a Learning System: Discovery, Invention, and Innovation Cycles Revisited*, available from IIASA. A report under the same title as the present article is forthcoming. Dr. Marchetti came to IIASA in 1974 from EURATOM. He had previously worked in nuclear physics and engineering internationally and in his native Italy. He is a co-editor of the *International Journal of Hydrogen Energy* and of *Technological Forecasting and Social Change*, and holds an honorary degree in science from the University of Strathclyde, Glasgow, UK.

A BI-EQUILIBRIUM MODEL OF BI-VALUED TECHNICAL PROGRESS EMBODIED IN INNOVATIVE INDUSTRIAL INVESTMENTS IN U.S. INDUSTRY BETWEEN 1900 and 1934

by
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Working Paper No. 53
December 1981

prepared for the Eighth International Economic History Congress 1982, Budapest, August 1982

Abstract

In a competitive economy, progress is a two-edged sword. A bi-valued concept of Schumpeter's notion of economic dynamics as a Process of Creative Destruction is being presented and applied to U.S. industry development 1900-1934. Both the cyclical variations and structural changes in production, employment and investment are being explained as consequences of shifting biases in extensifying and intensifying technical progress. The explanatory power of the bifurcation theory is evaluated by the correlation of observed and calculated trend deviations; the r-square value is .785 (see Figure 4.2 for an illustration of the goodness of fit).

Acknowledgments

The research was financially supported by the Weatherhead School of Management, Case Western Reserve University, in the context of establishment of a teaching and research program in technological innovations management and entrepreneurship (TIME), and assisted by Charles Coutinho, MBA.

Special thanks go to very special persons. David A. Bowers added confidence in the evaluation of the theory by suggesting to check its robustness against various methods of detrending. Wilhelm Krelle's insistence upon work on the economic foundations helped focussing the research. Gerhard Rosegger's views contributed significantly to the historico-inductive generalization presented in this and a forthcoming joint paper, and the exciting collaboration with Herman Wold on the application of his Partial Least Square Soft Modelling to a multiple-indicator version enriched the bifurcation analysis far more than is visible here, for example, by the use of Svante Wold's spline function.

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1. Introduction

Nathan Rosenberg's guidelines for this session of the 1982 Economic History Congress pose the following question:

> "What has been the precise nature of the interactions between technical progress, investment and employment in the process of economic growth?"

I am starting with the perception that the emphasis in the question is on precision of the answer. In other words, any historical description of the said interactions should receive evaluation, within some theoretical framework, of the explanatory power of the described relationships. Primary research objectives therefore are the assessment of r^2_{XP} (the square of the correlation coefficient r_{XP} between some observed indicators P and some theoretical values X calculated from a theory-based model), under the side condition that r^2_{XP} as a measure of explanatory power of the chosen theory should be fairly high, say, above α. In the bi-equilibrium model described in this paper and explained elsewhere (Mensch, 1977, 1980, 1981), an $r^2 > \frac{2}{3}$ obtains even in the case of a simple version based on the Bifurcation Theory of Innovation, which I consider as being a constructive specification of the dynamic economic system as a Schumpeterian Process of Creative Destruction.

Thus, my main proposition is that technological progress is ambivalent in general, and dialectical or bi-valued at the least. The known epistemological history of the Dialectical Principle reaches back to Socrates, and forth via Hegel's dialectics (under certain conditions, B is both A and non-A) into the fundaments of innovation research: Samuelson reports (in the Foreword to Georgescu-Roegen's Analytical Economics), that his "old master, Joseph Schumpeter, once hoped to collaborate with Nicholas Georgescu-Roegen on a definitive economic treatise." Technological innovations as processes of becoming cannot usually be classified by the Principle of Contradiction (B cannot be both A and non-A), because ambiguities prevail where there is innovation (Georgescu-Roegen, 1966, p. 23).

Ambiguity, however, is the very antidote to precision, confronting the theorizing economist with a dilemma. How has this dilemma been resolved in the past? By splitting up into separate attacks on the subject matter:

(i) On the one side, innovations research proceeded on the historico-inductive path of inquiry (case studies, statistical inferences, etc.), collecting rich stocks of specific data but remaining flabby with respect to normative aspects such as optimality, efficiency, etc.

(ii) On the other side, innovations research proceeded on the logico-deductive path of inquiry (axiomatizing, model building, etc.), developing rich stocks of general theory such as the neoclassical and neokeynesian systems of production and technical progress, but remaining flabby with respect to empirical aspects such as strategic behavior, shifting expectations, etc.

As separate approaches, both lines of attack have probably come pretty close to where the best practice research frontier could maximally be under constrained suboptimization. Thus, without infusion of (ii) type knowledge empirical innovations research cannot become more accurate (in H. Wold's sense: parameter accuracy and predictive relevance, Wold 1981). Without infusion of decisive evidence of (i) type, theoretical innovations research cannot become more informative (in K. Popper's sense). Under constrain suboptimization (over-specialization), any line of theorizing would soon reach the stage of satiation which Nelson maintains the neoclassical school has reached in toto: "It is my belief that research, guided by the neoclassical paradigm, has reached a stage of sharply diminishing returns, with many important questions still not resolved adequately" (Nelson, 1981, p. 1032). My view of the direction of theoretical advancement is different. In my view, the neoclassical achievement is not a barrier to but a basis for further progress in economic science and innovations research. Obviously, the research priorities (precision!) necessitate working with the theoretical system that has reached maximal precision this far. If improvements (increasing returns) have to come by way of combining theoretical approaches, then one would expect that in the medium run, the combination (intersection) of two logico-deductive schools would not increase returns if both were constrained suboptimizing in the first place, whereas the combination (union) of historico-inductive and logico-deductive researches would probably yield increasing returns even if both were constrained suboptimizing in the first place, when splitting into (i) and (ii).

Thus, it is my view that when further research is starting from neoclassical and neokeynesian theory, the observed decreasing returns under conditions of over-specialization can be turned around by two partial generalizations: One is giving up the restrictive practice of assuming the Inada Condition (uniqueness=non-existence of multiple roots of the production function and progress function), the other one is adopting the notion of phase transition or disarrangement of economic regime (Slutzky, 1937, Georgescu-Roegen, 1951), thus augmenting the set of possible developments. In other words: Discontinuous developments should not be ruled out *a priori* (as is done so often in models that adhere to Marshall's Principle of Continuity), and ambiguities in development should be made explicit (and not suppressed by assuming "well-behaved" production and progress). Progress just is not "well-behaved" but ambiguous, and if this were the appropriate place to state a <u>theorem</u> on "badly-behaved" progress, it would read:

Dialectical progress (bi-valued technological change) leads to:

(a) multiple roots (ambivalence made explicit) in neoclassical production functions and neokeynesian progress functions, and to
(b) structural instability (potential for regime change) of the economic system.

In the following sections, this essay gives the proofs by construction, and that purpose determines the structure of the essay.

2. Historico-Inductive Generalization: The Metamorphosis Model of Industrial Evolution

Space permits only a very eclectic depiction of the macro-dynamics of economic change, as they have emerged from a century of empirical work on change and innovation. Antithetical to the early work of the German Historical School, Julius Wolf (1912) developed some working hypotheses under the grossly exaggerated denotation of "laws", which later, however, greatly influenced the research of Wesley C. Mitchell and his young colleagues at the NBER; hence we find several references to Wolf's "Laws of Retardation of Progress" in S. Kuznets' 1928 article on Retardation of Industrial Growth and in his 1930 book on Secular Movements, and in A. Burns' Production Trends in the United States since 1870 (1934, pp. 41-43). On the other hand, Mitchell and other business cycle experts discounted the innovation cluster theory of business cycles which Schumpeter had accentuated in his Business Cycle (1939, p. 75):

> "Innovations are not at any time distributed over the whole economic system at random, but tend to concentrate in certain sectors and their surroundings."
>
> "Innovations do not remain isolated events, they are not evenly distributed in time... on the contrary, they tend to cluster, to come about in bunches."

Ruttan (1971, p. 76) correctly observed that "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 type of periodicity which Schumpeter identified." Lewis (1978, pp. 70-71) even questioned the correlation between clusters of innovations and business cycles. Hence, the early (Schumpeterian) version of innovation cluster theory must be judged a partial failure.

The modern (post-Schumpeterian) version of the innovation cluster theory is still in its formative stage. While synthetical to the earlier version, it differentiates more carefully between types of innovation, their short- and long-term preconditions and their micro- and macro-effects. These points I shall demonstrate within the subsequent two subsections. What I perceive of the main difference in the Schumpeterian and the post-Schumpeterian theoretical foundations is this: Schumpeter conceived of the innovator-entrepreneur as a disequilibrator (disruption of equilibrium), a point repeatedly made by Kirzner (who then overdid it by postulating in reverse a general equilibrating tendency in innovation); post-Schumpeterian theory views innovations times as equilibrating in effect, times as disequilibrating in effect, depending on persistence or transition of the economic regime then in place. In Section 4, I operationalize this ambivalence by means of a bi-equilibrium model.

2.1 Moving Industrial Frontiers: Basic, Improvement and Pseudo Innovations

Qualitative and quantitative growth of the production capacity of the economy means an extension of the time frame, the size, or the qualification

of physical and human capital in use. Productivity growth means intensifying of the usage. If extensification and intensification comes by way of strategic investment, much of it will be innovative to some positive degree and not mere pseudo innovation. Then progress can be modelled. The basic proposition is that progress is bi-valued, namely a stream of extensifying and a stream of intensifying effects.

In the aggregate, E_t is the stream of extensifying effects from investment and R_t is the stream of intensifying effects from investment, such that total investment I_t over $t = 0, 1, 2, \ldots,$ is

$$I_t = p_{11}E_t + p_{12}R_t \qquad (2.1)$$

Micro-economically, innovative investments mean moving "the extensive margin" and/or "the intensive margin" (Hahn and Matthews, 1964, p. 840, with reference to Ricardo) of products and productive services: Within a given branch of industry, such movements are improvement innovations on the best practice frontiers of industry, defined either as quality frontiers or as cost frontiers. It is customary to denote these improvements as product and process innovations, respectively. I furthermore distinguish basic and improvement innovations to indicate different degrees of radicalness (Mensch, 1972, 1979): Basic innovations establish new branches or revolutionalize existing branches of industry.

Whereas in the Schumpeterian version of the innovation cluster theory there is considerable ambiguity as to which type of innovation clusters when, there is specificity in my version. This is shown in Tables 2.1 and 2.2, where results of empirical research on the types and shifting frequencies of types of innovations are patterned in--what I hope --a meaningful way.

Table 2.1 assigns types of innovations by degree of radicalness (basic, improvement) and by main purpose (product versus process), and introduces the Principal Generalization grounded in empirical innovations research: Over long periods in economic history, there is a recurrence of Phases I, II, III and IV, and during these phases, the relatively most frequent type of innovation is (1), (2), (3), (4). The empirical analysis confirms Georgescu-Roegen's conjecture on the long-run cycles: "The economic cycles seem to be better described by phase-periodicity than by point-periodicity, since the relevant aspect of the business cycle is the recurrence of the phases and not the repetition, after a constant time-lag, of the same values" (Georgescu-Roegen, 1966, p. 303). Figure 2.1 (The Metamorphosis Model) depicts this phase-periodicity over the long haul.

These are the highlights of the empirical findings on the shifting relative frequencies of various types of innovations (see Table 2.2):

(1) Basic innovations of the product-and-service-additive, extensifying type cluster in Phase I (Mensch, 1979);

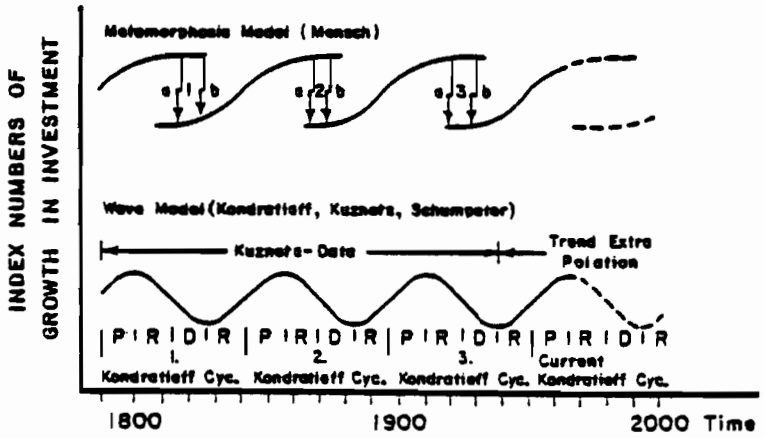
(2) Product innovations in young industries cluster (Freeman, et al. 1980) and come in sequences (Mensch, 1975) in Phase II;

(3) Process innovations increase in frequency and even crowded-out product innovations (Abernathy and Utterback, 1975) in Phase III;

(4) Basic innovations of the product-and-service-replacing, strongly intensifying type cluster in Phase IV (Mensch, 1979, Mensch and Schnopp, 1981).

Thus, the micro-economic movements of the extensive and intensive margins of industry drive the economic process in a certain pattern as depicted by the Metamorphosis Model (Figure 2-1). Corresponding to successive long-term sigmoid tend curves is the notion of a recurrent motion through the same trend phases as indicated by the circle in Tables 2-1 and 2-3.

THE METAMORPHOSIS MODEL OF LONG-TERM INDUSTRIAL FLUCTUATION



SOURCE: G. MENSCH, Stalemate in Technology, Cambridge 1979, p.73

Figure 2-1

In the long run, the most remarkable features of the Industrial Metamorphosis are the phase transitions, and their relationship to the relative frequency and degree of radicalness and effectiveness of innovations, shown in Tables 2.3 and 2.4. While the extensification and intensification of businesses moves the economy in the aggregate, the precise nature of the motion is determined by relative frequency times relative effectiveness of the activities. Table 2.3 indicates that the economy moves through the same quadrants as in Table 2.1. The motion is driven by micro-economically motivated, strategically planned, extensifying and intensifying moves of firms, on one end, and is paced by the aggregate effects on the whole economy, on the other end. Table 2.4 translates these perceptions into ordinal estimates which could be transformed into cardinal estimates on E_t and R_t, and E_t/R_t, the latter being a measure of bias. In fact, even more remarkable than the notion of economic growth $\Delta Y/Y$ of output Y as a function F of the difference of E_t and R_t is the hypothesis that in the short-run as

Long-Term Cyclical Variation in the Frequencies of Types of Technological Innovation Over Time: Circular Motion of Respective Innovation Clusters

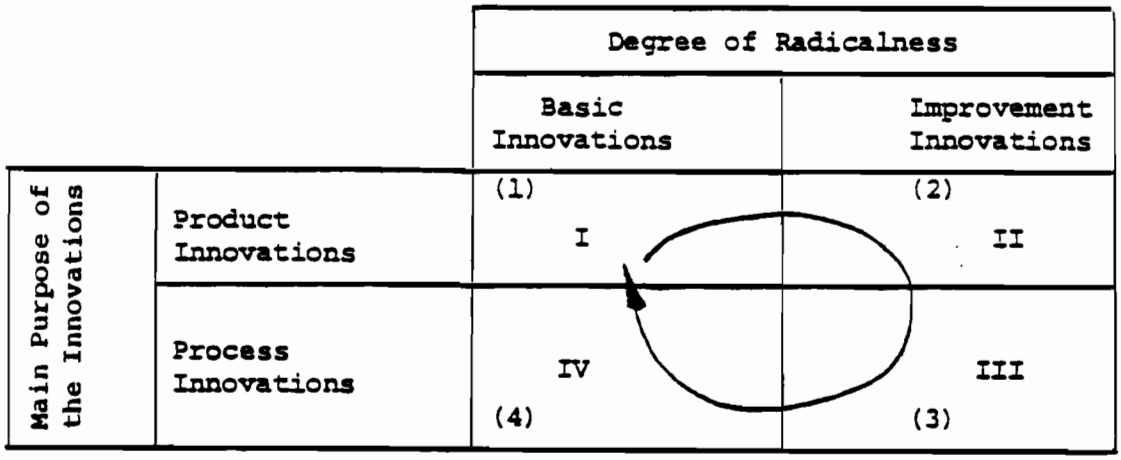


Table 2-1

Shifting Relative Frequencies of Types of Innovations and Phase Transitions in the Long Run

Trend Period (Phase)	Changing Frequency Mix and Cross-Overs (1)	(2)	(3)	(4)
I "Recovery"	rel. many	Ø	rel. few	Ø
II "Prosperity"	Ø	rel. many	Ø	rel. few
III "Recession"	rel. few	Ø	rel. many	Ø
IV "Depression"	Ø	rel. few	Ø	rel. many

Legend: Ø = average or lower

Table 2-2

Long-Term Shifts in Predominant Growth Effects:
Shifting Frequency Distribution of
Various Types of Technological
Changes over Time

Type of Strategic Effects		Degree of Effectiveness of the Mix of Investments	
		Radical	Moderate
	E = Extensifying	(1) I	(2) II
	R = Intensifying	IV (4)	III (3)

TABLE 2.3

The Shifting Balance of Speed-Up Factors and Slow-Down
Factors which Control the Rate of Economic Growth

	Various Effects of Mix of Innovations			
	Expansionary		Contractionary	
Trend Period	(1)	(2)	(3)	(4)
I "Recovery"	+++	+	-	--
II "Prosperity"	+	+++	-	-
III "Recession"		++	---	-
IV "Depression:	+	+	--	---

Legend: Highly expansionary = +++
:
Highly contractionary = ---

TABLE 2.4

well as in the long run, phase transitions from prosperity via recession to depression and from depression to recovery are intimately linked to the changes in frequency and degree of radicalness of innovation types; these transitions being determined as threshold levels on the bias indicator E_t/R_t. Obviously, $E_t/R_t \overset{\log}{\equiv} E_t - R_t$. It may be worthwhile to report that I have been able (together with Haag and Weidlich) to design a business cycle model and prove a limit cycle theorem on the motion of the variable

$$\frac{E_t - R_t}{I_t}, \tag{2.2}$$

which is an indicator of the biasedness of the investment structure, and applying it successfully to the analysis of industrial fluctuations in West German industry 1950-79 (The Schumpeter Clock. Mensch, Weidlich, Haag, 1981).

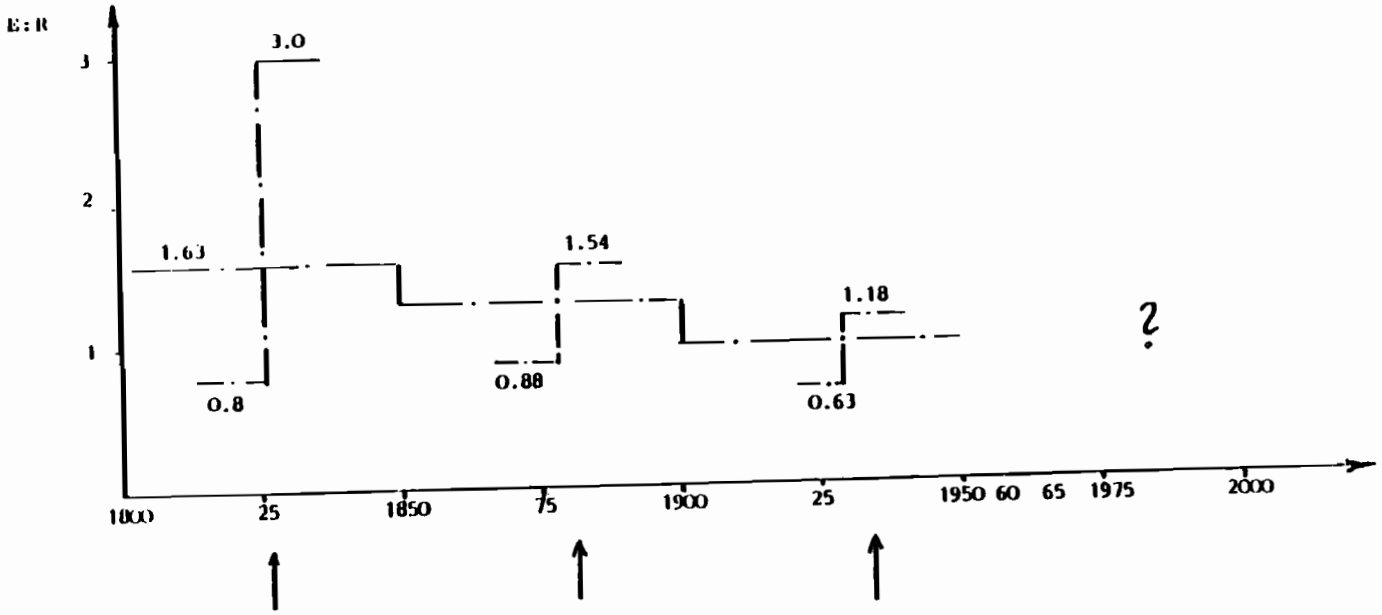
Our short-term model is based on formal relaxation theory (which should intuitively make sense, too, considering that the economy moves in response to tension created by extensionary and intensifying intentions). In the longer sweep of history, the relaxation potential of the economy is restored, from time to time, by extraordinary extensification (clusters of basic innovation such as around 1825, 1886, and 1935), driving the E/R ratio up temporarily into a multiple (in Phase I) of the low value previously obtained (in Phase IV), see Figure 2.2.

2.2 Lead Sector Growth, Retardation, the Rationalization Bias, and Structural Instability

By way of historico-inductive generalization, we have arrived at a specific formulation of dialectical economic change (a la Schumpeter's Process of Creative Destruction): total (strategic) investment in t is the sum of all expenditures $p_{11}E_t$ devoted to planned extension of useful industrial capabilities, and $p_{12}R_t$ devoted to the planned intensification of usages (rationalization); and production growth is a function F of the net effects E_t, R_t

$$\Delta Y/Y_t = F(E_t, R_t) \tag{2.3}$$

The existence of relation (2.3) was empirically validated by Kleinknecht (1979) with German data 1950-1979. He was showing that industries that were affected by basic innovations in the cluster around 1935 ("innovation industries") grew fastest in the 1950s and part of the 1960s, but lost their above-average growth rates later on, thus converging to cross-sectoral average growth (which stagnated in the 1970s). Thus, the innovative impetus of Phase I becomes reinforced in Phase II, is levelling off in Phase III, and becomes exhausted in Phase IV. Phase IV I call a "Stalemate in Technology", because the old technology is mature and becomes average-practice (Wolf's "Law"), but the new expansionary basic innovations have not yet emerged. In the meantime, the industrial firms seek to maintain their market and profit position by resorting to stronger intensification schemes. Whereas a rationalization bias develops already in Phase III, in Phase IV this bias becomes even stronger through the



The Step-up of E/R-Ratio at the Occasion of Clusters of Basic Innovations in the Years around 1825, 1886 and 1935. (All basic innovation in G. Mensch, Das technologische Patt, op.cit., have been classified in E-type (expansionary) and R-type (rationalizing) innovations by a team of colleagues at the International Institute of Management, Berlin, whom we want to thank for their help at this occasion).

Source; Mensch, G. and Schnopp, R.: Stalemate in Technology, 1925-1935: The Interplay of Stagnation and Innovation, in: H.W.Schröder und R.Spree, Wachstumszyklen der deutschen Wirtschaft im 19.und 20. Jahrhundert, Klett-Cotta, Stuttgart 1980

Figure-2.2

further diminution of the extensifying progress and the stronger reinforcement of the intensifying progress. The economy becomes structurally unstable because of the saving (reduction) of labor input, materials supply, and intermediate goods. Students call this "the factor squeeze."

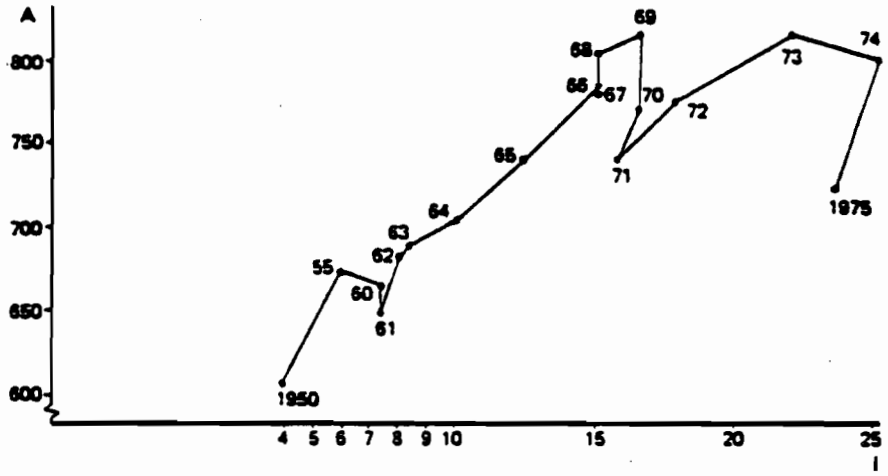
Hence, while the volume of strategic investment expenditures may be increasing or at least not falling, in the aggregate

$$I_t = p_{11}E_t + p_{12}R_t \qquad (2.1)$$

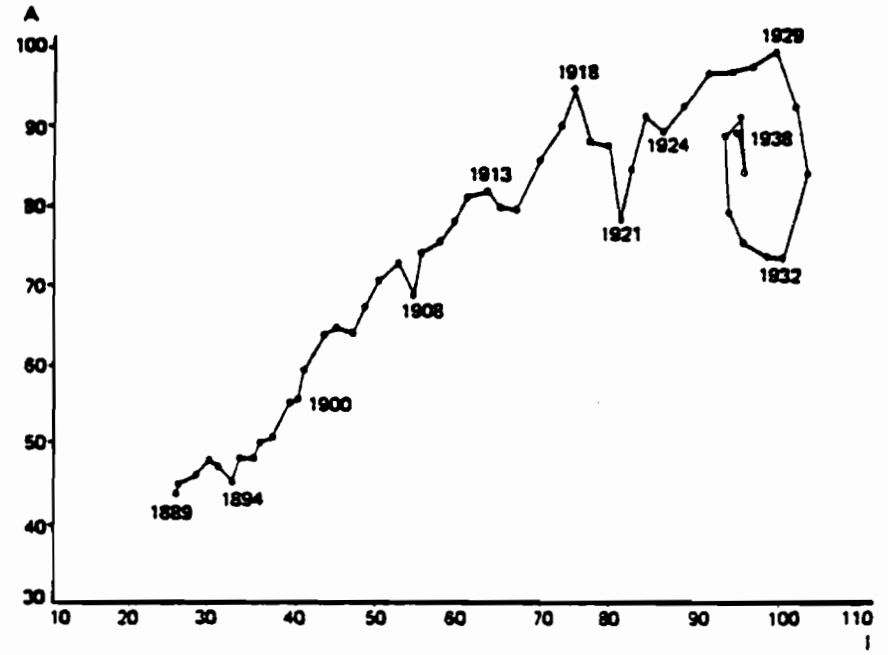
due to increasing $p_{12}R_t$, the effect on overall growth may be contractionary, which would explain the breakdown of the multiplier. At the same time, labor employment, measured in hours, A_t, would go down. Since employment is a planned commitment of employers to employees, and is planned simultaneously with $p_{12}R_t$ and $p_{11}E_t$, it will be set at the level

$$A_t = p_{21}E_t - p_{22}R_t \qquad (2.4)$$

Figures 2.3, 2.4 show the co-variance of I_t, A_t in U.S. industry in the period 1900-1938 and in period 1950-1975, indicating for both periods an increase in the volume of investment, but a structural change with labor-saving tendency (rationalization bias) beginning roughly in 1918/19 and in 1968/69, respectively. This is the time where I would expect structural instability to have come in, as will be discussed in Section 4. Before we can do this in the context of a model that allows for evaluation of precision, we must discuss the necessary extension of the models available (the neoclassical, postkeynesian). This is being done in the next section (Section 3).



Legend: A = labor input indicator [Bill. weekly manhours]
I = capital input [Bill. of current dollars]
Data source: Stat. Abstracts of the USA, 1976, Series 13o3
ILO-yearbooks, 58er, 66er, 76er.



Legend: A = labor input index (1929 = 100)
I = capital input index
Data source: Kendrick, J.W., *Productivity Trends in the United States*, Princeton University Press, 1961, p. 328.

Data for Capital - Labor Allocation in U.S.
Source: Mensch (1979) p. 76

Figures 2.3 and 2.4

3. Dialectical Progress Violates the Inada Condition

Since we are probing into "the precise nature of the interactions between technical progress, investment and employment in the process of economic growth" (Rosenberg), with emphasis on precision, the previous historico-inductive generalizations clearly are still too unspecific and wanting of an evaluation framework for precision. This section is devoted to the examination of neoclassical production theory plus its neokeynesian extension (Kaldor's technical progress function) as a possible evaluation framework.

It turns out that the standard and the extended neoclassical theory, as it stands, is unsuitable for evaluative purposes: The special, one-valued notion of progress leads to ambiguities. This does not mean, however, that the neoclassical analysis is useless; it only suggests that a formulation must be found which makes these ambiguities explicit.

3.1 On the Inappropriateness of Assuming Smooth Neoclassical Production

Let Y, K, and N denote real output, capital input and employed labor, respectively. Then F_1 is the standard neoclassical production function in extensive form, relating output in a positive way to input:

$$Y = F_1(K,N) \tag{3.1}$$

If the Inada Condition holds, (3.1) can also be written in intensive (per capita) form (Solow, 1956) by dividing through both sides by the total available labor force L

$$y = F_1(k,n) \tag{3.2}$$

where $y = Y/L$ is real output per head, $k = K/L$ is capital intensity, and $n = N/L$ is the employment rate. The Inada uniqueness condition requires that there are no multiple roots of F_1; this is stated as

$$\frac{dy}{dk} > 0, \frac{dy}{dn} > 0, \frac{ddy}{ddk} < 0, \frac{ddy}{ddn} < 0 \tag{3.3}$$

Simultaneously, (Darity, 1981, p. 980) a function F_2 defines the average product of capital, Y/K, as negatively related to k and positively related to n

$$Y/K = F_2(k,n) \tag{3.4}$$

such that

$$\frac{d(Y/K)}{dk} < 0 \quad \text{and} \quad \frac{d(Y/K)}{dn} > 0. \tag{3.5}$$

Now, if the Inada Condition (3.3) holds, the well-known neoclassical result obtains that the average product of capital exceeds the marginal product of capital (except in the odd cases of a zero or infinite capital intensity):

$$\frac{dy}{dk} < \frac{Y}{K} \quad \text{for all } 0 < k < \infty \tag{3.6}$$

Obviously, (3.6) is at odds with all evidence from innovations research. Hence, it is the imposition of the Inada uniqueness condition which constrains neoclassical analysis and rules out Schumpeterian effects. Hence, it has to be given up in work which does not ignore innovations.

3.2 The Historical Facts do not Allow Us to Assume Well-Behaved Neokeynesian Technical Progress

At this juncture, we ignore the possible difficulties that may arise in writing the intensive form (3.2) if the Inada condition is given up, and extend the intensive form in the Kaldor (1957) way (3.7). Whereas the intensive form of the production function postulates a relationship between output per man and capital per man, the technical progress function F_3 postulates a relationship between growth of productivity and growth of capital intensity

$$\frac{1}{y}\frac{dy}{dt} = F_3\left(\frac{1}{k}\frac{dk}{dt}\right) \tag{3.7}$$

If the technical progress function F_3 is linear

$$\frac{1}{y}\frac{dy}{dt} = a + b\,\frac{1}{k}\frac{dk}{dt} \tag{3.7a}$$

then it implies an underlying Cobb-Douglas production function with constant returns in the intensive form

$$y = c\ell^{at}k^{b}, \tag{3.7b}$$

where $y = Y/L$, c = constant, and $m = a/(1-b)$ is the Harrod neutral rate of technical progress. Since nonlinear F_3 is not generally integrable, there is not necessarily a production function lying behind it (Black, 1962).

Be that as it may, the point to be made is that in view of the empirical facts, F_3 ought to be nonlinear, and, furthermore, not constricted by the Inada Condition. In Figure 3.1 we present pertinent data (from Fabricant, 1942, Table 4) on the change of $\ell = L/Y$ in terms of average annual percentage changes $\Delta\ell/\Delta t$ for four periods 1899-1909, 1909-1919, 1919-1929, and 1929-1937 in a large sample of U.S. industries. Obviously, the relationship (3.7c), derived from (3.7),

$$\ell = F_3\left(\frac{1}{k}\frac{dk}{dt}\right)\frac{dt}{dy} \tag{3.7c}$$

Average Annual Percentage Change of ℓ = L/Y over Four Periods 1899-09, 1909-19, 1919-29, 1929-37

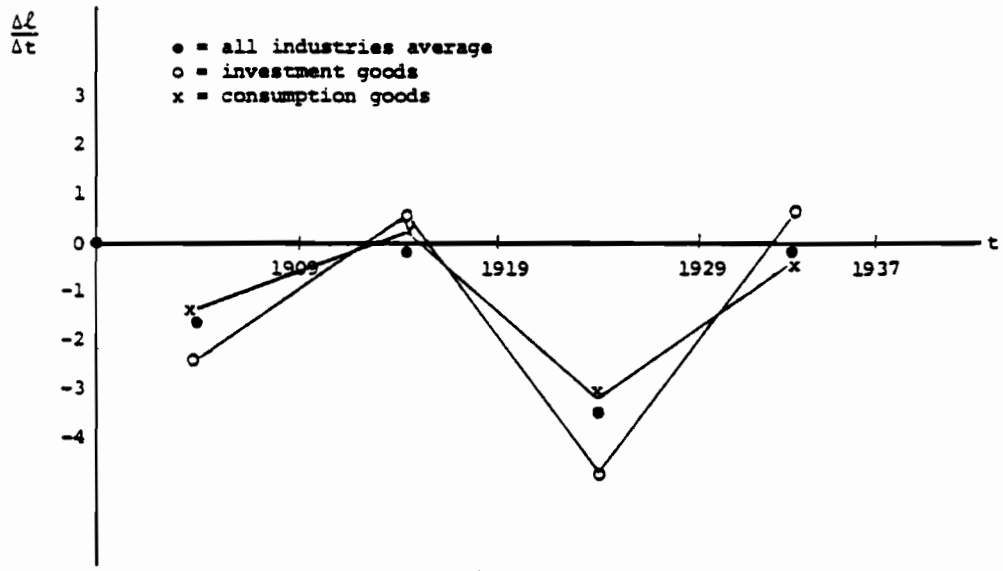


Figure- 3.1

Change in Average Percentage Change of ℓ = L/Y from Period to Period: 1899-09 to 1909-19, 1909-19 to 1919-29, and 1919-29 to 1929-37

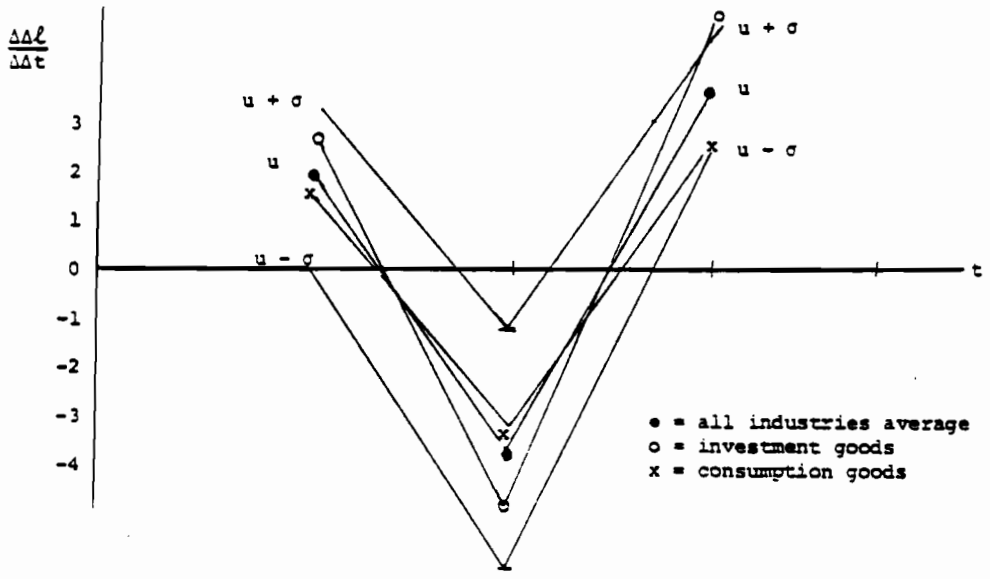


Figure- 3.2

cannot be linear. Furthermore, given the alterations of the signs of $\Delta\Delta\ell/\Delta\Delta t$ as illustrated in Figure 4, depicting the period-to-period change of $\Delta\ell/\Delta t$, it is also obvious that the Inada Condition (3.3) is violated by the historical facts. Since we cannot change the facts, we will have to stop imposing the Inada Condition instead in our theoretical research.

3.3 Dialectical Progress Creates Ambivalence

The issue, of course, is that by assuming a "well-behaved" production or progress function F_1, F_2 or F_3, the ambiguity involved in progress as a dialectical process is shoved under the carpet. Part of the ambiguity reappears, for example, in Uzawa's Two-Sector Model of Economic Growth (Uzawa, 1962, 1963), and Solow's (1962) comments on Uzawa's capital-intensity condition: if production is neoclassical, steady growth and stability maintains only if the consumption-goods sector is always more mechanized (investment-good absorbing) than the investment-goods sector. Solow pointed out that violation of this condition could come about only "if, while the separate machine labor ratios should be rising, the less machine-intensive industry should gain enough at the expense of the more machine-intensive one to permit a fall of the overall machine/labor ratio" (Solow, 1962, p. 49). "That is, the value of k may change continuously, but the value of dk/dt may change in discontinuous or capricious ways" (Inada, 1963, p. 122).

Precisely this "discontinuous or capricious" behavior of technical progress as embodied in the application of new investment goods in both the investment-goods and the consumption-goods sectors begs for an explanation. Wicksell knew this problem under the name Akerman's Problem, which he found "so complex that the vast majority of economists, including myself, have almost entirely passed it by as being too difficult to be susceptible to analysis" (Wicksell, 1934, p. 258).

Within the context of Uzawa's two-sector model we can show that the assumptions of neoclassical production theory, namely, on one end, the assumption of the co-existence of F_1 and F_2

$$\frac{Y}{L} = F_1(k,n) \qquad (3.2)$$

$$\frac{Y}{K} = F_2(k,n) \qquad (3.4)$$

and, on the other end,

the assumption of uniqueness of F_1 and F_2, are at odds with the historical facts--at least those facts that represent economic crises, such as the reconversion crisis 1920/21 and the great depression after 1929. The historical data indicate that in the period under consideration, the capital intensities in the two sectors move in violation of the Uzawa condition: There are cross-overs in the sector-specific time series on the motion over time of $\ell = L/Y$. Figures 3.1 and 3.2 show these cross-overs in terms of the data for $\Delta\ell/\Delta t$ and $\Delta\Delta\ell/\Delta\Delta t$, respectively.

Consequently, the assumption of non-existence of multiple roots of F_1 and F_2 is empirically unjustified. Both the cross-over of the sector-specific $\Delta\Delta\ell/\Delta\Delta t$ and the change in sign as the cross-over occurs (see Figure 3.2) indicate that the neoclassical conditions of well-behaving progress (the product of capital condition and the capital intensity condition) are not generally true, as Inada pointed out two decades ago, and contingent upon an untenable supposition; namely, that the Inada uniqueness condition would hold in practical application of neoclassical production theory and its neokeynesian extension.

This also completes the proof of part (a) of the theorem stated in the introduction: Provided the ambiguity displayed in Figure 3.2 is caused by bi-valued technical change (demonstrated in Section 2), then such a change would lead to ambivalence in the Inada-constraint neoclassical production function and postkeynesian (Kaldor) technical progress function; ambivalence to be made explicit as multiple root problems in further research. Table 3.1 exhibits the labor market turmoil associated with the ambivalence that results from dialectical progress (Fabricant, 1942, Table 13).

INCREASES AND DECREASES IN WAGE-EARNER EMPLOYMENT IN MANUFACTURING INDUSTRIES, SELECTED PERIODS

Period	*Total Number of Separate Industries*	*Average Number of Wage Earners*[a]	*Increases in Employment*		*Decreases in Employment*	
			Number of Industries with Increases	Sum of Job Increases	Number of Industries with Decreases	Sum of Job Decreases
1899–1909	266	5,370,685	225	1,773,601	41	80,320
1909–1919	290	7,350,597	221	2,443,313	69	372,490
1919–1929	307	8,382,720	144	994,693	163	1,051,019
1929–1937	289	8,472,662	150	834,525	139	629,122

Source: Based on an analysis of the data in Appendix B-1.
[a] Average of numbers employed in the two years compared.

TABLE 3.1

4. Logico-Deductive Specification of a Bifurcation Model of Bi-Valued Change in Investment, Production and Employment

We have seen with the help of neoclassical theory that unsteady economic growth is connected with ambigious economic development, namely, critical cross-overs in the co-evolution of parts of the economy. Schumpeter's concept of the Process of Creative Destructions aids us in understanding the sources of ambiguity: In a world of inter-firm rivalry (Schumpeterian Competition), super-additive effects of technological innovations, embodied in new capital goods owned by a minority of innovating firms, reverse the neoclassical product of capital condition by impacting upon the average capital productivity of the majority of firms' installed old capital stock. Hence, in such situation of critical development, the marginal product of capital exceeds the average product, because the potential contributions of old capital stock turn out to be smaller than planned (sub-additive) after innovations have occurred.

Similarly, neoclassical theory helps understanding the development of structural instability in terms of violations of the neoclassical capital intensity condition, which in turn can be understood as an excess of destructive side effects over the creative effects of technical progress. Such imbalance typically occurs as a transition of phase III to phase IV (see Table 2.1), after a rationalization bias in the composition of investments has weakened the propensity to consume both via a lack of consumer-demand stimulating product innovations and via strong emphasis upon cost-saving, labor-substituting process innovation in industry. The sub-additive effects on the "wage-goods sector" are further reinforced by super-additive effects of basic process innovations which revolutionize established industries and market structures. Again, the Schumpeterian concepts provide an explanation for the bad-behaved temporary disequilibrium cases where the capital intensity of the investment goods sector at least temporarily exceeds the capital intensity of the consumption goods sector.

"The limitation of the neo-classical approach is that it leaves wide open the question: what happens when the output-capital ratio at any time is not that appropriate for steady-state growth?" (Allen, 1967, p. 259). Methodologically, the answering of the question seems to require neo-neoclassical, post-Schumpeterian modelling which incorporates the super-additive main effects and sub-additive side effects of progress into the mathematics of the equations of motion of the economic system. Of the class of models which incorporate such high degrees of nonlinearity, the following example is selected for reason of simplicity and relatively high degree of explanatory power.

4.1 The Production Potential Function

At any time t (say, years 0,1,2,...) investors in industry are planning on improving their strategic production capabilities on the extensive and intensive margins. In terms of total strategic investment expenditures the extensifying effects E_t and intensifying effects R_t amount to

$$I_t = p_{11}E_t + p_{12}R_t \qquad (2.1) = (4.1)$$

for the macroeconomic entity under consideration. Ignoring super-additive effects and sub-additive effects on labor for the moment, we can write a balance equation for the employment effects of E_t and R_t as

$$A_t = p_{21}E_t - p_{22}R_t \qquad (2.4) = (4.2)$$

Equations (4.1) and (4.2) are used to estimate E_t and R_t by a cause-effect transformation analysis, where the four parameters are determined as time constants in an orthogonal transformation scheme

$$\begin{pmatrix} p_{11} & , & p_{12} \\ p_{21} & , & p_{22} \end{pmatrix} = \begin{pmatrix} \sin @ & , & \cos @ \\ \cos @ & , & -\sin @ \end{pmatrix} \qquad (4.3)$$

Although this first approximation appears rather rigid, the high value of r-square achieved with the orthogonal transformation and constant $p_{..}$ in the case of U.S. Industry 1900 - 34 attests to the fruitfulness of the approach, which works with a potential production function as the core construct.

Sub-additive and super-additive effects of technical progress (E_t,R_t) are incorporated in the potential production function Q(Y), which is for any t a function Q_t of planned (=theoretical) production parametrized by the intended effects E_t and R_t on the strategic production capabilities such that after responses of rivaling firms there is a good proximity of effective (market clearing) production Y_t and planned (strategically anticipated) production X_t, such that

$$Y_t = X_t \qquad (4.4)$$

The potential function approach, which is used to compute X_t for the years 1900 - 1934 for U.S. Industry, yields a correlation coefficient $r_{YX} = .886$ for the criterion (4.4), corresponding to r-squre of .785, see Figure 4.2.

The production potential function approach approximates the highly non-linear production potential function $Q(E,R,Y,t)$ by a family of parametrized and periodized functions $Q_t(E_t,R_t,X_t)$ such that

$$Q(E,R,Y,t) \equiv Q_t(E_t,R_t,X_t) \text{ for } t = 0,\ldots,n \qquad (4.5)$$

subject to (4.4).

There exist a number of ways for constructively specifying (4.5) in theoretically meaningful fashion. What makes the specification chosen in this paper both neo-neoclassical and post-Schumpeterian is the incorporation of the Bi-equilibrium Property and the Hysteresis Property.

The Bi-Equilibrium Property is an extension of the neoclassical concept of checks and balances in the forces E(t) and R(t) that control the motion of the productive system over time and usually hold it near some partial equilibrium defined by

$$dQ(E,R,Y,t) / dY = 0 \qquad (4.6)$$

In these marginalist terms, for Q to have the Bi-equilibrium Property requires that under profit maximization, Q should have two maxima separated by a minimum, such that (4.6) holds for all three extrema in general, but for one maximum only at a specific time. Consequently, Q must be double-bivariate, for example, a polynomial of fourth power .

Approximating (4.6) according to (4.5) by a family of functions D_t, called the Production Potential Change Function (PPCF), such that

$$dQ(E,R,Y,t)/dY \equiv D_t(E_t,R_t,X_t) \quad \text{for} \quad t = 0,\ldots,n \qquad (4.7)$$

we can specify this family of functions D_t as a group of cubic polynomials using a Taylor expansion around X_t. For (4.6) to hold in the bi-equilibrium fashion (the system is in a specific production state X_t at any time t, although it sometimes has the potential of switching into an alternative state as there sometimes exist three real roots, depending on the values of E_t and R_t), it is well known that the parameter on the quadratic term must be zero. Hence, a constructive specification of (4.6) and (4.7) is

$$D_t(E_t,R_t,X_t) = X_t^3 - vR_tX_t - E_t = 0 \quad \text{for } t = 0,\ldots,n \qquad (4.8)$$

as depicted in Figures 4.3 and 4.4 in different perspective.

Figures 4.3 and 4.4 reveal why the bifurcation theory of progress is post-Schumpeterian: The relation (4.8) has the Hysteresis Property in terms of inertia in the proportionality between X and E. With the exception of high R (namely, R greater zero) and medium E (namely, E near zero) there is a piecewise linear, positive relationship between X and E, however, with a great potential for switching from a low regime of proportionality to a high regime of proportionality in the medium range. The Hysteresis Property is that the economy would not instantly undertake this transition when the possibility arises; rather, it exhibits inertia (persistence in the historically attained partial equilibrium position). Figure 4.5 shows for the E_t,R_t co-evolution between 1900 and 1915 that the U.S. Industry stayed in a regime of high growth since the E/R ratio was positive (in the lower-left corner). During this period of stable growth, the motion of the economic system was characterized by gyrations near and around the upper-level equilibrium state. After WW1, however, the type of progress changed dramatically: As of 1918, R_t became high, and the resulting rationalization bias modified the gyrations into bang-bang motions in E:R space. Correspondingly, the level of output gyro-cycled until 1916 and then bounced up and down from 1917 on, see Figure 4.2.

At this point, the bifurcation process can be specified more precisely: it is the dialectical nature of the intensifying component of progress (with R(t) as the "splitting variable") that creates structural instability and the potential for the economic process to become discontinuously bouncing instead of continuously cycling. Analytically, this change in the nature of progress comes in focus in Figure 4.4, where the double-bottom nature of the relation between X and R is depicted as the family of curves (4.8) D_t parametrized by E. The splitting character of R comes also to the fore if the proportionality between X and E is made stronger, such that $X = E$. Then (4.8) gives $X=X^3-vRX$, yielding

$$X = \sqrt[2]{vR + 1} \qquad (4.8a)$$

such that the "explosive force" ("implosive force") incorporated into this model is associated with positive values of vR; if vR is, say, -1,0,3,8, then these forces on the level of X and E are +0,+1,+2,+3 and -0,-1,-2,-3, respectively. Hence, vR_t has a critical value, and for the U.S. Industry in the period under consideration, this critical threshold was reached at the end of World War I, when $.9\,R_t$ exceeded zero, see Figures 4.5 and 4.2.

4.2 Empirical Analysis: The Evolution of U.S. Industry Between 1900 - 1934

The evolution of the U.S. industry during the 35 years under study is first of all characterized by the observed index of industrial production based on real output; see Table 4.1 and Figure 4.1 for time series information and definitions. Table 4.1 also gives the employment input (real, physical inputs in terms of labor hours) and new capital input (nominal, strategic expenditures in plant and equipment) for those years. According to Formulas (4.1) and (4.2) these input values give estimates for E_t and R_t as tabulated in Table 4.2. The transformation procedure involves standardizing the observed inputs (dividing by maximal value in the time series as to index the data between zero and one), and orthogonal transformation (with the angle of rotation @ = $1o^{o}$ having been identified the optimal one under parametrical variation).

The co-evolution of E_t and vR_t (the scaled version of the splitting factor, see Table 4.2) is depicted in Figure 4.5. Formula (4.8) with v=.9 (found by parametrical variation as being optimal) is used to determine the three roots X1T, X2T, X3T for the years 1900 to 1934, see Table 4.2. In the right column of Table 4.2 stands the theoretical Index of Industrial Production, XT, as specified by the rules of the Hysteresis principle in the case that in some years there is ambiguity (multiple real roots). See Footnote 2) to Table 4.2 for procedural remarks.

The goodness of fit of the observed index of industrial production, PT (as a measure of Y), and the theoretical value computed from the bifurcation model is given as the correlation coefficient $r_{PT,XT} = 0.874$ ($r^2 = .764$). For the econometricians who prefer to work with detrended values (as I do), the correlation between the detrended criterion variables PDEVT and XDEVT (given in Table 4.3) is 0.886 ($r^2 = .785$).

YEAR	PT	LABHS	FCINV
****	****	*******	*******
1900	50.600	56.000	1.220
1901	56.700	59.500	1.300
1902	63.200	63.000	1.490
1903	65.400	65.500	1.440
1904	62.300	63.900	1.390
1905	73.600	68.200	1.570
1906	78.900	71.800	1.910
1907	80.600	73.800	2.110
1908	68.000	69.300	1.820
1909	80.200	74.400	1.990
1910	85.300	76.900	2.040
1911	82.200	78.400	1.940
1912	93.700	81.400	2.150
1913	100.000	82.500	2.380
1914	94.100	79.600	2.040
1915	109.300	79.200	2.010
1916	129.600	87.200	2.620
1917	129.700	88.800	3.050
1918	128.800	87.500	3.210
1919	113.200	84.300	3.700
1920	124.000	85.300	4.770
1921	100.000	76.200	2.950
1922	125.900	83.000	3.560
1923	144.400	91.600	4.640
1924	137.700	88.500	4.460
1925	153.000	92.100	4.950
1926	163.100	96.300	5.110
1927	164.500	96.700	4.840
1928	171.800	97.300	4.790
1929	181.300	100.000	5.600
1930	155.600	91.500	4.370
1931	129.700	80.900	2.750
1932	100.000	69.400	1.560
1933	119.900	68.500	1.530
1934	129.700	69.700	2.200

Table 4.1

Statistical Indicators on the Evolution of U.S. Industry between 1900 and 1934

PT = Industrial Production Index (1913 = 100) [1)]

LABHS = Annual Man-Hours in Nonagricultural Industries (1929=100) [2)]

FCINV = Fixed Capital Investment (Private Domestic Investment in Producers Durable Equipment in 10^9 $ current prices) 1900 - 1934 [3)]

Sources:

1. Series A15 in Bureau of the Census (1966, p. 168; definitions, p. 133): This index measures the changes in real output in manufacturing, mining, utilities (gas, electricity) exclusive of transportation, construction, service industries.
2. Series A70 in Bureau of the Census (1966, p. 174; definitions, p. 137): Average annual manhours in total private manager-cultural industries, constructed by Kendrick by multiplying his employment estimates by average weekly hours worked and by 52 weeks for each of the included industrial groups, and aggregating them.
3. Series F56 in Bureau of the Census, Historical Statistics of the United States, Colonial Times to 1957(1960) and 1970(1975).

Calculation of a Theoretical Index of Industrial Production

YEAR	ET	RT	VRT	X1T	X2T	X3T	XT
1900	-0.322	-0.676	-0.608	-0.414			-0.414
1901	-0.280	-0.654	-0.588	-0.381			-0.381
1902	-0.234	-0.578	-0.520	-0.360			-0.360
1903	-0.207	-0.615	-0.553	-0.317			-0.317
1904	-0.227	-0.631	-0.568	-0.334			-0.334
1905	-0.172	-0.564	-0.508	-0.290			-0.290
1906	-0.119	-0.416	-0.375	-0.267			-0.267
1907	-0.089	-0.329	-0.296	-0.249			-0.249
1908	-0.151	-0.448	-0.403	-0.304			-0.304
1909	-0.087	-0.390	-0.351	-0.218			-0.218
1910	-0.057	-0.378	-0.340	-0.156			-0.156
1911	-0.043	-0.433	-0.390	-0.108			-0.108
1912	-0.002	-0.346	-0.311	-0.006			-0.006
1913	0.019	-0.239	-0.215	0.085			0.085
1914	-0.026	-0.391	-0.352	-0.073			-0.073
1915	-0.032	-0.403	-0.363	-0.085			-0.085
1916	0.081	-0.145	-0.131	0.333			0.333
1917	0.114	0.056	0.050	0.520			0.520
1918	0.105	0.140	0.126	0.560			0.560
1919	0.086	0.393	0.354	0.692			0.692
1920	0.136	0.909	0.818	0.978	-0.806	-0.171	0.978
1921	-0.032	0.068	0.061	-0.381			-0.381
1922	0.067	0.332	0.298	0.635			0.635
1923	0.202	0.815	0.734	0.971	-0.650	-0.320	0.971
1924	0.161	0.743	0.668	0.918	-0.649	-0.269	0.918
1925	0.219	0.963	0.867	1.038	-0.762	-0.276	1.038
1926	0.272	1.021	0.919	1.082	-0.744	-0.337	1.082
1927	0.267	0.888	0.799	1.029	-0.585	-0.443	1.029
1928	0.272	0.861	0.775	1.021			1.021
1929	0.332	1.241	1.117	1.182	-0.854	-0.327	1.182
1930	0.192	0.684	0.616	0.909			0.909
1931	0.014	-0.052	-0.047	0.178			0.178
1932	-0.159	-0.575	-0.517	-0.269			-0.269
1933	-0.170	-0.585	-0.527	-0.281			-0.281
1934	-0.132	-0.265	-0.239	-0.360			-0.360

Table 4.2

Procedural Remarks:

1) The indicators ET and RT of extensifying and intensifying technical progress, respectively, for T = 1900 - 34, have been calculated from the time series LABHS and FCINV (in Table 4.1) according to the algorithm explained in the text: formulas

2) The theoretical index of industrial production, XT (for T = 1900 - 34) has been determined by choice of one of the three roots X1T, X2T, X3T of the potential function (4.5). In Table 4.2, only the real roots are printed: there is one or there are three per line T.

   If for a year T only one real root exist, XT (in the last colums of Table 4.2) is identical with this X.T

   If for a year T three real roots exist (ambivalence), XT (in the last column of Table 4.2) is identical - according to the HYSTERESIS PRINCIPLE - with that X.T which has the same sign as the index had had in the previous year T-1.

Detrending of Observed and Theoretical Indexes of Production

YEAR	XT	PT	XTREND	PTREND	XDEVT	PDEVT
1900	-0.414	50.600	-0.337	59.360	-0.077	-8.760
1901	-0.381	56.700	-0.305	62.333	-0.077	-5.633
1902	-0.360	63.200	-0.273	65.305	-0.087	-2.105
1903	-0.317	65.400	-0.241	68.277	-0.076	-2.877
1904	-0.334	62.300	-0.208	71.249	-0.126	-8.949
1905	-0.290	73.600	-0.176	74.221	-0.114	-0.621
1906	-0.267	78.900	-0.144	77.193	-0.122	1.707
1907	-0.249	80.600	-0.112	80.165	-0.137	0.435
1908	-0.304	68.000	-0.080	83.137	-0.223	-15.137
1909	-0.218	80.200	-0.048	86.109	-0.169	-5.909
1910	-0.156	85.300	-0.016	89.081	-0.139	-3.781
1911	-0.108	82.200	0.016	92.053	-0.123	-9.853
1912	-0.006	93.700	0.048	95.025	-0.053	-1.325
1913	0.085	100.000	0.080	97.997	0.005	2.003
1914	-0.073	94.100	0.112	100.969	-0.185	-6.869
1915	-0.085	109.300	0.144	103.942	-0.229	5.358
1916	0.333	129.600	0.176	106.914	0.157	22.686
1917	0.520	129.700	0.208	109.886	0.312	19.814
1918	0.560	128.800	0.240	112.858	0.320	15.942
1919	0.692	113.200	0.272	115.830	0.420	-2.630
1920	0.978	124.000	0.304	118.802	0.674	5.198
1921	-0.381	100.000	0.336	121.774	-0.717	-21.774
1922	0.635	125.900	0.368	124.746	0.267	1.154
1923	0.971	144.400	0.400	127.718	0.570	16.682
1924	0.918	137.700	0.432	130.690	0.486	7.010
1925	1.038	153.000	0.464	133.662	0.574	19.338
1926	1.082	163.100	0.496	136.634	0.586	26.466
1927	1.029	164.500	0.528	139.606	0.501	24.894
1928	1.021	171.800	0.560	142.579	0.460	29.221
1929	1.182	181.300	0.593	145.551	0.590	35.749
1930	0.909	155.600	0.625	148.523	0.285	7.077
1931	0.178	129.700	0.657	151.495	-0.478	-21.795
1932	-0.269	100.000	0.689	154.467	-0.959	-54.467
1933	-0.281	119.900	0.721	157.439	-1.001	-37.539
1934	-0.360	129.700	0.753	160.411	-1.112	-30.711

XTREND = -0.369 + 0.032*(YEAR)

(-47.02) (4.09) T-STATISTIC

(16.70) F-STATISTIC

PTREND = 56.388 + 2.972*(YEAR)

(174.30) (9.19) T-STATISTIC

(84.40) F-STATISTIC

Table 4.3

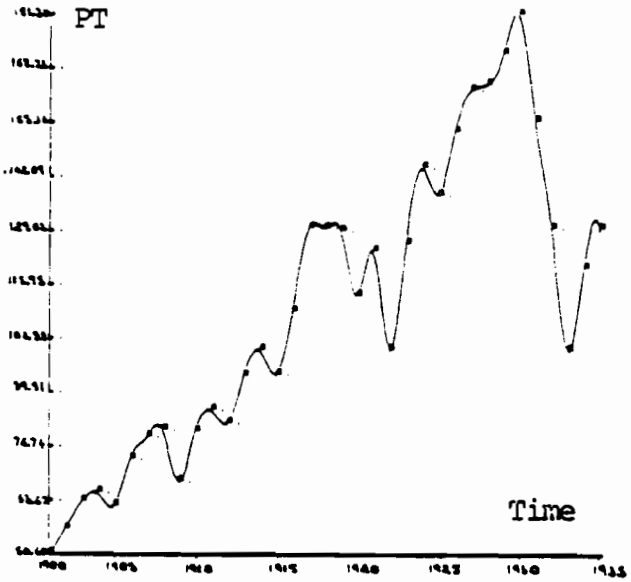


Figure 4.1

PT = Industrial Production Index

This index measures the changes in the physical volume or quantity of output in manufacturing, mining, and gas and electricity utilities. Farms, construction, transportation, and the trade and service industries are not included.

Data Source: Table 4.1, Column 1.

Remark: The curve connecting the time series data points has been computer drawn using the Spline Function of Swante Wold

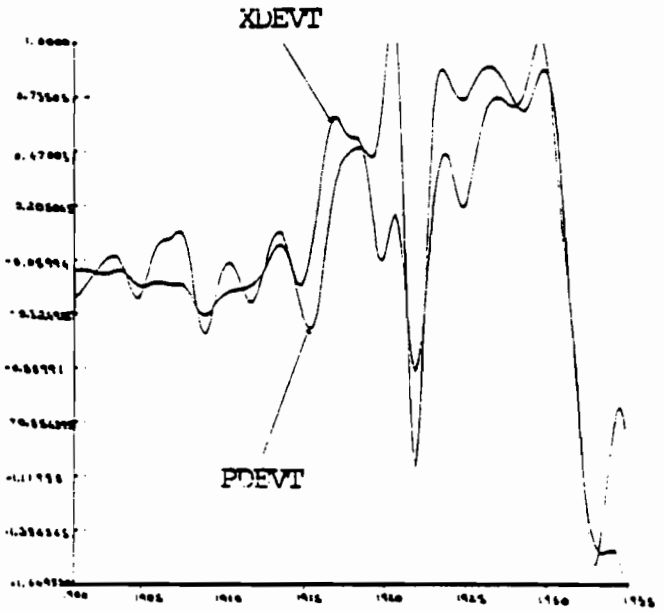


Figure 4.2

PDEVT = detrended value of PT, the statistically observed deviation of the Industrial Production Index from its trend

XDEVT = calculated value for PDEVT, using the bifurcation model

Data Source: Table 4.3

Remark: The coefficient of correlation between the two time series is r = .886 ; r-square = .785

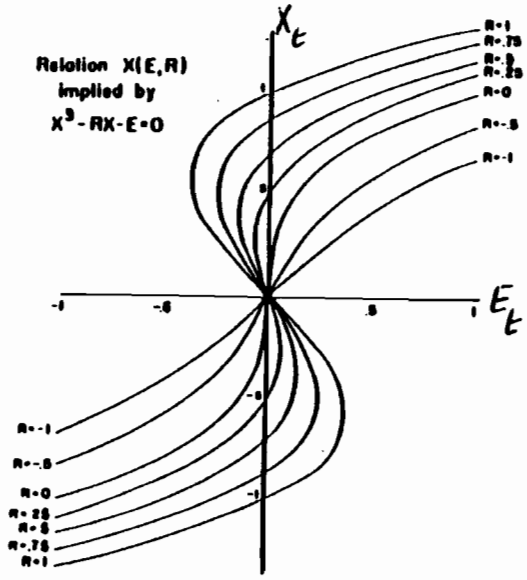


Figure 4.3

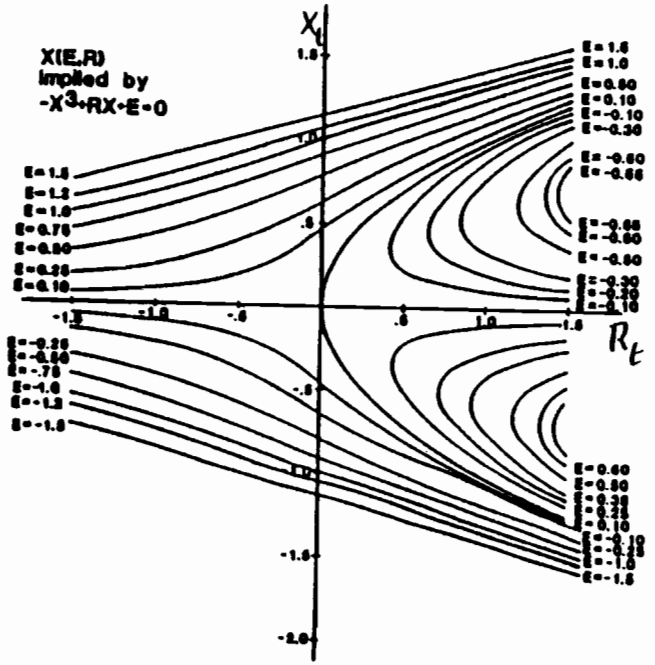


Figure 4.4

Bi-Equilibrium Property:

The relations $D_t(E_t, R_t, X_t)$ imply a piece-wise linear relation between X and E; parametrized by R. If R is large, the relation between X and E is multi-valued, and X can vary widely in response to minor changes in E.

Hysteresis Property:

The relations $D_t(E_t, R_t, X_t)$ imply the possibility for the economy to be in alternative states, and switch from state to state, provided some threshold levels are being passed. Otherwise the system stays where it is: on the higher or lower equilibrium level

Observations of the Cyclical Nature of Progress

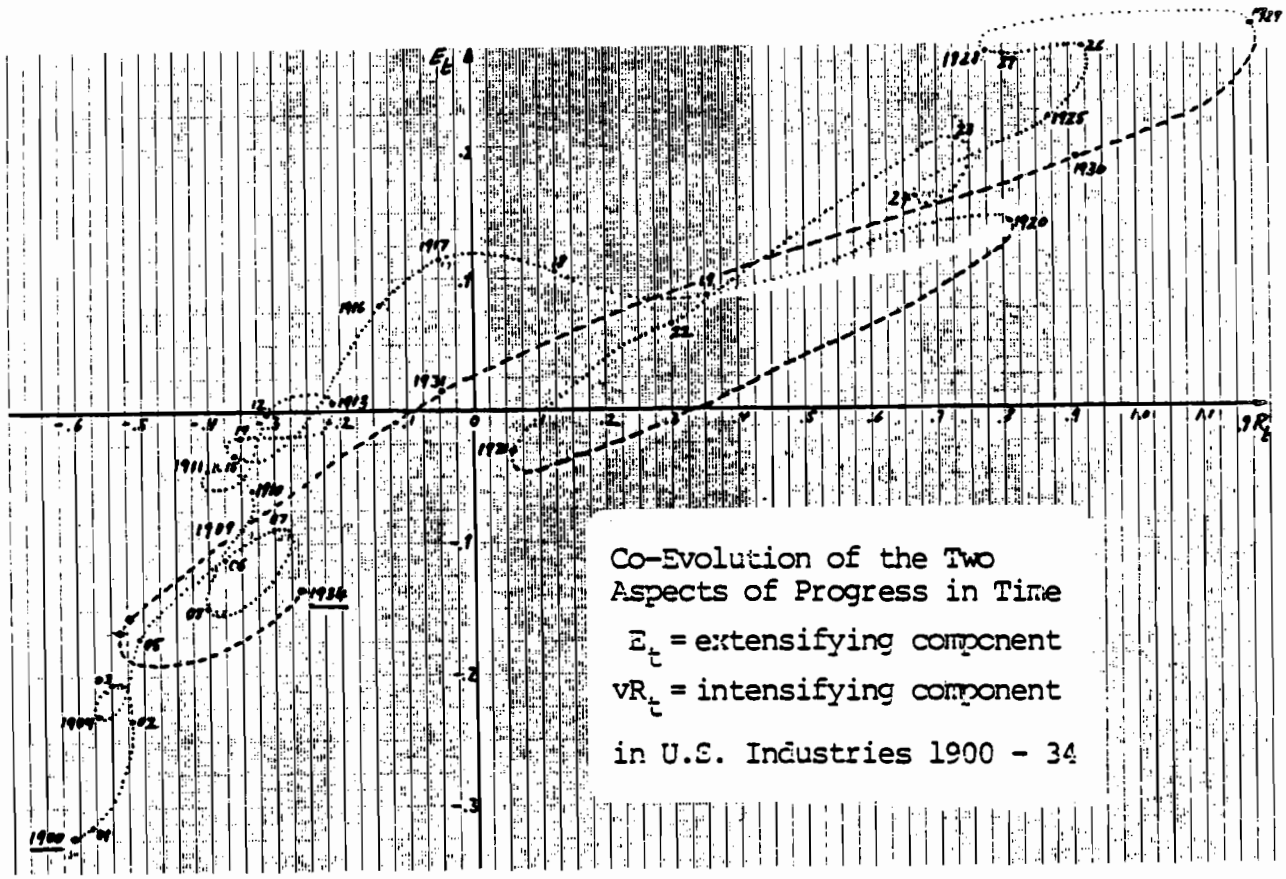


Figure 4.5

Empirical Observation:

Of the two types of technical progress, extensifying and intensifying, the intensifying is the splitting factor, leading to bifurcation in the economic process when vR exceeds zero. In the U.S. Industry 1900-34 case, the critical value for .9R exceeding zero is the rear 1918.

Before WWI, the economy was driven by bi-valued technical progress that advanced by gyrating movements; after WWI it was a bang-bang process.

Theoretical Consideration:

The Null-Hypothesis to the Bifurcation Theory advanced in this paper is the contention that the discontinuous development was a consequence of the war, or the reversal to a peace economy.

On the basis of the data analysis, the Null-Hypothesis is not falsifyable. However, the Bifurcation Hypothesis is. The explanation of the economic motion depicted in Figure 4.5 and 4.2 is powerful (as evaluated be r-square).

Thus, the bifurcation theory - operationalized in this paper by a bi-equilibrium model - explaines nearly 80% of the variance found in the time series data on the evolution of the U.S. industry between the years 1900 and 1934. This establishes the (b)-part of the theorem stated in the introduction: Dialectical progress (bivalued technological change) leads to structural instability (potential for regime change) of the economic system. The precision of this theoretical result - an r-square of .785 attained by applying the simplest of all models that are contained in the class of multiple root models - warrants further investigation of the interactions between technical progress, investment and employment along the line of the bifurcation theory.

5. Conclusions

The high level of precision attained with the bifurcation theory is a consequence of modelling post-schumpeterian concepts (ambivalence results from dialectical progress which is a Process of Creative Destruction) on the basis of neoclassical achievements in the area of capital theory that are, however, not generally true:

(i) the capital productivity condition: in the aggregate, the marginal product of capital is smaller than the average product of capital (provided the Inada uniqueness condition holds)
(ii) the capital intensity condition: in the two-sector disaggregate parts, the capital intensity of the capital-goods sector is smaller than the capital intensity of the consumption-goods sector (again, provided the Inada condition holds).

The application and operationalization of post-schumpeterian concepts lead to deeper and different disaggregations, especially in terms of investments which incorporate extensifying and intensifying types of innovations in industry. This has been forshadowed by P.A. Samuelson (1962, p. 193), and denoted "neo-neo-classical":

"Repeatedly in writings and lectures I have insisted that capital theory can be rigorously developed without using any Clark-like concept of aggregate 'capital', instead relying upon a complete analysis of a great variety of heterogeneous physical capital goods and processes through time. Such an analysis ... might therefore be called neo-neo-classical".

The neo-neoclassical, post-schumpeterian analysis strikes out beyond the Inada condition into the realm of models with multiple roots, thus making explicit the ambiguities that creep into the neoclassical analysis as soon as the production function and its extension, the post-keynesian (Kaldor) technical progress function, is applied to data on periods with "badly behaved progress", such as the 15 years after World War I, that spanned the post-war crisis of 1920/21 and the great depression after 1929. The research strategy pursued in my research pro-

gram on innovation takes recognition of the fact that critical developments in the economy move the economy in violation of the neoclassical results (i) and (ii), and are thus in need of explanation based on endogenous factors such as bi-valued (ambivalent) progress embodied in the aggregate investment activities.

Clearly, the level of precision already obtained by the simple and stringently specified model presented in this paper could be enhanced by either advancing to a more complex model, such as the one I work on with Haag and Weidlich (The Schumpeter Clock, 1981), or by relaxing the stringent assumptions built into the model, such as the time-invariance of the parameters p_{ij} and the orthogonality of the transformation of causes and effects, and by reducing the degree of white noice from the variance in the data which is contaminated by statistical errors that the theory cannot explain. The latter approach I take in collaboration with H. Wold (A Multiple-Indicator Soft-Modelling Assessment of Bi-Valued Technical Change, forthcoming).

There are two reasons why the application of the bifurcation theory to the industrial evolution between 1900 and 1934 should be particularly revealing: Firstly, given the fact that it is a development from prosperity via recession into depression, it is the test par excellence for neo-neoclassical discontinuity theory which tries to reach beyond neoclassical continuity theory, not leaving it behind but rather using its precision as minimum requirement on the post-schumpeterian operationalizations. Secondly, it is a particularly probing development in regard to the requirement that the economic theory should be based on endogenous factors. The empirical analysis of the evolution of U.S. industry between 1900 and 1934 shows that structural instability as a result of the two-edged nature of technological progress developed in the post-war period; the endogenously created instability began, according to this analysis, when in 1918 the splitting factor vR passed beyond the threshold of stability. But what about the externalities?

The Null-hypothesis to this bifurcation theory of endogenously determined change is some random shock theory, which would simply maintain that all the post-war bang-bang motions of the U.S. economy, including its industrial sector fluctuations, were probably the ripples of the reconversion of the U.S. economy to a peace economy (and the failure of achieving this reconversion smoothly). At this juncture, it should be reported that an application of the bifurcation theory to the data on U.S. industry 1947 - 79 also reveals structural instability (beginning in the late sixties; r-square greater .75). Is this also because of war and friction in reconversion? Thank God the German people did have no war since 35 years: but despite its reportedly favorable economic development (as compared to other contries') during the previous decades, the analysis of West German industry after 1950 reveals structural instability since the mid-sixties (r-square greater .75, again). This cannot be explained exogenously. Hence, there is no escape from the need of further study of the endogenously determined, ambivalent Process of Creative Destruction on the basis of the neo-neoclassical economic theory.

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ON LONG WAVES IN THE ECONOMY

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Topics 1, 2, 3 are too interconnected to be discussed separately. We shall attempt to comment on all three topics together and choose the most important issues.

1. THE SUBJECT OF STUDY

Let us define the subject of discussion. We are talking about long fluctuations in economic processes and indicators, but which processes and which indicators? Perhaps it would be useful to concentrate first on waves in aggregate indicators of *material production*, i.e., in Gross Domestic Product (GDP) or industrial production (IP), where National Accounts statistics are not available. Then we could take up indicators that explain the behavior of GDP or IP, namely investment, fixed capital stocks, capital and labor productivity, and profitability. And, finally, we could touch upon processes and indicators of distribution and circulation, such as trade, prices, interest, and money stock. Granted that all these processes are interconnected, we proceed from an assumption of primacy of material production (of goods and services) and of the secondary nature of distribution and circulation.

Let us distinguish between economic *waves* and *cycles*. By cycles we denote fluctuations in which the downward movement periodically leads to absolute contractions of material production for not less than half a year (in monthly or quarterly series) or of less than a year (in annual series). By waves we understand any more or less periodic fluctuations of output, which are manifested by deviations of growth rates from the trend, but not necessarily by negative growth. Thus cycles are special cases of waves. This difference is

stressed in order to retain the definition of economic cycles as fluctuations with a periodic repetition of *crises*. Crises are the constituent phase of the economic cycle.

2. IDENTIFICATION OF LONG WAVES

Do long waves of 50 years duration really exist? There is no unanimity in literature either on empirical evidence of their existence, or of their underlying theory. Neither are we aware of convincing arguments of their theoretical impossibility.

The contemporary discussion of the subject has been revived by crises of 1973-75 and 1980-82, as well as by the pronounced slowdown of economic growth in the 70s and early 80s. If, in the history of the cycle, one singles out crises that are deeper or longer than their neighbors, then they are crises of 1872-75, 1929-33 and the two latest crises. The approximate distance between them is 45-50 years.

Such comparisons are very flimsy. "Strong" crises differ substantially in depth of contraction. In this respect the crisis of 1929-33 has no historical precedent. The crisis of 1872-75 in the US was weaker than both 1892-94 and 1907-8; in addition it occurred rather on the crest of a long upswing, than in a downward phase, like 1929-33 or presumably 1973-75.

If one proceeds deeper into the 19th century, one does not find adequate criteria to choose 1825-26 as the natural claimant to the role of a "Kondratiev" crisis. Thus such historical comparisons do not look convincing.

The statistical identificaton of long waves is not a trivial problem and needs refined mathematical methods.

Most economic series reflect complex movements determined by secular trends and various periodic fluctuations, modified by concrete historical conditions and purely stochastic influences. Methods of separating such heterogeneous movements are often intuitive and depend on the subjective approach of the researcher. Thus, for example, the notion of the secular trend depends on the choice of the mathematical model representing it (stochastic or deterministic), on the assumption of how it applies to other movements (multiplicatively or additively), on the concrete type of function describing the trend.

Methods of estimating and eliminating the trend (of which the most prominent are least squares and difference transformations) may influence the remaining movements and even distort them. For example, difference transformations of the first order which largely eliminate the trend described by a broken line, will also increase purely stochastic influences, so that some systematic movements of average duration may become hardly distinguishable. On the other hand, least squares in the case of an erroneously chosen model may introduce false movements, which are not subject to reasonable interpretation.

The separation of long waves against a background of rising or other trends is further impeded by the existence of shorter systematic fluctuations. For example, the observation of annual statistical series makes it possible, without previous transformation, to single out reliably medium length cycles (K. Marx, C. Juglar) of 8-9 years and short cycles (Kitchin) of 3-4 years. Let us call them respectively *economic* (or *major)* cycles and *intermediate* (or *additional)* cycles. The influence of these cycles is so great that long systematic fluctuations often become visually indistinguishable.

In order to eliminate high and medium-frequency fluctuations one often uses such linear filters, as moving averages of varous kinds. However in some cases-- namely, when the dispersion of long fluctuations is smaller or approximately equal to the disperson of shorter systematic fluctuations -- the use of averages may lead to the emergence of false waves in the smoothed-out series (Howrey 1968). The use of such filters for distinguishing long waves is proper only when fluctuations are systematic and close to deterministic. This hypothesis is satisfied for most of the series which we have analyzed.

Taking note of these problems we have used the following methodology for analyzing statistical indicators:

(1) We assumed that the movement of alll indicators is described by multiplicative models with deterministic trends.

(2) The deterministic trend is described by an exponential function where the degree of the exponent is a polynomial of the first or second order. If, after eliminating the exponential function, waves were observed substantially longer, than 50 years, then the latter were eliminated by trigonometric regression.

(3) If the residual after eliminating the trend visually showed waves of 40 to 60 years, then the series was smoothed out by a 9-year moving average.

We studied GDP series for the US (1889-1982), IP series for the US (1964-1982), FRG (1860-1982), Japan (1900-1982); IP and agricultural production series for the UK (1700-1982). In every case, except the UK, it was possible to discern a *quasi- periodicity* of about 50 years in deviations from the trend.

We talk about quasi-periodicity, because:

(1) the relative shortness of the series (90 to 120 years) makes it possible to identify no more than 1.5-2.0 complete oscillations;

(2) in the opening parts of the series the movement is practically indistinguishable from the deceleration of the secular trend;

(3) the period of oscillation, as measured by the distance between the assumed peaks or upcrosses, changes from period to period and from country to country.

In the UK (the only country for which series of data on material production are available for nearly 300 years) super-long waves in growth rates (of 180 to 200 years of duration) are clearly discernable around an astonishingly stable secular exponential trend of the first degree. A periodicity close to 50 years is very weak in this case. It is identified by using both high and low-frequency filters and is manifested in deviations from super-long waves.

In the past the UK has been the country of classic capitalism, and the analysis of its statistics bears conclusions on dynamics of capitalism in general, not just for its later, predominantly monopolistic stage (as in the case of statistics for the US, FRG and Japan). Here we clearly observe in the *manufactory* (pre-factory) *period* (1700-1780) a major dependence of super-long waves on growth rates of the population, but later -- on the successive phases of *Great Industrial Revolution*. The upswing in industrial output of consumer goods starts in 1780 and continues until 1860 (80 years), and in the output of producers goods it lasts from 1818 to 1883 (65 years, and coincides, by chance, with the life period of K. Marx). It is interesting that the *first general cyclical crisis* of 1825-1826 occurred as early as 7 years after the turn of the tide in the output of means of production.

In the US, FRG, Japan the upswings of the 50-year wave are clearly associated with the *massive spread in the economy of major technical innovations*, leading to a complete overhaul of the industrial structure. It is true that only two such long upswings have historically occurred: the age of railroads and steel (in the US also of petroleum): 1870-1910 in the US, 1870-1913 in Germany, 1900-1919 in Japan; the age of chemistry, electronics, aviation, and in FRG and Japan also of the automobile and petroleum: 1935-1970 in the US, 1950-1975 in FRG, 1955-1975 in Japan.

As to the "Great crises", they may have reflected the superposition of three shorter waves ending of the downswing in the long wave. But, obviously, other factors have played a major role, including institutional factors, i.e., *changes in the production relations* of capitalism. In 1929-1933 the moving force was the conflict between the tendency toward mass production, strengthened by large corporations, and the unreadiness of the mass market for mass consumption; and the underlying necessity of a transition to government intervention. In 1973-1975 it was the deep crisis of government regulation caused by stagflation and the growth of transnational corporations, and the underlying necessity of a transition to international government intervention to coordinate economic policy.

The identification of two nearly complete long waves does not, however, make it possible to assert with assurance that the events of the 1970s and the early 1980s are a prelude to a new long upswing in the future. Whether this will in fact occur -- for technological or socio-economic reasons -- or whether we are in fact observing a transition to a slower secular growth trend, cannot be determined without additional qualitative analysis.

3. A THEORY OF LONG WAVES

Fluctuations of material production should have material prime causes, i.e., a *material foundation*. For shorter waves such foundations are:

- for the intermediate cycle (3-4 years) -- fluctuations of commodity inventories;
- for the economic cycle (8-9 years) -- fluctuations of fixed capital in producer's durable equipment;
- for the "construction wave" (18-20 years) -- fluctuations of fixed capital in producer's structures.

The common feature in all three is that waves of different duration are associated with the different duration of fluctuations in the various *components of constant capital* – commodity inventories or fixed capital -- and that the wave frequency is in direct correlation with the *speed of liquidation, depreciation, and depletion*, of such components.

Capitalistic production tends to follow profitability. A downturn in the rate of profit will by necessity cause adjustment, including the physical and value decrease of invested capital. Such adjustments are always painful and violent; they are executed by cutting-off parts of the "capital flesh" -- variable capital, such as the labor force, as well as constant capital. Therein lies the material foundation of *perodic economic crises* under capitalism.

The capitalist is first tempted to do away with the easiest parts-excess inventories, and investment in floating capital -- which do not need a depreciation period. He has to wait longer for an opportunity to change equipment, and even longer for a change in structures.

Long waves (50 or more years) are also associated with the movement of capital. But in this case it is the *general change in the technical base and technology in the economy at large*. Such transitions need more time (two or three major cycles), and in the UK, as we have seen, even more. Not only the spread of new technology, but also the depletion and depreciation of old technologies that clears the road for new technology, go on for decades. To repeat, we are talking about fundamental revolutions in the technical basis of the whole economy, not just of some branches of industry, or individual technical innovations.

We effect such revolutions by far-reaching structural changes in the economy, by the transformation of inter-industry ties, by emerging clusters of new industries. At the macroeconomic level, these revolutions are reflected by large oscillations in growth rates of fixed capital, investment, labor and capital productivity, the capital output ratio, and the rate of profit. These fluctuations show the existence of waves in the rate and character of technical progress and its applications to production.

A theoretical explanation of these processes has been given by K. Marx (in "Das Kapital", v.III), although Marx himself could not observe and did not identify long waves. Capitalism, he wrote, has an intrinsic *law of the tendency of the rate of profit to fall*. This is caused, in the final analysis, by a rise in the organic composition of capital, i.e., the relation between constant and variable capital, means of production and labor force. The capital intensity of labor is constantly increasing. Had workers created a constant amount of surplus value (profit) per unit of time, the rate of profit would have fallen systematically and monotonously. By creating an increasingly necessary product (the value of his own labor force) and surplus value (profit) per unit of time, the worker prevents the fall of the rate of profit in the economy as a whole.

The average rate of profit depends on the rate of surplus value (and the share of wages in newly created value, i.e., in national income) and on the relation between capital and product. In accordance with this the profit rate falls in some periods, rises in others. These oscillations are determined by the movement of such indicators, as the capital-labor ratio, productivity of labor, and share of profit, and in turn induce waves in these indicators.

We have studied the related time – series for the US (1889-1982) smoothed by 9-year moving averages. Detailed results will be presented at the workshop. In short, there exist clearly identifiable long waves in all such indicators, and it is possible through lags to observe their causal relationships. The latter can be expressed by the following generalised model:

(1) $y = -a(y-bk)$

(2) $k = -c(k-dp)$

(3) $p = z-k$

(4) $z = -e(z-fy)$

where:

y -- growth rate of labor productivity;

k -- growth rate of capital-labor ratio;

p -- growth rate of the rate of profit;

z -- growth rate of profit created per unit of labor time;

y,k,z -- change in the growth rate of y,k,z;

a,c,e -- speeds of reaction, adjustment;

b,d,f -- coefficients.

The logic of the model is as follows. The growth rate of the capital-labor ratio depends on the movement of the profit rate. The underlying mechanism is fixed capital investment and formation. The model abstracts itself from the movement in employment, though labor is present as a denominator in the variables Y/L, K/L and P/L of which y, k and p are difference derivatives.

The growth of labor productivity follows, with a certain lag, the movement of the capital-labor ratio. In some cases labor productivity grows more slowly than capital-labor intensity, and then the capital-output ratio is on the rise. These periods are associated with massive utilization of existing technology or with the opening stages of the introduction of new technology. When labor productivity overcomes the movement in capital-labor intensity, the capital-output ratio decreases, and the efficiency of capital investment rises. These periods are associated with massive applications of new technology.

The growth of real wages (W/L) tries to follow productivity growth. Equally strong is the same drive on the part of profit created per unit of labor time. In reality these indicators are in sharp mutual conflict and rivalry. The faster the growth of unit-time profit, the slower the growth of real wages, and vice versa. This rivalry reflects the conflict between labor and capital, the situation in the labor market, the unemployment rate, etc. Unit-time profit sometimes grows more rapidly than productivity, sometimes more slowly. Their relation determines the movement of both the rate of surplus value and the share of profit in national product.

Finally, the profit rate is determined by the relation between unit-time and capital-labor intensity, or between the share of profit in national product and the capital-output ratio. Periods of the rising capital-output ratio may coincide either with increases in the share of profit, or with its fall. In the first case the profit rate may be stable, in the second it falls. When the capital-output ratio decreases, the rate of profit is either stable or rising.

Thus we observe a closed circle of quality indicators, showing the state of the economy, andthe speed and character of technical change.

The model may be transformed into a linear differential equation of the third degree. It may generate oscillations under certain relationships between the parameters. *Oscillations of 50 years* are generated when coefficients, showing speed of adjustment, are very low (0.02 to 0.08). A detailed description of theoretical and empirically estimated parameters will be presented at the workshop.

4. TAXONOMY OF LONG-WAVE THEORIES

Among existing theories of long waves it is useful first to single out those which attempt to explain their material foundation. These are:

- -- the theory of innovations, which explains long waves by introduction of new products and associated technologies (Parvus, Siemand, Schumpeter, Lange). The concept of new technology clusters (Forrester) comes close to this group.
- -- investment theory, which puts an accent on reproduction of fixed capital (Kautsky, Tugan-Baranovsky, Spectator, de Wolff, Tinbergen, Sweezy).
- -- the theory of capital, which concentrates on profit and its tendency to fall (Tugan-Baranovsky, Sweezy, Mandel, Amin, Boccara).

While we do not adhere to these theories, let us note that some of them contain interesting elements, which reflect reality, although, perhaps, in a one- sided manner.

There is also a group of theories that trace causes of long fluctuations to various particular phenomena in material production. These are:

- -- Agrarian theories (waves in agriculture, in raw materials output -- Lootz, Sirol, Rostow).
- -- Demographic theories (waves in growth of population or labor force -- Rostow, Boccara).
- -- New markets theories (Parvus, van Gelderen, Dieterlen).

Processes studied by these authors, have to be included into fundamental research on long waves but they are not the prime basis for such fluctuations.

Another group of theories has concentrated on secondary processes in the economy. Prominent among them are:

- -- Monetary theories explaining long waves by changes in phases of deflation and inflation, fluctuation of prices, interest, gold output, etc. (Kassel, Schumpeter, Duriez).

Though this group of theories does not play an important role in current discussions of long waves, a study of long-term fluctuations in price formation, credit and money circulation are absolutely essential.

Finally, there is a group of concepts which put a major accent on socio-psychological and other non-economic, specifically military and political factors. The role of some of these factors is more or less clear (i.e., the role of wars), in other cases nothing is too obvious. Further research is necessary in this area.

It is not suggested that all or part of these theories be integrated. Most of them were incorrect from the beginning. Others have become outdated, still others are too one-sided to be taken seriously. However, in some of them it is possible to find correct hints of real processes related to long waves.

5. ON INTEGRATED MODELS OF VARIOUS WAVES

Models which concentrate on individual waves have the advantage of simplicity and are easy to analyze theoretically. Integrated models explaining various waves at the same time will by necessity be complex and hard to analyse theoretically.

In our experience we have attempted to use one product model for analysis of two cycles of different duration, and multi-industry models for simultaneously generating a number of different waves.

A *one- product model* of the US economy (built together with Yu. Chizhov, Novosibirsk) has been used for the following experiment. In its principal variant, where the general investment equation included inventory investment, the model generated fluctuations of 3.5 years, reflecting the intermediary cycle.

When, however, inventory investment was excluded from the general investment equation and was treated exogenously, the model generated waves of 7.5 years, representing the major cycle.

In the first case the model acted as if it concentrated on *two cycles simultaneously*. This is possible since, as a rule, two intermediate cycles coincide with one major cycle. In the second case the model *chose only one cycle* and ignored the second.

This example shows that in the analysis of shorter waves it is possible to build one-product models that would simulate the specific mechanisms inherent in both cycles and their interrelationships.

A *multi- industry model* of the US (together with E. Levitsky, Novosibirsk) was built in the hope that it would simultaneously generate an endogenous growth trend and fluctuations of different length. This goal was indeed reached. The analysis of the model's dynamic properties showed the existence of waves of 4.7, 6.6, 9.9, 18.0 and 61.5 years. Dampening decreased with the rise in duration of the fluctuations.

Since the base period used to estimate the econometric equations of the model was only 20 years one may contest the significance of these findings. How ever, note that an important role in generating fluctuations of various frequency is played by the matrix of input-output coefficients, which do not depend on the length of the base period. From this we conclude, that given the high stability of the I=O matrix, the coexistence of various waves is somehow associated with the current structure of a highly developed industrial country.

As to one-product models, the experience of work with the system described in paragraph 3, above, deserves attention. This system is built on smoothed-out macroeconomic series, which obviously minimize the effects of the intermediate and major cycles. Perhaps it is technically feasible to build an integrated model which in addition to the usual statistical variables would also include smoothed-out variables tuned to waves of different frequencies. It would be useful to study this and other variants of an integrated model.

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LONG WAVES

Johann Millendorfer (Austria)

STUDIA is working on long term mechanisms of societal development. The investigations are based on a wealth of empirical data including not only economic and technological variables but also so-called 'soft' variables like measures of motivation, socio-psychological variables, indicators for the quality of the family, etc.

The outcome of the investigations are conditioned forecasts and sometimes unconditioned forecasts like our forecast of structural development which is fully verified now.

Regarding the issue of long waves STUDIA has three approaches:

-- Oscillations from growth reducing (self-inhibiting) factors;

-- A socio-psychological feedback system;

-- Main-Plain-Analysis of differential equations and turning vectors.

A combination of these three approaches leads to a new understanding of the interrelationships between 'hard' and 'soft' variables in long waves.

1. Oscillations from growth reducing factors

A research order of the Institut für Weltwirtschaft, Kiel about institutional determinants of economic growth led to an investigation of growth reducing factors starting from a Bernoullian differential equation.

The form in which the growth reducing factors depend from economic growth or from economic level (i.e., GDP) determines the dynamic behavior of the societal system. If the growth reducing factors depend on a time integral of wealth then we have a situation described by Volterras differential equation and under certain circumstances long waves.

Equation (2) is well founded on empirical data. Very high significance is obtained, if the z_i are variables describing high government activities, big units, levelling factors and desublimation. The last factor shows interesting single correlations.

For equation (3) there are some empirical observations, but not with high significance. Therefore the form of Volterras equation is empirically not well defined. Another approach described below helps to solve this problem.

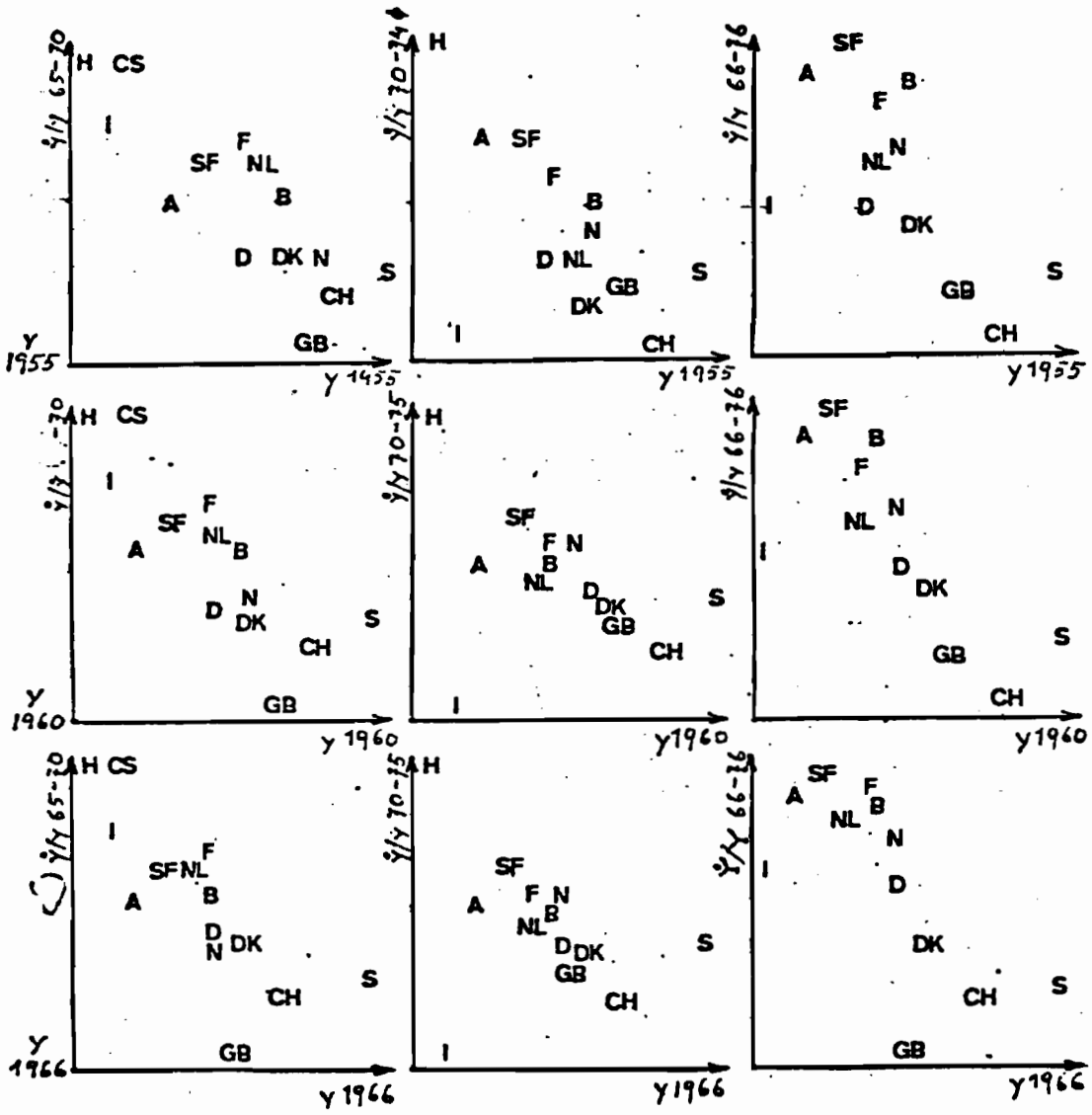


Figure 1. Relation between growth rates and per capita income for different years

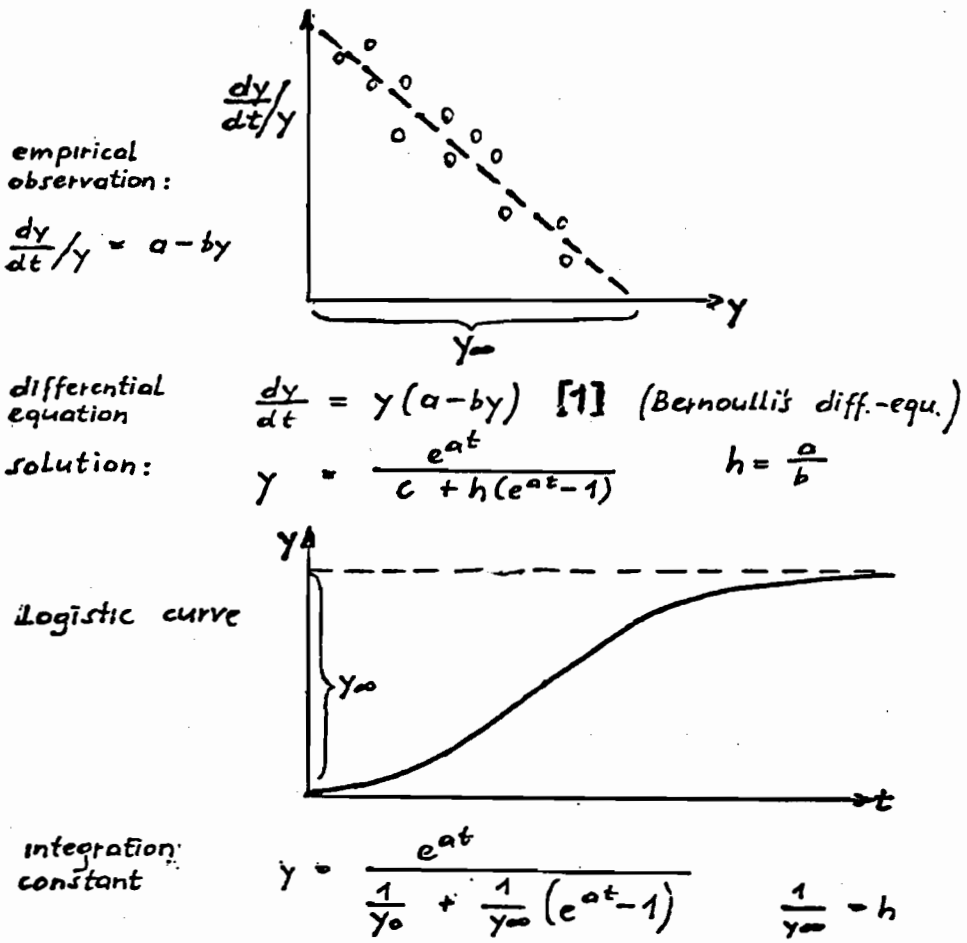


Figure 2. Mathematical description of Figure 1: Bernoulli's differential equation

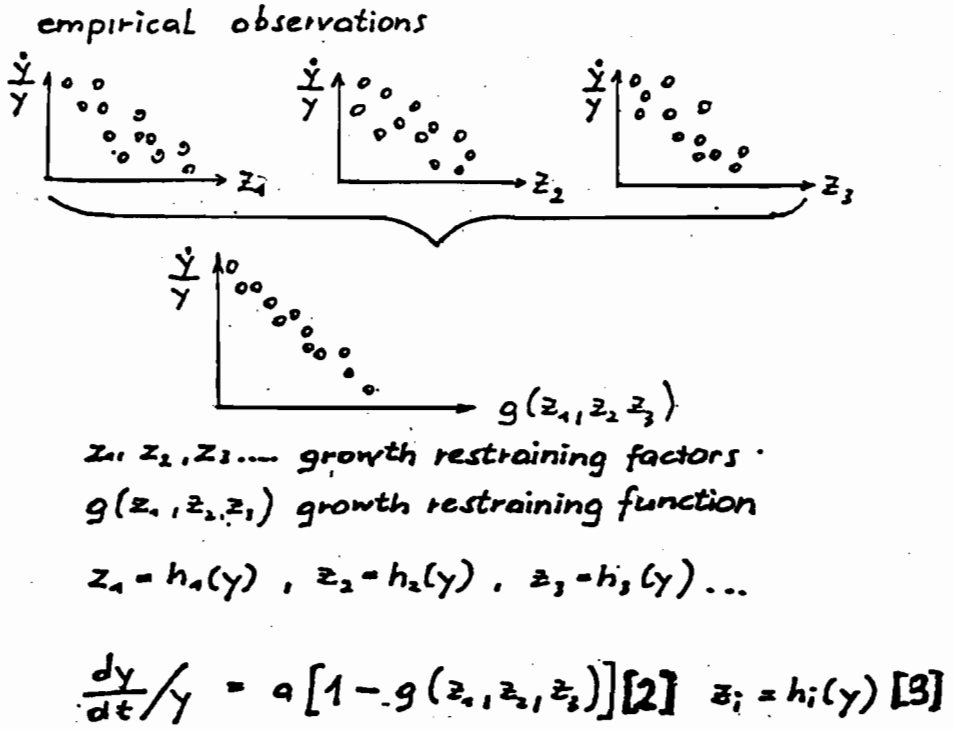
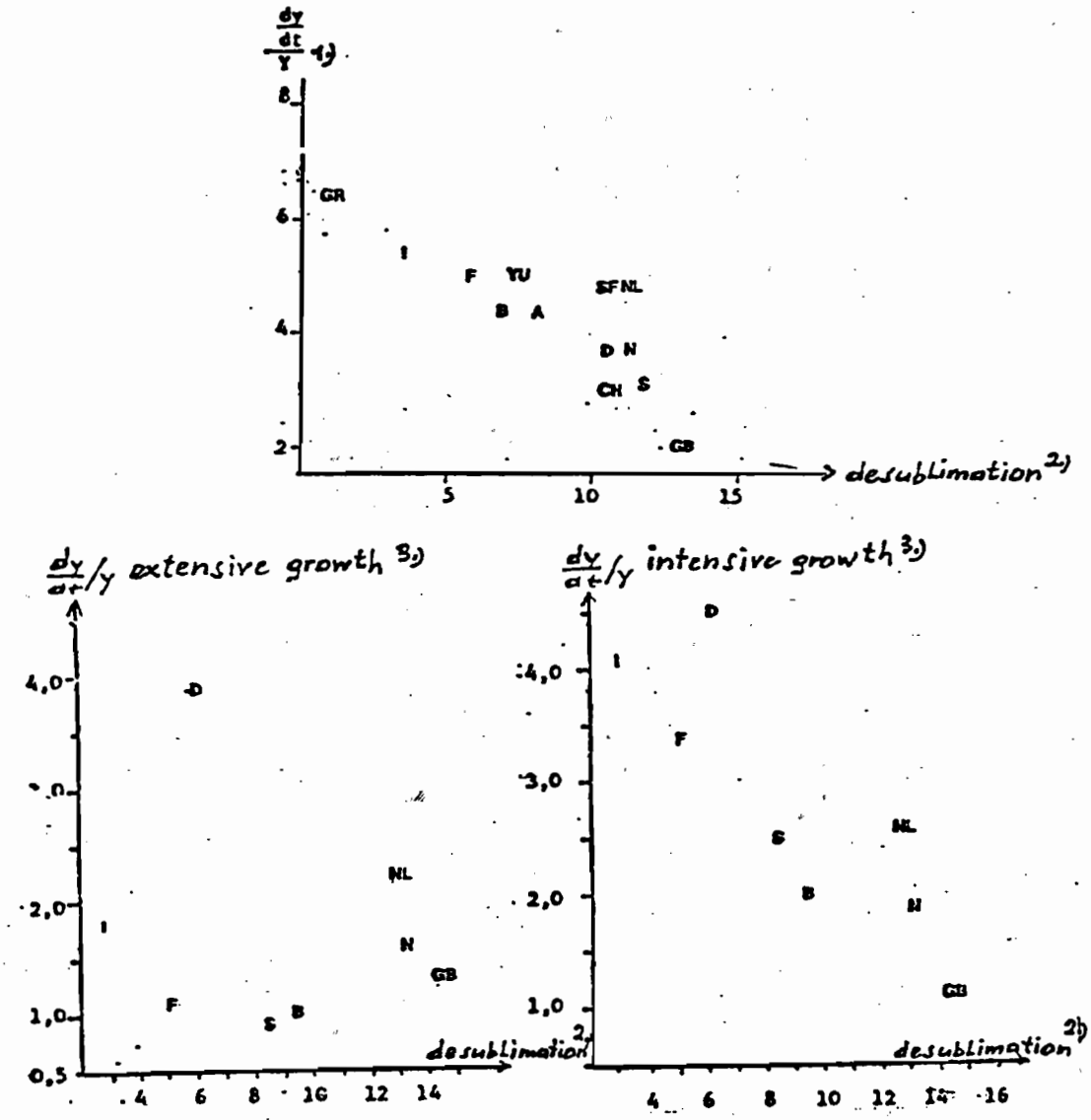


Figure 3. Substitution of y to growth reducing factors z_1, z_2, z_3*

*The substitution of y to z_1, z_2, z_3 enables us on the one side to identify growth reducing factors. On the other side it is a new formal situation. If we explain z_1, z_2, z_3 by integrals of y then we arrive to Volterras differential equation and under certain conditions to oscillations respectively to long waves, depending on the form of $z_i = h_i(y)$ resp. $z_i = c_i \int_{-\infty}^{t} y(s)\, k_i(t-s)\, ds$ k_i...kernel.



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2) age corrected death rate of cancer cervix uteri
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3) O. Aukrust: "Factors of Economic Development - A Review of Recent Research" Productivity Measurement Rev. II/65

Figure 4. Desublimation as a growth reducing factor*

*Note that there is no relationship between extensive growth and desublimation and a negative correlation between intensive growth and desublimation. This can be interpreted with the help of Freud's hypothesis that sublimation is the precondition of creativity and our interpretation that creativity causes a new technological progress and efficiency.

2. A socio-psychological feedback system

A macro-psychological investigation of the situation of the family in Europe led, by the use of factor analysis, to an indicator for the quality of family. This indicator is with a time-lag of 25-30 years negatively correlated with the achievement motivation-index of David McClelland. This index depends according to David McClelland from the quality of family. So we have a negative feedback and something like a control circuit with a delay of 25-30 years. Such a control circuit should have oscillations with cycles of 50-60 years.

That such oscillations exist was already suggested by the negative correlation between McClelland's indices for 1925 and the differences between these indices for 1925 and 1950. This observation can be adequately described using differential equations.

Schumpeter's description of the upswing of the long waves with new technologies does not explain why these innovational pushes occur at all and why the length of the cycle is between 50 and 60 years. If we find that our socio-psychological feedback system mentioned above is connected with the cycles of innovations then we learn something about the reasons of the innovational pushes and the length of the cycles.

The following figures give insights into details of our socio-psychological feedback system.

3. Main-Plain-Analysis

In the mentioned studies STUDIA developed a new formal method of multivariate analysis, the Main-Plain-Analysis, which facilitates the theory building on a large empirical data base.* The results of M-P-Analysis plotted graphically show clearer the relationships between hard and soft variables in different main-plains which are related to certain issues. (One main plain is related to the issue policy and social psychology, another to the issue of economy and institutional psychology, another to the issue of economy and institutional structures, etc. The investigation of the relationship between the main plains needs special studies on the basis of canonical correlations.) In addition M-P-Analysis can be used for the empirical estimation of the parameters of differential equations without strong theoretical preconditions, simply putting in the computer variables and their integrals and derivations. On this basis interesting mechanisms between soft and hard variables were found. Preliminary formal results are differential equations of the second order which leads under certain conditions to oscillations. These differential equations have until now only numerical solutions; STUDIA is still working to get differential equations with explicit solutions.

*M-P-Analysis can be described from two approaches, factor analysis and Cholesky-factorization. Factor analysis is looking for artificial vectors while M-P-Analysis is looking for artificial plans or in a more generalized form for (n-k) dimensional sub-spaces in the n-space. From this point of view M-P-Analysis can be also understood as a form of hyperplane-analysis. Cholesky-factorization transforms the correlation matrix to find sub-matrices along the diagonal of a matrix, while M-P-Analysis does not transform the whole correlation matrix but calculates the eigen values of subgroups of interdependent variables. Advantages of M-P-Analysis: The results plotted graphically stimulate theory building; a very flexible step-by-step approach in a dialogue with the computer; well defined levels of significance.

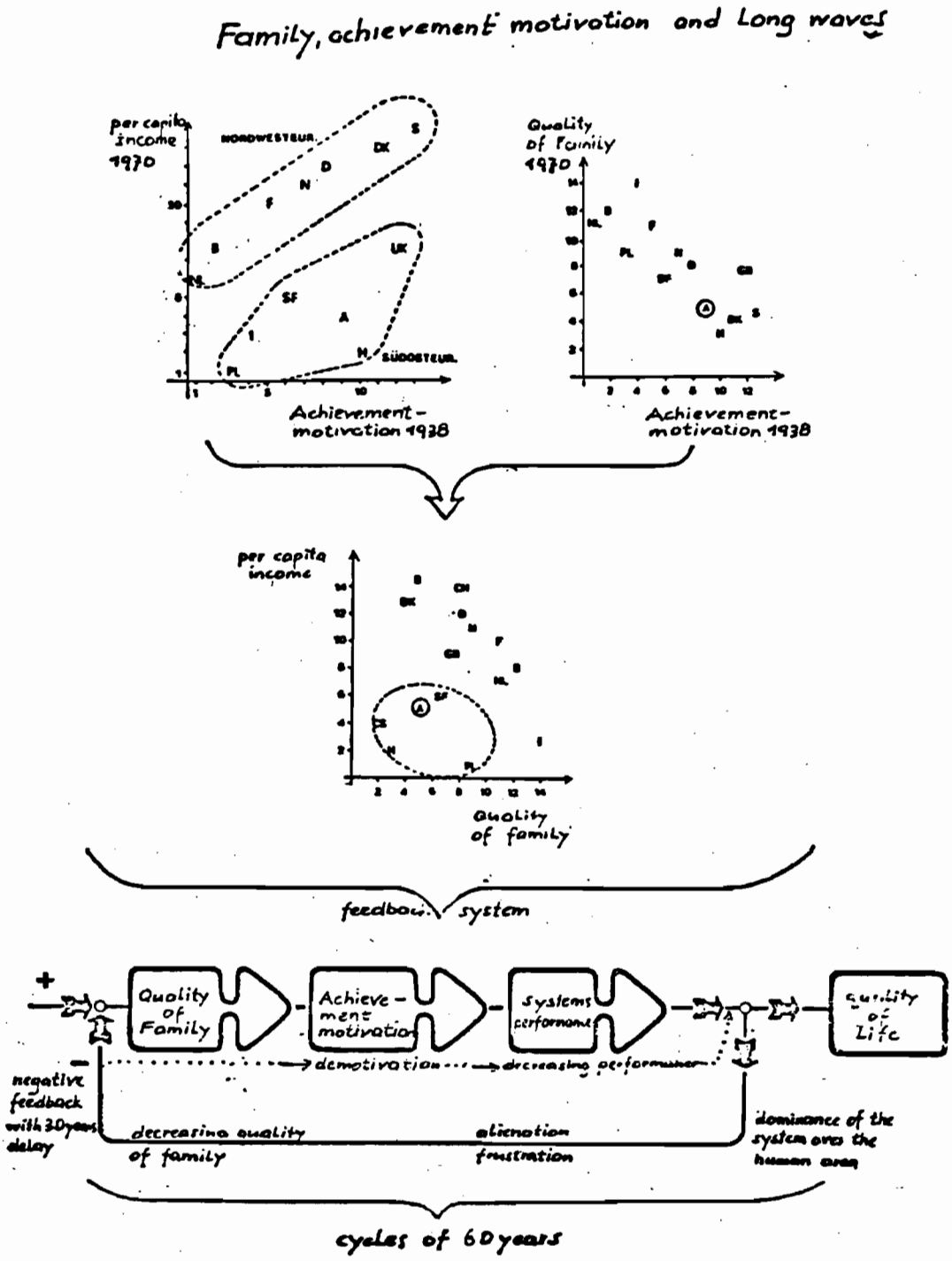

Figure 5. Socio-psychological feedback system*

*The empirical observation can be understood as a feedback system with a delay of around 30 years. According to control theory such a system should have oscillations with a cycle of 50-60 years.

M-P-Analysis is also used in studies to understand the details of the interrelationships between the hard variables and the soft variables and especially the interrelationships between the different soft variables. An interesting detail are vectors turning in a main plain during 20 years.

The following figures show empirical estmation of parameters of differential equations and turning vectors.

A first hypothesis to understand this formal result of turning vectors is that the content of government activities and the reasons of divorces have changed: government activities which supported the families and their qualities became more and more an obstacle in the fifties. On the other hand the divorces are now more and more influenced by this changed form of government activity. An interesting question is if it is possible to analyze in this way oscillations of the form of government activities in long waves.

4. Combining the three approaches

Combining the results of the three approaches we can say that all explanations of long waves must not neglect the interrelationships between the economic and technological variables describing socio-psychological and institutional circumstances; i.e., Schumpeter's description of long waves with the innovational pushes has no explanation, why this innovational push occurs in cycles of 50-60 years. If we introduce our observation of the feedback system, we can explain the length of the cycles. In addition we understand psychologically the states of the system in which inventions as a consequence of creativity and innovation as a consequence of achievement motivation emerge: creativity and innovation have strong roots in the living area, described by our soft variables and their mechanisms. The length of the cycle in the feedback system is determined by something like anthropological constants governing the dynamics of the interrelations between generations. In addition to this understanding of the length of the cycle we can use the oscillations of creativity and achievement motivation in the socio-psychological cycle to understand the oscillations of inventions and innovations. If invention has something to do with creativity and innovation with achievement motivation then we can extend the approaches for the explanation of long waves: we introduce in addition to the economic and technological variables our soft variables and have a more general picture of the process. (Table 1.)

5. Final Remark

Table 1 is an attempt to enlarge the scope on long waves in that direction which becomes more and more important: the inclusion of non-economic factors to understand economic processes. In the first look this new approach may be strange for professional economists. But there is an increasing awareness that even such a strange approach is necessary to renew a discipline and to make it able to solve the unsolved problems.

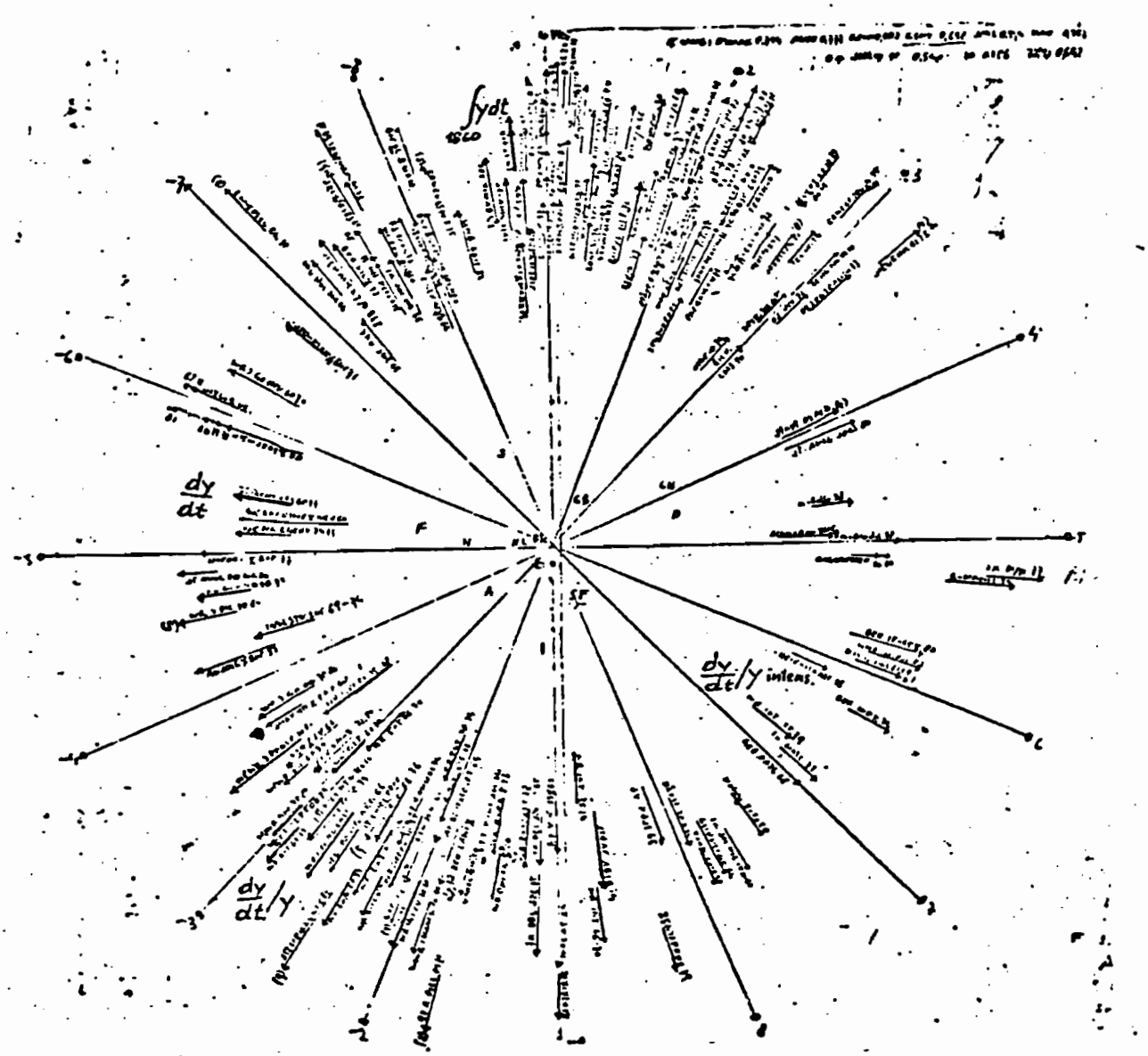

Figure 6. Main plain with the issue economy, economic growth, bank dynamics, big units, etc.*

*The various variables are interdependent. The kind of linear dependency is expressed in the direction of the arrows. The degree of dependency is shown by the length of the arrows. The main plain contains also y (GDP per capita) and integrals and derivations of y. Transforming the arrows into equations we obtain differential equations.

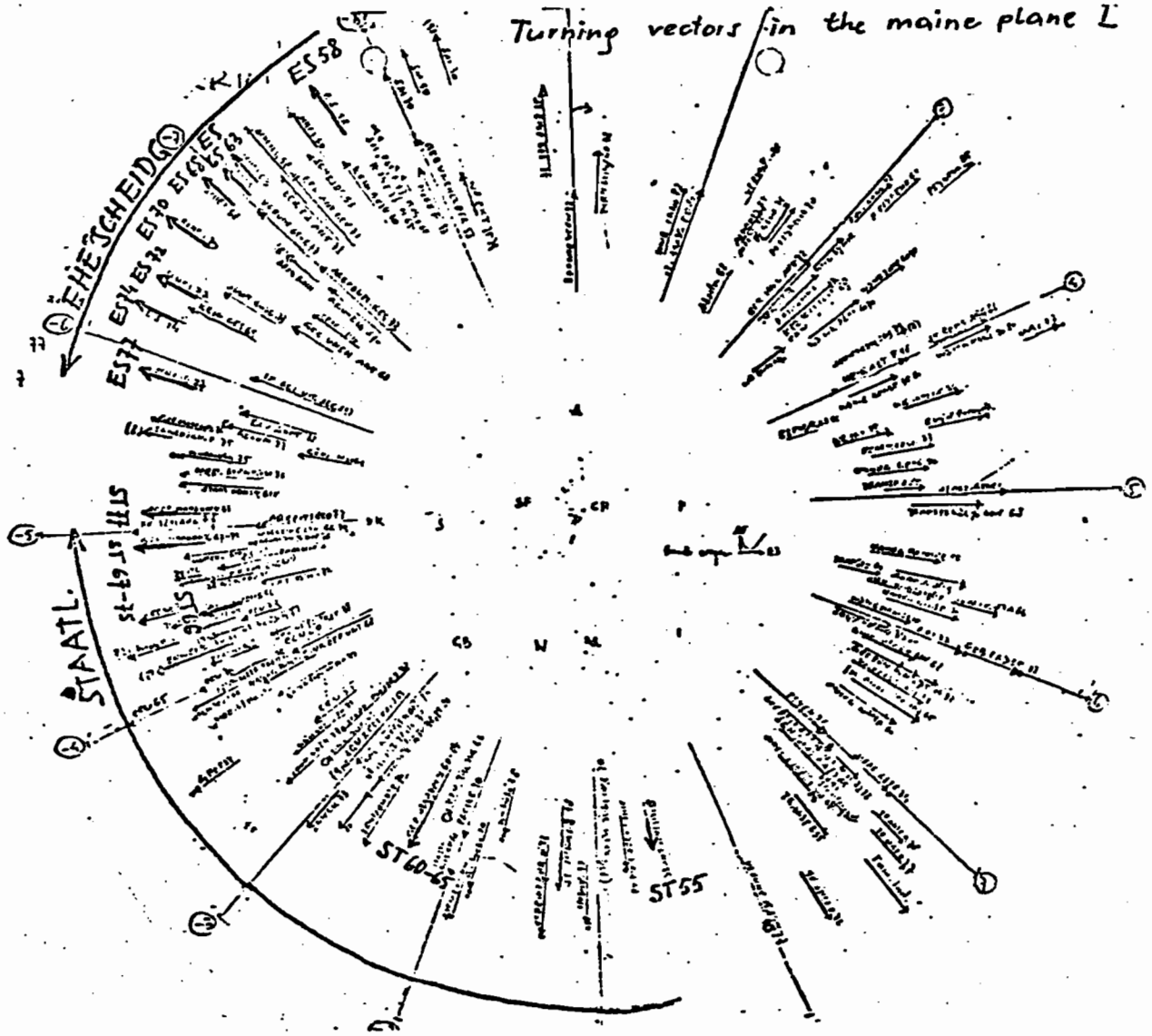

Figure 7. Turning vectors in the main plain I*

*Main plain I describes the issue government activities and socio-psychological determined behavior patterns. An interesting and not expected detail is, that some vectors in the plain are turning: in the 50's government activities and an indicator for the quality of the family were nearly parallel and the vector of divorce had the opposite direction. In the following decades the vectors of government activities and divorces turned in a opposite direction so that now government activities and divorces are nearly parallel.

Table 1. Hard and soft variables in the long wave

State of the long wave	'hard'	'soft'			
	Economic and technological variables	Quality of family	Achievement Motivation	Sublimation	Institutional rigidity
upswing	Innovation new sectors increasing investment increasing employment	high	increas.	high	low
	Competition rationalization concentration capital goods overemployment	decreas.	high	decreas.	increas.
	increasing export overaccumulation capital intensity labor-saving-investment	low	decreas.	low	high
downswing	flight into money- and capital markets underinvestment		low	increas.	unstabl.
	unemployment	increas.			break down

ELASTIC MECHANISMS OF INTERCOUNTRY ATTRACTION OF LOGISTIC INDUSTRIAL GROWTH

Roberto Vacca (Italy)

SUMMARY

This paper attempts to analyze the mechanism for the progressive decrease of growth time constants for the penetration of cars in certain countries. The phenomenon, clearly illustrated by Marchetti, consists of faster progress to lower levels of car saturation in countries that are later motorized. A mathematical analysis is provided to explain the phenomenon. A discussion is given on the possible repetition of similar patterns -- leading to third world countries being significantly involved in the next innovation wave.

— oOo —

Schmidt and Marchetti [1] have observed that the penetration rate of cars on the market of an industrial country is faster the later that country starts getting motorized. The time taken to go from 10% to 90% saturation, along a logistic curve, is termed T, the penetration time constant. The logistic curve of car registration in the United States has the equation:

$$L = F/1-F = 2.1833^{-54} \cdot e^{(x/15.98)} \qquad (1)$$

where F is the current fraction of the saturation level, L is the current level and x is the current year (date). For the United States T is 79 years. Later, other countries have seen their car registrations grow following logistic curves with shorter and shorter time constants (58 years for Canada, 47 for Sweden, 30 for England and France, 22 for Italy, 21 for Germany, 12 for Japan). If we call x the year in which the car population was 1% saturation for a given country, the time constant decreases regularly as a function of x according to the equation

$$T = 2.103 \cdot e^{(2000-x)\ .04146} \qquad (2)$$

Marchetti also noted that countries arriving later on the scene reach lower and lower saturation levels in terms of the number of inhabitants/car. At saturation this figure will be: 1.13 for the USA, 2.7 for France, 3.29 for the UK, 3.21 for Germany, 2.85 for Italy and 5.57 for Japan. This suggests that the saturation level is very roughly in inverse proportion to the time constant T.

A possible explanation of this state of affairs is that each country has been attracted to follow in the USA's path, the attraction being stronger the higher the level reached by the USA in the year the new country appeared sizably on the scene. In this very simple model the current level L (= F/1-F) in the USA would play the role of the constant determining the elastic attraction force. The time constant T would play the role of the period in the ensuing harmonic motion. The per capita saturation level of each country would play the mass role, being attracted elastically with a force proportional to the square of L. Since per capita saturation, as noted above, is roughly inversely proportional to T, this would suggest that the third power of T is inversely proportional to the square of the USA current level L in the year the country reaches 1% of saturation. In other words T should be proportional to the power -2/3 of the USA current level L. Fitting the constant in order to minimize the least square differences, indicates that the time constant T is expressed by the relationship:

$$T = 5.8686 \cdot L^{-2/3} \qquad (3)$$

The difference between values of T given by equations (2) and (3) is less than 1% up to about 1974 -- after which the values of T are so low that they appear to bear little relationship to the real world anyway.

All this rather naive exercise -- which results, however, in strikingly good numbers fit -- is intended to stress the point that the perception of saturation levels reached by leader countries may indeed have an effect on the development of follower countries.

On the other hand, a vast literature indicates that well known prerequisites to the development of given industrial sectors and to development per se, are:

- capital accumulation, possibly replaced by extended credit,
- lively investment in innovative ventures,

- -- availability of a work force with adequate levels of skill,
- -- adequate cultural levels of users,
- -- opening of external markets to integrate the growth of internal markets.

Marchetti stresses the fact that durable goods markets are reaching saturation simultaneously in all industrial countries. This is equated to the filling -- and consequent closing to new arrivals -- of ecological niches. The pattern, however, applies roughly only to one quarter of the world population. The three quarters of the world which have not taken off on the path to development could represent a vast new niche waiting to be filled. They have not functioned as new pastures for the expanding species of new industries because of the lack of the prerequisites indicated above. This was also true of industrialized countries in the days before their development set in. Decisive unleashing factors may have been: for England, Sir Francis Drake's plunder of Spanish gold; for the United States, the steady immigration for many decades of millions of trained artisans and professionals.

Marchetti contends that innovation from previous waves hardly ever is taken up again in subsequent waves -- even in different geographical areas. Witness that no canal transportation nor railway networks have been built in this century or that, as noted before, the level of cars per capita at saturation tends to decrease monotonously. But the overall picture is far from clear. Subway systems and electric grids are still being built, although they are almost one century old. Furthermore the elastic attraction mechanisms proposed above can only be analyzed after they have taken place. Their modeling, as attempted here, is hardly more than a simile, since no cogent reasons are apparent for explaining, e.g., the trend to ever lower levels of cars per capita at saturation. A consequence of the above is that planning and policy making cannot and should not avoid massive recourse to experimentation and cut and try. This, however, should not be done on the basis of documents which have essentially a literary character, as has been customary to date. Plans should be expressed explicitly and preferably flowcharted and PERTed. One of the main scopes of the exercise would be to define and analyze development mechanisms in order to review and rebuild policies adequate to reach desirable ends.

Three main areas should be tackled in innovative ways:

- -- **Capital and credit.** At present the chronic and increasing indebtness of third world countries points to moratoriums and a stop to further credit just to service credits obtained in the past. A largely untapped source of capital may be represented by the exploitation of large renewable energy sources, e.g., hydroelectric. The untapped hydroelectric potential of Africa, for example, is many times larger than all the European electricity demand. It could be exploited first with direct current transmission lines many thousands of kilometers long, to be integrated later in a African grid interconnected to the European system. A mortgage system would then provide ample development and venture capital. Similar arrangements may be reached with other types of natural resources provided modern tools are adequately used for their prospection and assessment.
- -- **Mass diffusion of culture.** The population of a country cannot engage meaningfully in the production -- and later in the use -- of fairly modern durable goods unless its cultural level exceeds a given threshold. This threshold can be defined for the moment only in a fuzzy

way. It certainly includes elementary literacy for the large majority of the population. It certainly does not include any depth of knowledge of the physical world, except in very narrow contexts and for fairly small population subgroups (designers, technicians). It appears very probably to be, perhaps, the largest single cause of automatic demographic control. The overcoming of this first threshold, however, was not consciously planned by statesmen or educators. It just happened, although it was certainly made easier by larger and slightly better school systems.

It appears, though, that the cultural level reached in industrialized countries is adequate to support the transition to an innovation wave largely consisting of information generation, processing and use. In order for the next innovation wave to swell and roll on, tools developed in the last wave (TV networks, computers, automated teaching aids) will have to be used in advanced countries to help the population overcome higher cultural thresholds. This process should also produce the spinoff of defining mass education procedures capable of leading third world population to overcome the first threshold. Incidentally modern mass schooling could well be a vital new sector for the next innovation wave. The inventions of educational TV and of computerized instruction go back a few decades, but have been implemented only very marginally so far.

-- **Migration of populations.** So immigration of professional and skilled workers was a significant force behind the development of the United States. In a much slower and disorderly way the migrations of people in the Middle Ages produced flows of ideas and knowledge finally leading to the Renaissance and to the birth of modern science and technology. Again the positive side effects of these large movements of population were not planned.

At present current means of transportation foster mass travel which, in general, has short duration, most effects on balances of payment and no cultural effects. Planned mass migration in either direction between North and South could transfer: technology, ideas, increases and favors mass diffusion of cutlure.

CONCLUSIONS

It is quite difficulty to measure cultural levels of achievements. It is even more difficult to assess their effects on industry, on the economy, on society. Common sense suggests that cultural factors are very relevant for innovation, development and, perhaps, for survival. Difficulty in quantification should not deter us from trying to design societal systems possibly capable of averting dire material and moral risks to society and to individuals. This paper is a modest contribution in this direction.

REFERENCES

[1] Marchetti, C., 1982 'The Car in a System Context. The Last 80 Years, and the Next 20.' WP-82-5, Laxenburg, Austria: International Institute for Applied Systems Analysis, January.

APPENDIX 1

International Institute
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A-2361 Laxenburg/Austria

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Telex 079137 iiasa a

ANNOUNCEMENT OF A MEETING ON

LONG WAVES, DEPRESSION, AND INNOVATION:

IMPLICATIONS FOR NATIONAL AND REGIONAL ECONOMIC POLICY

Siena/Florence, Italy, 26-29 October, 1983

Organized by: International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria

Istituto Regionale per la Programmazione Economica della Toscana (IRPET), Florence, Italy

Sponsored by: Monte dei Paschi di Siena

Under Patronage of: Regione Toscana
Comune di Firenze

Background: In recent years, it has been increasingly recognized that the present economic situation cannot be explained as merely a short-term recession. As a result, the "long wave" behavior of global, regional, and national economic activities has become the subject of thorough scientific investigation. But, despite this widespread interest, there is still no generally accepted interpretation of these cycles or fluctuations, much less of their causes. It is particularly difficult to draw an analytical line between cyclical and structural impacts, and this severely handicaps attempts to identify the underlying causes of economic depression (or upswing).

The meeting will bring together, for the first time, the leading scientists working in this field, with the twin goals of advancing theoretical insight into the problem and examining policy implications on the national and the regional level. In this context, the role of innovation will receive particular attention.

APPENDIX 2

TOPICS TO BE TREATED

TOPIC 1: *Theories of the Long Wave*

What are the basic alternative theories of the long wave?
To what extent are they competing or complementary?
What is the most meaningful taxonomy of long-wave theories?

TOPIC 2: *Identification of Long Waves*

To what extent can the long wave be clearly distinguished empirically from business and Kuznet's cycles?
What are the specific problems and ambiguities in attempting to clearly identify historical long waves?
To what extent can the causal mechanisms underlying different cycles be distinguished?
Is it possible for a single, all-encompassing model to represent the diverse mechanisms underlying the different cycles?

TOPIC 3: *Theory Testing and Integration*

What is the range of appropriate tests for alternative theories of the long wave?
Are conventional econometric methods appropriate?
What can computer simulation contribute to testing theories of the long wave?
Is it possible to develop valid tests given the paucity of long-term time series data?
How close are we to an integrated theory of the long wave?
What specific methodologies exist to meaningfully integrate theories and test their relative explanatory power?

TOPIC 4: *Possibilities for Influencing Long-Wave Behavior*

To what extent can the long wave be influenced by economic policy?
What fundamental parameters and structures seem most important for determining the period of the long wave?
How do the policy options that can potentially influence long-wave behavior vary from the expansion phase to the downturn phase?
If advanced economies are in the downturn phase of the long wave, what meaningful policy options currently exist and how can they be brought to the attention of policy makers?
In what ways are the appropriate policies for a long-wave decline different from the policies currently being implemented in the Western industrial economies?
What policies are the most dangerous ones, which should therefore be avoided during a long-wave downturn?

TOPIC 5: *National and Regional Aspects*

To what extent are different nations, different regions, or the Third World affected by long waves?
To what extent do they have different policy alternatives available to them?
Insofar as the transition to new industries may occur during a long-wave downturn, what forms of government intervention are appropriate to diminish the negative consequences for regions heavily reliant on declining industries?

APPENDIX 3

TENTATIVE PROGRAMME

for a meeting on

LONG WAVES, DEPRESSION, AND INNOVATION:

IMPLICATIONS FOR NATIONAL AND REGIONAL ECONOMIC POLICY

WEDNESDAY, OCTOBER 26

Morning: Arrival of participants at Rome and Florence. Transfer by coach to Siena. Accommodation and lunch at Jolly Excelsior Hotel and Villa Patrizia Hotel. The Jolly Excelsior Hotel is a new building, within walking distance from Monte dei Paschi; all non-Italian participants will be accommodated there. Hotel Villa Patrizia is 3 kilometers distance and transportation will be provided.

Afternoon: 16.00 Welcoming Addresses

P. Barucci, President of Monte dei Paschi di Siena

C.S. Holling, Director, IIASA

The Mayor of Siena

16.30 Introduction to the Meeting

Evening: 19.30 Concert at Chigiana Academy of Music

21.00 Official Banquet at the Town Hall Palace

THURSDAY, OCTOBER 27

09.15-11.00 *TOPIC 1:* Theories of the Long Wave

Coffee Break

11.15-13.00 *TOPIC 2:* Identification of Long Waves

Lunch

14.15-16.00 *TOPIC 3:* Theory Testing and Integration

Tea Break

16.15-17.30 *SPECIAL TOPICS*

18.30 Departure for a typical farm house of Chianti (30 minutes by coach). Visit and Dinner.

FRIDAY, OCTOBER 28

09.15-11.00 *TOPIC 4:* Possibilities for Influencing Long-wave Behaviour

Coffee Break

11.15-13.00 *TOPIC 5:* National and Regional Aspects

Lunch

14.15-16.00 *GENERAL DISCUSSION*

Tea Break

16.15-17.00 *FINAL REMARKS AND CONCLUSIONS*

18.00 Departure by coach to Florence

19.30 Arrival and accommodation at Kraft Hotel, near the Arno river and the railway station. From its roof garden with restaurant, is a magnificent view of Florence.

SATURDAY, OCTOBER 29

10.00 General Session at Palazzo Vecchio (Simultaneous Translation)

17.30 Défilé at Palazzo Pucci

20.30 Dinner

SUNDAY, OCTOBER 30

Morning, upon request: Sightseeing tour of Florence.

SPECIAL SPOUSES' PROGRAMME

THURSDAY, October 27, 9.30:	Sightseeing of Siena (with local guide)
FRIDAY, October 28, 9.30-12.30:	Guided excursion to S. Gimignano (medieval small town near Siena)
SATURDAY, October 29, 9.00:	Sightseeing of Florence (with local guide)

For further information please write to:

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