NOT FOR QUOTATION
WITHOUT PERMISSION
OF THE AUTHOR

LONG WAVES, DEPRESSION, AND INNOVATION: IMPLICATIONS FOR NATIONAL AND REGIONAL ECONOMIC POLICY

PROCEEDINGS OF THE SIENA/FLORENCE MEETING (26-30 OCTOBER 1983)

Giuliano BIANCHI
Gerhart BRUCKMANN
Jos DELBEKE
Tibor VASKO
Editors

March 1985
CP-85-9

Collaborative Papers report work which has not been performed solely at the International Institute for Applied Systems Analysis and which has received only limited review. Views or opinions expressed herein do not necessarily represent those of the Institute, its National Member Organizations, or other organizations supporting the work.

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
2361 Laxenburg, Austria

FOREWORD

The opening sentences in the IIASA Charter speak about the problems generated by industrialization. Therefore industry, technology, and the economy have been implicitly or explicitly embodied in most of the Institute's projects.

The first big IIASA research program, on energy, naturally entailed studying the impacts and dynamics of technology diffusion. This was the first research at the Institute to touch on the possible causes of long-term economic growth. Later studies of the management of innovation acknowledged the need to understand the interaction of technological with economic (and social) development beyond the frame of classical and neoclassical economics. One particular question reflected that need: How could cyclical influences be distinguished from structural ones? We tried to gain a better view by doing some case studies, which only increased our conviction that examination of these issues promised to be rewarding.

The small meeting on long waves that we started to arrange eventually developed into a conference. The way the conference was organized and the cooperation it engendered further demonstrated that studies of these issues are timely. The problem that the organizers had to face was how to make maximum use of all the creative potential of the participants. It was therefore decided to arrange the conference in the following way:

- Full papers describing results of research on long waves were distributed before the conference and not read to the audience.
- Position papers on particular topics were selected before the conference so as to focus attention on the most important issues; the ensuing discussions and comments captured interesting views and ideas, reflecting the creative atmosphere of the meeting.

This proceedings volume is structured accordingly: Parts I and II consist of a selection of the papers and comments on the five topics, and Part III includes further discussion by various participants. Part I starts with J. Delbeke's, paper which gives an overview of the conference. This paper is particularly useful for those who are making a first acquaintance with this topic. We were also fortunate that several complete models or position papers on different long-wave schools were submitted to us. To keep the proceedings volume to a manageable and economic length, we were obliged to publish several of the papers submitted (by A. Piatier, A. Kleinknecht, J. Sterman, and J. Delbeke) separately as IIASA Collaborative Papers. We feel that this strikes a sensible middle course between the need to document the conference's work and the dictates of size and finance.

The presence of leading representatives of different theories of long waves made it possible to gain first-hand insight into the state of the art, as well as to hear about the more promising directions for further research.

Most meetings on long waves tend to be exclusively economy oriented, but the Siena/Florence meeting was rather different. Consistent with IIASA's interdisciplinary role, representatives of other disciplines were present and it is worth recording that researchers working in biology, demography and sociology hinted, in their contributions, at mechanisms studied in their own disciplines that could also lead to long-wave phenomena.

In spite of the fact that many economists do not accept the existence of long waves as proven, the majority of scientists at the meeting did not question the existence or relevance of long-wave phenomena, irrespective of their cause. Nevertheless, it is extremely difficult to identify long-wave phenomena and several participants mentioned the problems to be expected in such investigations.

IIASA and IRPET both focus on policy orientation and policy instruments. Proponents of all the theories represented were united in the idea that numerous phenomena could be better understood by applying long-wave theories. This understanding is essential for the design of optimal policies; therefore it appears that future research into long-wave issues is both desirable and necessary.

We were very fortunate to have the support of our Italian hosts at an early stage in the development, preparation and organization the Conference. It is also to their credit that the meeting surpassed all expectations as far as scientific coverage of the topics and international representation was concerned, and we owe them our thanks for their warmth and generosity. Finally, the meeting in Siena and Florence was exceptional, both in that its scope was wide and that it integrated the work of researchers from East and West.

The publication of this proceedings volume was fraught with more than the usual amount of difficulties and changes of plan. Our thanks are due to many IIASA staff members without whose perseverance and hard work we would have been unable to bring the volume to a successful conclusion.

Tibor Vasko　　　　Gerhart Bruckmann

ACKNOWLEDGEMENT

The Conference which led to these proceedings would not have taken place without the generous support of

Monte dei Paschi di Siena,

Regione Toscana,

Comune di Firenze.

Giuliano BIANCHI
Director
IRPET

Thomas H. LEE
Director
IIASA

CONTENTS

PART II – COMMENTS ON TOPICS 1-5

Topic 1: Theories of the Long Wave

Topic 2: Identification of Long Waves

Topic 3: Theory Testing and Integration

Topic 4: Possibilities for Influencing Long-Wave Behavior

Topic 5: National and Regional Aspects

PART III – ORAL COMMENTS/DISCUSSIONS

APPENDICES

THE FIVE TOPICS

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 Kuznets cycles? What are the specific problems and ambiguities in attempting to 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 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 reduction of the long wave different from the policies currently being implemented in the Western industrial economies? What policies are the most dangerous, and therefore should 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?

Video Message from J. Tinbergen (Netherlands)

Ladies and Gentlemen,

I apologize for not being able to attend this Conference. I very much appreciate, however, the possibility given to me by Professor Bruckmann to make a contribution on tape. The main point I would like to deal with is the following: it seems to me that to do research on the causes of the long waves does not necessarily supply us with the information that we need in order to follow the optimal policy, that is, to eliminate, as far as possible, these long waves. The reason is that not all causes of some past movement can indeed be eliminated in order to avoid any movement. The causes can be divided into two types. There are causes that can be changed, there are other causes that cannot and for the best policy to be found we have to think of other problems, namely to find means and instruments that will affect employment in the sense we desire. This means that not all the knowledge about the causes is useful for finding the best policy. In addition we have to know instruments that are able to compensate for those causes that cannot be changed. Now, assume that technological developments cannot be changed but are the outcome of an autonomous process, technological research. In that case we have to look for other means to affect employment in the way we wish and it is these other factors that I think we have to discuss especially. I would like to call them social innovations in contradistinction to technological innovations and as a first example I would give first of all the implementation of the recommendations of the Brandt Report. That means, among other things, that the quota of the International Monetary Fund would be increased.

Another example of possible social innovations may be found from looking at the Japanese example. It is remarkable that Japanese management consults its collaborators much more often than is customary in either the United States or Europe and it seems that, as a consequence, the satisfaction from work in Japanese enterprises is definitely higher than it is in the other continents. There are further examples to be found by studying the Japanese economy. Another aspect is that the income distribution in Japan is much less unequal than for instance in the United States and this too, of course, may contribute to a better atmosphere in an enterprise. Finally, we may even remind ourselves of the fact that also the Japanese worker works very hard, which also could be a contribution to improving the position of especially Europe on the world market. Therefore it seems to me that alongside doing research about the causes of the long waves it is important also to organize research that brings us to find social innovations able to create an employment policy more in correspondence with our desires.

I thank you very much for your attention.

PART I

PAPERS ON TOPICS 1 TO 5

LONG-WAVE RESEARCH: THE STATE OF THE ART, ANNO 1983

Jos Delbeke

1. INTRODUCTION

Given the current state of long-wave research, it is difficult to present a comprehensive summary of all the papers and discussions at the Conference. Therefore, this paper presents only one of the possible interpretations of the state of the art. Nevertheless, we are convinced that this disadvantage represents at the same time a merit of the paper. Indeed, it is in the early stages of research, when the confusion is considerable, that insights are essential. This is why the paper will not adhere to the five planned topics, but will review the most important issues.

In the next section, we sketch the theories that have been revived or developed recently and classify them according to which variables are considered crucial in the different explanations. The rest of the paper deals with relatively new methods and models. After a short review of the inductive investigations, the fourth and most extensive section concentrates on theory building. Four main classes of explanations can be discerned: the historical–institutional, the growth-theoretical, and the macroeconomic approaches, completed with theories based on the influence of noneconomic variables. The final discussion is dedicated to policy issues and the probable directions of further research.

2. A CLASSIFICATION OF RECENT THEORIES

In a general sense, we may state that long-wave research deals with structural changes in the economy. Nevertheless, there are many different approaches, and several authors have developed schemes of the most important ones. In our view, three main categories of theory can be discerned: the real, the monetary, and the institutional. At the time of writing, the real theories clearly are the most attractive, and this was made evident at the Conference.

Delbeke (1981) classifies the real theories according to the production factor that is supposed to be crucial and shows the complementary character of the different approaches. The role of entrepreneurship is considered to provide the most important approach (*Bruckmann*)*. Schumpeterian innovation theories are certainly the most widely debated since *Das Technologische Patt* (Mensch 1975). Freeman stresses the impact of innovation on labor demand, and he and his Science Policy Research Unit (SPRU) at the University of Sussex are becoming increasingly involved in a fundamental discussion with Mensch (Freeman *et al.* 1982). The capital theories of Forrester (1977) (excess capacity) and Mandel (1980) (the Marxist law of the falling rate of profit) are taking up and modifying the original ideas of Kondratiev. Rostow (1978) stresses the availability of raw materials and is, to a certain extent, generalizing from the oil scarcity of the 1970s.

This classification scheme can be broadened to incorporate relative prices, which many authors treat either implicitly or explicitly. In our scheme, we observe that the production factors gradually become scarce during the upswing and abundant during the downswing, but to varying degrees. This is, in principle, reflected in the relative factor prices. However, this redistribution of factor income, which is an essential feature of the long wave, can be hindered by inertia. Some institutional theories consider this disturbance explicitly, and interpret the time lags as necessary to produce the long-wave depression. Some authors take the Marxist approach to be a different class of real theory. However, Marxists are opposed to this, in our view rightly, because the declining and rising rate of profit, i.e. the rate of capital accumulation, is also inherent in any other approach. In fact, they take the distribution of factor income, and the concomitant social struggle, as the most important element of their theory.

Theories based on the relative prices of goods can also be included in our classification scheme sketched out above. For example, the rapid growth of leading sectors is caused by declining relative prices of their products, made possible by improvement innovations in the products and in the production processes. Similarly, on an international scale, Rostow's theory deals explicitly with the terms of trade of primary versus industrial goods.

The monetary theories can be treated as a second category. Interest in the monetary aspects of the long wave has been remarkably low in recent research. During the interwar period it was quite the reverse, when most researchers stressed that the price level most clearly reflected the long wave, being the link between the real and the monetary sector (Dupriez 1947, 1959). Of late, few researchers have been attracted to this type of analysis because of the constant rise in prices since the 1930s. Therefore, when prices were analyzed, interest shifted more to relative prices. Moreover, most researchers are troubled by the stress laid by Kondratiev and Cassel on gold discoveries, which have, of course, been important to the gold standard but much less so to the fiduciary standards since the interwar period.

Some Conference participants mentioned, however, that the price level, calculated as the wholesale price relative to gold, showed the clearest long wave (*Craig and Watt*, *Goodwin*). Others stated that a study of long-term fluctuations in price formation, credit, and money circulation is absolutely essential (*Menshikov and Klimenko*). The group from the Massachusetts Institute of Technology emphasizes the role of these variables in the downswing, particularly for economic policy. Two papers were presented to stimulate long-wave analysis of the monetary sector. *Senge* analyzed the interplay of nominal interest rates and inflation, i.e. the real interest rate, while *Delbeke and Schokkaert* studied the interaction of investment and debt, indicating the possibility of endogenous money creation

---

* Authors' names are italicized where references are to Conference papers (see list of References at end of paper).

during the long wave.

Theories that emphasize social and institutional structures can be considered as the third main category of long-wave theory. A very appealing approach of this kind was presented by *Perez-Perez* of the SPRU. She calls for a global view instead of a too narrow economic analysis: to explain long waves the total system must be studied, i.e. the interactions of the technological, social, and institutional components with the economic subsystem. (The work of Gordon *et al.* (1982), stressing the social structure of capital accumulation, should also be mentioned here.) For example, the distortion of market signals as a result of the counterproductive behavior of institutions, which prolongs the depression, can be interpreted as a specific case of institutional factors at work (*Glismann*).

This classification of real and monetary economic theories and of theories referring to social structure allows us to make some useful observations. All three types of approach agree, implicitly or explicitly, that the long wave is inherently based on capital accumulation and is therefore most noticeable in the industrial economies, especially the market-oriented economies. Moreover, it seems that a fruitful integration of long-wave theories is not possible if these three main categories are not included. The monetary and financial sector seems to be particularly neglected in research, because it has to be considered as more than a mere reflection of the real sector. Finally, it should be noted that any classification is only possible with some degree of simplification. In fact, many long-wave theories belong to more than one of our categories, because the present classification uses the basic variable as its sole criterion. This classification is therefore first and foremost a logical scheme developed for the confused observer who wants some insight into a rapidly expanding field of research.

3. THE INDUCTIVE RESEARCH

The identification of the long wave is the crucial first phase of research for several reasons. *Mensch* (Paper B) calls it "exploratory research [which] usually means descriptive, historiographic, empirico-inductive (data-driven) work directed at formulations of tentative hypotheses and tentative assumptions." We think this is an unavoidable phase, since there is no firm body of deductive reasoning available. Hence, the different long-wave theories had to start from diverse empirical indications, and this has led to different conclusions – at first sight, at least.

Secondly, and related to the first reason, mainstream economists feel quite skeptical about the long-wave concept. Statisticians see the long wave as a "result" of wrong statistical procedures, especially of detrending with moving averages, with filters in spectral analysis, or with the choice of the basic movement (Slutzky effect; see Slutzky 1937, Adelman 1965). Others argue that there are very different statistical procedures that empirically show the existence of the long wave (*Glismann*). Indeed, we may at least accept that there are some recurrent unstable movements over the long term. Another criticism is that the statistical procedures are applied to series that are found to be too short, given a length of about 50 years for one long wave. Thus, the whole idea of the long wave could have started erroneously, from overinterpretation (*Entov*). Forrester and his MIT group try to avoid this problem by rejecting correlation analysis in favor of the methods of system dynamics. In their view, a model that generates data comparable to the historical data forms a good statistical test, while what remains unexplained by the model consists of historical peculiarities.

We are convinced that a reconstruction of economic time series for the whole industrial period is a crucial task, of which the largest part still has to be done. Freeman even remarks that this task should be seen as an art (*Freeman and Soete*). Moreover, when reconstructed data, especially national accounting data, are available, historical criticism remains essential to show where the weaknesses are situated, in order to avoid drawing empirical conclusions from *a priori* reasoning. We consider this art of data reconstruction as one of the most important and promising forms of research, which must be continued despite the rapid development of the more deductive approaches.

However, empirical analyses were of minor importance at the Conference, and we attribute this to the absence of economic historians. Nevertheless, a good sample of inductive long-wave research was presented. Firstly, there was the approach of Craig and Marchetti, who collected, selected, and analyzed several groups of long-term data. They concluded that a certain long-wave pattern was observable, and made extrapolations for the future, the former cautiously, the latter self-confidently.

Craig found some, but not abundant, evidence to support the idea of the long wave as a metaphor for change. His long waves were strongly correlated with war, and therefore the extrapolation suggests an extremely dangerous period early in the 21st century.

Marchetti can be considered as the leading advocate of the inevitability of logistic growth caused by innovation processes (*Craig and Watt*). Craig sees the saturation problem as very difficult for this type of analysis. Indeed, the fit of logistic equations assumes that one knows in advance what the saturation level is, while at the point where saturation is reached there seems to be ample reason to believe in further growth, e.g. in the automobile sector (*Craig and Watt*). In contrast, *Marchetti* uses the logistic curve as the best method to describe physical phenomena and concludes that "the signals... are crystal clear" when one is "getting out of the quicksands of money indications". In his view, long waves go beyond economics, and therefore he prefers to define them as "long-term pulsations in social behavior". He concludes that "A pulsation of about 50 years seems to pervade all sorts of human activity", and that this takes place without much decision making. For example, "car populations grow exactly like animal populations", while nuclear fusion can be expected for 2025, "*Alles im Schritt*". What Craig mentioned as possible is strongly advocated by Marchetti, i.e. that strict biological rules are at work in the economy, and in human society.

This kind of research raises a lot of interesting questions. The use of logistic curve analysis, showing saturation levels, is taken up by several authors, implicitly or explicitly (e.g. *van Duijn* and *Vacca*). However, one has to realize that saturation in economics is never absolute but relative. But most of all it is crucial to know whether economic behavior follows the deterministic rules of a biological system. If the answer is positive, the search for policy measures has no sense at all. This suggestion will be taken up in Section 4 when we deal with the self-organization paradigm. However, at this moment it is good to keep in mind the warning of Schumpeter (1942), quoted by *Islam*: "Analysis, whether economic or other, never yields more than a statement about the tendencies present in an observable pattern. And these never tell us what *will* happen to the pattern but only what *would* happen if they continued to act as they have been acting in the time interval covered by our observation and if no other factor intruded."

The inductivist approach, borrowed from natural science, was not followed by *Bieshaar and Kleinknecht*. They analyzed GNP and production data for the world and for seven individual countries. Their aim was to supply some practical evidence as a basis for further development of long-wave theory. Their most interesting conclusion is that the evidence for the existence of long waves before 1890 is ambiguous, except for Belgium, Italy, and Sweden, but that there is a fairly significant pattern after that date. The pre-1890 ambiguity can be explained in three ways: by underestimated data, by movements with stronger impacts than the long wave (e.g. the hegemonic life cycle of Great Britain), or by the hypothesis that long waves become primarily important for the era of *Hoch- und Spätkapitalismus*. A complementary explanation could be the remark of *van Duijn* that, during and after its economic take-off, a country is less affected by the next long-wave downswing. This claim is confirmed by Bianchi's empirical regional analysis for Italy (*Bianchi et al.*). Indeed, since 1890 all countries analyzed by Bieshaar and Kleinknecht have become mature economies.

In our view, the latter way of empirical analysis is helpful and must be pursued further, not only for production data but also for more qualitative and social information. In this way new insights can be brought to the fast-growing deductive research. However, it would be more successful if this theoretical development could help define important areas for further empirical investigation.

4. THE MORE DEDUCTIVE RESEARCH

In recent years, most energy has been dedicated to the interpretation of the long wave, and to the search for underlying causal mechanisms. In fact, several people implicitly assume that further efforts to demonstrate empirically the possible existence of long waves may be subject to rapidly declining marginal returns (e.g. *Delbeke and Schokkaert*). Several researchers even doubt whether a definite statistical proof can be produced in the near future (*Freeman and Soete*, *Bieshaar and Kleinknecht*, *Tinbergen*), while for van Duijn using the long-wave concept is an act of faith (van Duijn, oral comment). *Mensch* (Paper B) goes a big step further, claiming that we are leaving the inductive phase and entering the deductive one. Indeed, waiting for the next hundred years has no sense at all, while we can take the prediction by several authors (e.g. Mandel) of the present downswing as an indication that "something" is happening over a very long term. *Menshikov and Klimenko* offer some consolation with the remark that we have neither strong empirical evidence for the existence, nor convincing theoretical arguments for the impossibility of the long wave. Given that any science needs a framework of thought for its development, we are convinced that enhanced deductive reasoning becomes essential.

Critical observers often state that the long-wave concept can only attain credibility if scholars develop theoretically convincing endogenous models for it (*Bieshaar and Kleinknecht*). While most Conference participants fully agreed about this need, it remained dubious within which boundaries the fundamental forces are supposed to be at work: within the economic system or within the whole society. *Goodwin* made a remarkable intervention, doubting the possibility of an endogenous economic explanation of the long wave. In particular, he thought the determination of the lower turning point extremely difficult. In our view, Goodwin's remark goes to the heart of the present research. The assertion that the long wave is intimately connected with the whole of society, i.e. with economic, social, and political variables, gained support from many researchers. This argument can also be found in the older theories, which state, for example, that wars accelerate existing processes and are responsible for the change in their direction (Dupriez 1947, Akerman 1957). However, within such a broad framework, some made a deterministic interpretation, e.g. Marchetti, while many others made a nondeterministic one, e.g. Goodwin, Freeman, and Tinbergen. According to Tinbergen, only conditional predictions can be made because of the important role of exogenous variables. Therefore, we may state that the economic–holistic and deterministic–nondeterministic dualities in long-wave analysis will have strong implications for the design of economic policy.

Freeman pointed out that a meaningful division of the various long-wave theories might be between the neo-technological theories and the rest (*Freeman and Soete*). Indeed, most interest in the recent past was given to Schumpeter's thesis about innovation as a process of creative destruction. In 1975, in his work *Das Technologische Patt*, Mensch reopened the debate by claiming that a long-wave depression can only be overcome by a cluster of basic innovations. This cluster breaks through because entrepreneurs are forced to innovate, given the saturation of existing markets and the urgent need to create new ones. The following upswing is carried by rapidly expanding leading sectors, in which the basic innovations are improved. Mensch's interpretation of Schumpeter's work has been named the "depression-trigger" hypothesis, because in the middle of the downswing, the "technological stalemate", numerous radical innovations are the only way out of it.

This hypothesis has been criticized by Freeman and his SPRU group. They question the supposed clustering of basic innovations in the depression. According to them, recovery is based upon the rapid diffusion of applications of new technologies that had emerged as basic innovations before the depression. Moreover, counting basic innovations can be misleading, as it is not primarily the individual innovations but rather the systems of interrelated product and process, technical and managerial innovations that seem to be of most importance. According to the SPRU, then, the main policy objective is not so much to stimulate new basic innovations as to develop policy measures aimed at fostering the diffusion of the new, and existing, technological complex in such a way as to minimize social costs worldwide and to reap the maximum social benefits. Freeman's stress on the diffusion of the new technology complex is also indicated in the literature as the "demand-pull" hypothesis.

This technology debate opened a wide and fruitful discussion on the basis of Schumpeter's work and forced both groups of researchers to deepen their analyses and arguments. In this way two very different methodologies developed. Mensch refined his hypothesis on a more mathematical basis, and together with his collaborators he tried to integrate his innovation hypothesis into formal growth theory using nonlinear dynamic models. Freeman and his SPRU group followed a completely different way of research. They stressed the need to analyze the unique features of microelectronics and related technologies. In their view, a rapid diffusion of the new technologies is hindered because there is an urgent need for accompanying institutional innovations, on both the national and the international level. Using an historically oriented and institutional approach, they are able to develop clear, operational directions for economic policy.

To these two important technological theories must be added two other approaches, namely the more macro-oriented research and the analysis of noneconomic variables. However, we have the impression that these might possibly be integrated into the two methodologies described above. The system dynamics methodology of Forrester and his MIT group emphasizes the growing excess capacity in the upswing, which must be brought back to "normal" levels during the downswing. Technological innovation is essentially playing a passive role, although it can be activated. The basis of their analysis is the microstructure of self-ordering in the capital goods sector, although numerous amplifying variables can also be integrated. Menshikov and Klimenko utilize the Marxist law about the tendency of the falling rate of profit. In a small model they illustrate the interplay of labor and capital productivity and the effect on profits and industrial change. Delbeke and Schokkaert demonstrate that long-wave instability may also follow from financial and monetary variables and that even a simple linear dynamic model can generate long waves. They describe some important macroeconomic barriers to rapid diffusion of innovations. Finally, Millendorfer and Screpanti model the important influence of noneconomic variables. Following these principal lines of thought, we will review the different contributions to the building of theories of the long wave.

4.1. The Historical–Institutional Approach

Freeman and the SPRU group can be considered as the main representatives of what we can call "the historical–institutional approach". Indeed, they reject any deterministic conclusions from history, and look for concrete policy measures, particularly of an institutional character, in order to cope with the enormous problems accompanying the diffusion of the present technological complex.

Following Freeman, we can learn a lot about the historical relationship between innovation diffusion and economic growth. However, mechanistic predictions have no sense at all, because the actual technology complex and its effects must be placed in the broader framework of human society. Each long wave must be studied as an historical epoch, containing constant and variable relationships, both having considerable importance. For example, it is essential to take into account that Great Britain was overtaken as a technological and world leader in the third Kondratiev cycle. Analogously, researchers must be very careful with historical statistics, because their classification is closely connected with past historical circumstances.

Partly for that reason, the counting of innovations and the division between basic and improvement innovations, the basis of Mensch's work, seem to be problematic. We must urgently study the diffusion of the present interrelated group of fundamental innovations, i.e. the microelectronics sector. Not only economic but also institutional and social factors are determining whether this potential carrier of new growth will have a positive impact on society. In particular, an accompanying policy will determine the demand for, and thus the speed and the effects of diffusion of the new technology complex. We must realize that technological and institutional innovations are two sides of the same coin, but that very different combinations of both are possible.

The diffusion of the microelectronics sector has been analyzed in detail by Soete and Dosi. Their most interesting conclusion is the enormous rise of capital productivity, and hence the capital-saving potential that could ease the shortage of this production factor to a considerable extent. At the same time, however, the labor displacement effects are significant and therefore handling the combined consequences, including the inevitable resistance from workers, will require skillful and imaginative policies. As regards the diffusion issue, Soete points out that the conditions for successful entry into the area of microelectronics technology are different from those of the more traditional industries. Instead of requiring production experience ("learning by doing"), as in mechanical engineering, or overall plant experience ("learning by investing"), as in the chemical and other process industries, these technologies, at least in the present phase, can be based on direct application of scientific and engineering knowledge. Since, in addition, the particular features of the technology make it difficult to protect, technological competition on a world scale could increase in importance. For these reasons, the international diffusion of microelectronic applications to the newly industrializing countries might be more rapid than generally expected. In Soete's view, a period of recession and depression is not only a period of dramatic national structural "shake-ups"; it is also a period of shake-up in the relative ranking of countries according to both growth and technological performance.

Perez-Perez has worked further on the social and institutional innovations by adding an attractive dimension to the long-wave debate. She claims that, while the economic subsystem can largely be treated as self-contained, this cannot explain long waves. The depression in the long wave must be conceived as the symptom of a serious mismatch between the technoeconomic subsystem and the socioinstitutional framework, while the upswing is a positive interaction between these two spheres: "depression is a 'shouting' need for full-scale reaccommodation of social behavior and institutions in order to suit the requirements of a major shift that has already taken place, to a considerable extent, in the technoeconomic sphere." The depression is thus a process of "creative destruction" not only in the productive sphere but also in the social and institutional spheres. The mismatch is occurring because the two subsystems have very different rates of change: the economic sector, spurred by profit and growth motives, is rather flexible in comparison with institutions, which suffer from a high degree of inertia.

Perez-Perez' main contention is that technological evolution is neither continuous nor haphazard, but that it occurs in successive distinct waves related to the dynamics of the relative cost structure of all possible inputs to production. She suggests that, in a very broad sense, each technological wave would be built around the intensive use of a particular input or set of inputs – which she calls the "key factor" – with certain basic characteristics: (a) low (and descending!) relative cost, (b) apparently unlimited availability, (c) potential all-pervasiveness, and (d) a capacity to reduce the unit costs of capital, labor, and products and to change them qualitatively.

Perez-Perez proposes that, around the peak of a Kondratiev cycle, the technological wave, or "technoeconomic paradigm", based on the prevailing "key factor", exhausts its capacity to increase productivity and profits further. During this period, through a trial-and-error process, a new group of technologies emerges, based on a new low-cost input, involving not only strictly technical innovations but also new managerial and organizational principles. This new set of technologies allows a quantum jump in potential productivity, which is why it gradually turns engineering and managerial "common sense" toward intensive use of the new "key factor" and toward the now higher "best-practice frontier".

Thus, she suggests that the oil-based "mass production" paradigm, which lay behind postwar growth, is being substituted by an information-intensive, microelectronics-based, "flexible production" paradigm, which increasingly determines the new "how", "what", and "where" of profitable production, transforming the pattern of investment and influencing the behavior of most markets. But the social and institutional framework that was appropriate for the deployment of the energy- and material-intensive industries does not suit the requirements of the new technological wave, and even constitutes an obstacle to its diffusion. This increasing "mismatch" between the socioinstitutional framework and the technoeconomic sphere is, according to Perez-Perez, responsible for the continuation of the downswing. And it is only through appropriate social and institutional innovations, which take into account the specific characteristics of the new paradigm, that the next upswing can be unleashed.

This broad analysis stresses the need for a qualitative dimension in the long-wave debate, and offers clear insight that the social–institutional barrier is hindering further diffusion of technological innovations in the downswing.

Moreover, it is attractive because it is consistent not only with the approach of Freeman but, as Perez-Perez stresses, also with that of Forrester, Mensch, and van Duijn. However, her call for more interdisciplinary research was most actively answered by proponents of Marxist analysis, perhaps because, paradoxically, her theory about how capitalism goes through, and overcomes, long-wave crises has a similar structure to the original thesis of Marx about how the collapse of the capitalist system would come about. Indeed, the depression can be interpreted as a manifestation of the tension between the productive forces and the social relations of production. *Entov* describes the depression as "the crisis of the entire structure of established socioeconomic relations". *Menshikov and Klimenko* deal explicitly with "the major role of changes in the production relations of capitalism, which do not neatly coincide with long waves in material production". These changes have to be associated with consecutive stages in the evolution of capitalism, which are clearly accelerated by the long wave.

Goodwin comes very near to the hypotheses of the SPRU group. In his view, "long swings are the result of the slow perfection and adaptation of major technological innovations, which persisted over a number of shorter fluctuations". Gradually, the whole production structure becomes transformed as a result of a great number of successive small improvements and adaptations of the new technology. However, this constant flow of technological change is converted by the economy into fluctuating growth, because accelerator and multiplier mechanisms accompany investment. Once the potential of the new technology is exhausted, weak booms and prolonged depressions occur until a new set of innovations becomes feasible. In this process, the role of extraeconomic variables is considered to be essential in the long run of the economy, e.g. the role of state activity such as wars, social services, and control efforts. Goodwin therefore concludes: "How long the present depression will last and how vigorous will be the recovery will surely depend on such extraeconomic factors and not on systematic, economic relations".

4.2. The Growth-Theoretical Approach

Starting from inductive insights, Marchetti and Craig took up the idea of the economy or society behaving as an ecological or sociobiological system. "Our view is that the same laws of nature that gave rise to all other living systems are also controlling for man" (*Craig and Watt*). They suggest that the long-term instability, of which the long wave is a major expression, be analyzed along such lines. Indeed, if we define the long wave as the succession of recovery, growth, recession, and depression, there is only a small difference from the statement of Prigogine (1980), quoted by *Islam*: "All self-organization systems operate in the cycle of becoming, growing, changing, and decaying." But also economists have already launched this idea, as indicated by *Silverberg*: "That socioeconomic development can be considered an ecological history of human artefacts and populations is the theme of Boulding (1978, 1981)".

The attractiveness of this view of economic life stems from the inability of current economic theory to analyze the processes of transition, which is in fact the essence of industrial development. Especially the deeper insights of Schumpeter on the "creative destruction" nature of innovation have largely failed to find entrance into the main stream of analytical economics (*Silverberg*). Therefore, more and more economists are treating the technological innovation embodied in investment as the core of growth theory. They use nonlinear dynamic models to study the emergence of new configurations from structural instability. Two variations can be distinguished: that of Mensch–Haag–Wold and Nijkamp on the one hand, and that of Silverberg on the other. While the former concentrate on models in which stable and unstable periods alternate, the latter stresses more the existence of an essentially unstable historical trend. They all prefer the use of the term "structural instability" instead of "long waves", but they do not exactly indicate the difference between the two.

Mensch starts from a metamorphosis model of long-term industrial innovation. Its four phases can be discerned from the existing mix of innovation types, distinguishable by their basic/improvement, radical/moderate, or product/process character. Innovative investment causes intensifying (R) and extensifying (E), or contractional and expansionary, effects, but to a different degree in each phase. This double aspect of technical progress has to be interpreted as the origin of structural instability in economic life: "Progress just is not 'well-behaved' but ambiguous" (*Mensch*, Paper A).

To integrate this view into growth theory, the equilibrium tendency restriction of the neoclassical and neo-Keynesian models has to vanish. In this way, the ambivalence of economic growth can be made explicit, while at the same time a potential for regime change is introduced. Then, a bifurcation model is constructed with, in Mensch's words, "neoclassical and post-Schumpeterian features".

A bifurcation model allows for a critical domain, where either small unpredictable fluctuations or facts will decide which of the alternative paths – potentialities – will be chosen. More concretely, Mensch uses a production potential function, explicitly allowing for E and R effects. The neoclassical specification indicates that the capital factor is heterogeneous over time and that a biequilibrium property is incorporated, i.e. that two maxima are separated by a minimum while only one maximum can exist at a specific time. The post-Schumpeterian feature reflects the ambivalence of innovation by the hysteresis property, i.e. inertia causes a discontinuous pattern between periods of high growth and E/R figures and periods of low growth and E/R figures (*Mensch*, Paper A).

Mensch is refining his theoretical and empirical research in collaboration with Haag, Weidlich, and Wold. The latter proposes his Partial Least Squares (PLS) method for the estimation of Path Models with Latent Variables (PMLV). This technique has the advantage of modeling and estimating directly and indirectly observed variables, or manifest and latent ones. Starting from the theoretical basis he developed with Weidlich, *Haag* elucidates some crucial points of Mensch's model by empirical investigation (Weidlich and Haag 1983). From economic data, he develops a macroeconomic potential, i.e. a nonlinear relationship that can assign to one set of input variables more than one set of output variables, in times of structural change. At a critical point, closely related with the business cycle, the economy changes from a stable to a less stable structure, or undergoes a phase transition from a monostable to a bistable potential. Haag is able to calculate from the empirical data the parameters of this potential that show the combination of E and R effects chosen by the economy. Moreover, he claims that it is possible to link the potential parameters with an appropriate set of input variables with the help of an optimization procedure (Haag *et al.* 1984). In this way, Haag's analysis allows for prediction and analysis of possible human influence for realigning the economy toward a monostable path. At the same time, many relevant structural macroeconomic variables can be formulated explicitly, while the parameters and their significance can be determined from the set of known data.

Nijkamp developed a nonlinear dynamic model including the element of space as both a driving and a constraining factor for economic dynamics. He gives particular attention to a specific kind of Lotka–Volterra equation used for modeling in population biology. Such a model has the advantage of incorporating some key factors (innovation, public overhead investments) that act as driving forces for a spatial system. It is possible to insert technological progress in the "depression-trigger" as well as in the "demand-pull" hypothesis. Moreover, the model is able to generate a wide variety of dynamic growth patterns, of which the long wave is only a particular case. Nijkamp's conclusion is that long waves are not a necessary phenomenon, but may emerge under specific economic and technological conditions in a spatial economic system.

While the former models concentrate on the dichotomous alternation of stable and unstable growth periods, *Silverberg* refers more to historical instabilities in the underlying trend. Starting from Goodwin's 1967 growth cycle model, he developed a pair of equations formally equivalent to the Lotka–Volterra model. Then he incorporated innovations embodied in new capital goods and analyzed the consequences in terms of nonlinear dynamic interaction between wages, profits, sectoral and aggregate employment, and productivity. In this way, the dynamics of technological progress are fundamentally integrated because of the feedback from the level and composition of investment to the growth of productivity and effective demand. He emphasizes that this way of analysis is far more than a capital-stock adjustment model (Silverberg, oral comment).

Silverberg argues that within his model the rather new "self-organization paradigm" can be used for a thorough analysis of structural instability. This theory, derived from natural science, is in fact built on the dialectic of whole and part, on the one hand, and on chance and necessity, on the other. Physical, biological, and chemical systems normally show a tendency to equilibrium, because their various components compensate each other's behavior. However, at certain moments the disequilibrium forces are more powerful and they drive the whole system to a new state. This theory was originally formulated by H. Haken (Stuttgart) under the name "synergetics", and by Prigogine (Brussels), who named it "dissipative systems". This notion of negative and positive feedbacks is also used by Toffler (1980) to explain the transition from an industrial toward a "Third Wave" society.

According to Silverberg, the transition processes of the industrial system, or the whole of industrial history, can be interpreted along these lines. The dynamic interaction between the macrosystem and its component subsystems can be analyzed using nonlinear dynamic models (e.g. bifurcation), while the outcome of innovations can be treated as stochastic fluctuations. This would allow for the simultaneous existence of a diversity of expectations, techniques, and rates of profit, a feature that has been neglected by economic theorists. The interaction between the system's components and external constraints will create a structure characterized by a certain stability and historical instabilities, driving the system toward new basic technological conditions and institutions. Once the dominant trend can be observed, it will be possible to describe its further evolution, i.e. the final outcome from instability or the beginning of a new equilibrium period. This prediction is based on the dynamic interaction of the system's heterogeneous components, such as labor, various capital and consumer goods, and energy.

As a conclusion, we can state that the integration of the long wave into growth theory is a promising field of research. The essential feature is that, owing to the embodiment of technology, instability pressures are crucial. Thus, long-wave research is only one sign of the recent evolution in economic analysis, where the attention paid to nonlinearity, microeconomic heterogeneity, and macroeconomic disequilibrium is growing fast. There are, some questions left, however. For example, the precise difference between long waves and structural instability was not made clear. In particular, there seems to be no agreement whether the former is a specific or a general form of the latter. Moreover, all models presented were treated in real terms while monetary and financial variables were completely neglected. It can also be argued that socioeconomic systems are characterized by intentions and expectations, and that social research cannot be controlled in the same way as laboratory investigations. In neoclassical models, one assumes that the market is working perfectly, and that the entrepreneur has a perfect knowledge of the future, while in reality he is speculating on a favorable outcome. In other words, the basic lesson from Keynes' work seems to have been forgotten, while economic policy is implicitly considered as ineffective or of minor importance.

Silverberg is nevertheless convinced that human aspects can be modeled within an ecological—evolutionary framework, because this approach is not marred by a deterministic starting point. He agrees that endogenizing everything into a closed dynamic model creates a straitjacket on thinking. Yet, an open dynamic system is critically dependent on the interaction of stochastic and deterministic elements, and this means far more than imposing noise on a closed deterministic system. "In an interdependent nonlinear system, fluctuations, innovations, or changes in external constraints can play a decisive role in triggering bifurcations and changes in regime, and thus serve as the driving force in an evolutionary process" (Silverberg, oral comment). In this way, theory can be opened to history and irreducible diversity. In other words, this fundamental point is very close to that of the SPRU group, and in particular of Freeman, who stresses the role of unique historical factors, despite the very different methodology used.

4.3. The Macroeconomic Approach

Various authors constructed macroeconomic models that do not strictly belong to the growth-theoretical approach described above. We think the study of the long wave along these lines is important, in particular when an economic policy has to be designed, and when financial and monetary variables have to be included. The system dynamics method of Forrester and his co-workers is in this regard very interesting. Menshikov and Klimenko model the Marxist law of the falling rate of profit, and indicate useful leads and lags. Lastly, Delbeke and Schokkaert show that even a traditional linear model, based on financial variables, can offer useful insights for theory and policy.

Since 1975, the System Dynamics National Model (SDNM) has been the vehicle for the development of an endogenous structural theory of the long wave at MIT. There, the System Dynamics Group is basically modeling the behavior of microeconomic agents, and the macro-result is a self-sustaining long-term cycle which, once set in motion, grows in amplitude up to a limit. Several important channels contribute to the generation of the long wave, such as self-ordering, debt/price dynamics, technology and innovation, and political and social values. However, *Sterman* emphasizes that self-ordering is the basic mechanism at work, because it is sufficient to generate the long wave. The other factors have a more amplifying character. The self-ordering of capital reflects the dependence of the capital-producing sectors of the economy, in the aggregate, on their own output. In fact, self-ordering amplifies the disequilibrium pressures created by the interaction of locally rational decision rules (bounded rationality) and the lags involved in capital acquisition within a firm. As a result, "irrational behavior" is produced on a macro-level. Therefore, Forrester states that the accelerator mechanism of self-ordering "creates the 50-year cycle of what would otherwise be a 20-year medium cycle in capital acquisition" (Forrester 1977, p.534).

Sterman stresses that this self-ordering principle does not exclude other approaches. On the other hand, he calls for a demonstration of the sufficiency of other mechanisms for the generation of long waves. In particular, the role of technological innovation, essentially treated as passive in the SDNM, seems to be more the result instead of the origin of self-ordering (Graham and Senge 1980). This view has considerable implications for policies directed at stimulating innovation, because they may be insufficient to mitigate the effects of the current downswing. Therefore, economic policy has to be directed more toward the solution of excess capacity in the capital goods sector, which is caused by the self-ordering accelerator. Indeed, during the upswing, this mechanism creates a serious excess of capital stock, and the downswing has the function of bringing the economy back to internal equilibrium.

Senge expanded the SDNM by developing a theory of the real interest rate behavior in a long-wave perspective. In his view, real interest rates tend to rise as the inflationary pressures of the upswing give way to deflationary ones during the downswing. Once they start to rise, they reduce demand, reinforce the deflationary pressure, and keep increasing. A crucial assumption concerns the relative sluggishness of nominal interest rates in adjusting to changes in inflation. Nominal rates rise until credit shortages are eliminated, i.e. at the end of the upswing. Prices tend to move in parallel with nominal interest rates, and increase until the excess demand of the expansion is absorbed. However, inflation, being the rate of change in prices, starts to decline considerably before nominal interest rates reach a peak, and hence the rise in real interest rates. Senge shows that the simulated data are consistent with historical observations and with Fisher's empirical analysis. A major implication of his theory is that it questions the "crowding out" effect of government deficits and tight monetary policy as being responsible for the recently high real interest rates.

The system dynamics analysis develops a causal theory, offering an endogenous structural explanation of the long wave. It rejects the direct use of historical data, but compares them with the data generated by the model. It allows for historical particularities and for a qualitative dimension, being a powerful complement to the formal analysis of model behavior. In other words, the System Dynamics Group looks for a mechanism, not for a determinism (Senge, oral comment). The major advantages of the system dynamics method are, however, not clear to us. In our opinion, macroeconometric models can also be powerful tools of analysis. They offer the opportunity for interdependent theoretical and empirical analysis, while historical data can be used directly. Following the remarks of Freeman and of Perez-Perez, the basic microstructures used can change fundamentally over a long period (cf. pure and monopolistic competition during, respectively, the industrial revolution and late capitalism). In any case, the Conference produced a fruitful confrontation between the different views on this matter, and the opportunity for publication of some parts of the model, which had unfortunately remained largely a "black box" until then.

Menshikov and Klimenko utilize the law of Marx about the tendency of the rate of profit to fall. Firstly, they empirically investigate indicators of labor productivity, capital intensity, the output–capital ratio, the rate of profit, and the profit per man-hour. They conclude that long waves clearly exist and that a new recovery in growth rates can occur only after a recovery in the output–capital ratio. They then construct an economic model in which the relationship between the growth rates of the capital–labor ratio and the rate of profit is considered as the driving force behind the long wave and as crucial for explaining the turning points. In the simulated figures, the leading and lagging variables are analyzed. The turning point of the growth rate of the profit rate (p) precedes the change of the growth rate of the capital–labor ratio (k) in the opposite direction by 7 years, while the turn in the growth rate of labor productivity (y) comes 6 years later. It takes another 13 years for p to reach its peak or trough.

Delbeke and Schokkaert presented a macroeconomic model for the financial sphere. They emphasize the role of small partial models, which are as simple as possible, deepening our understanding of the basic mechanisms at work. In particular, the interaction of investment and debts, being a simple stock–flow mechanism, is able to generate endogenously a long wave for empirically reasonable values of the parameters. In the upswing both investment and debts are increasing, until the debt position, and hence the cost of credit, become too high. At that moment, investment starts to decline until a normal debt level is reached again. The recurrence of the long-wave phenomenon can only be produced by the introduction of exogenous shocks, such as innovations. However, when prices are inserted in the debt inflation and deflation model, the cycles become permanent. This suggests that the integration of a monetary sector may be a promising track. In particular, the money supply seems to be endogenously determined along the long-wave path. This simple model shows the necessity of studying the macroeconomic conditions that dominate the diffusion of innovation. Further exploration in this direction seems worth while, especially for the analysis of the downswing and for the design of economic policy. Of course, this form of partial analysis is extremely useful for integration into other approaches.

4.4. The Importance of Noneconomic Variables

Most authors stress the role of noneconomic variables in the long wave, as was the case in the interwar period. Perez-Perez of the SPRU was the most active proponent of this approach at the Conference. However, two other papers explicitly dealt with sociopsychological factors, within a model framework, namely those of Millendorfer and of Screpanti.

Millendorfer presented some remarkable insights from the Austrian STUDIA model, investigating long-term mechanisms of societal development. He claims, and proves empirically, that we must try to understand the economy by looking beyond the economy to a comprehensive holistic approach. Therefore, STUDIA uses a huge quantity of empirical data, not only on economic and technological variables, but also on "soft" variables like measures of motivation, sociopsychological variables, indicators of the quality of family life, etc. To analyze the observed growth-reducing factors every five to six decades, a new formal method of multivariate analysis, named Main Plain Analysis, was developed. This method facilitates theory building on a large empirical base, and in particular the relationships between hard and soft variables can be made clearer. Then, with the help of sociopsychological mechanisms, STUDIA tries to explain why the innovative push occurs in cycles of 50–60 years, a question unanswered by Schumpeter. The length of the cycle in the feedback system is determined by something similar to anthropological constants, regulating the dynamics of the relationships between generations. In addition, the oscillations of creativity and achievement motivation in the sociopsychological cycle are used to help understand the oscillations of inventions and innovations. Indeed, intensive growth rates, i.e. those mainly caused by innovations, are positively correlated with constructed Freudian sublimation indicators. Thus, creativity and innovation have strong roots in the living area, described by soft variables and their mechanisms.

The analysis by Millendorfer has a rather deterministic character. This is shown, in particular, when he concludes that "the length of the cycle is determined by something like an anthropological constant. It means that we have no instrumental variables, no political tool to change the length of [it]." Nevertheless, Millendorfer suggests some policy advice that is close to the proposals of the SPRU. "What we can do is to minimize the amount of the downswing by anticipation of the coming upswing". In more concrete terms, he proposes four principles: (1) the human-economic principle: more emphasis on the importance of man instead of things in economic life; (2) the priority of nonmaterial over material factors: more creativity, initiative, qualification of labor, and a reduction in the exploitation of material factors; (3) finely structured formations rather than "gigantomania": rejection of the overemphasis of the large scale; (4) context and totality: a maximum of autonomy and freedom of decision making for small units, which acknowledges their rightful place in the wider context.

Screpanti analyzed a set of social variables in addition to economic variables and constructed a model with the use of catastrophe theory and the notion of transition phases. In the years 1808–20, 1866–77, 1911–22, and 1967–73, being the upper turning points of the Kondratievs, major proletarian insurgencies broke out. These periods must be considered as transition phases, with more than "normal" unrest. The upswing brings improvement in workers' achievements, but at the same time their frustration rises at an increasing rate. Social tension accumulates until the effects of frustration overcome those of achievements. At that moment, workers express in a few years the tension suppressed over a long time. As a consequence, capitalists' "high spirits" collapse and investment declines. The downswing begins and has a worsening effect on workers' achievements. Only after some time does frustration adapt to the decreasing achievements, when the workers realize their defeat. According to Screpanti, "In a sense it could be said that the entire B-phase of the long cycle serves to bring workers back to reason." The declining militant behavior then paves the way for a new upswing. The whole process is further strengthened by the coming of new generations of young workers, because major wars occur during the critical transition phases of the long cycle. In fact, the generational cycle of Screpanti is closely analogous to the anthropological constant of Millendorfer. In our view, these methods of analysis are good illustrations of the promising field of interdisciplinary research in the long-wave perspective.

5. IMPLICATIONS FOR ECONOMIC POLICY AND FURTHER RESEARCH

There is considerable agreement that the long wave cannot be considered as a monocausal phenomenon, and that future lines of research have to integrate the several theories. The System Dynamics Group at MIT is calling for "a grand unification theory" (*Forrester et al.*), while Mensch perceives a regrouping of the existing theories under only two umbrellas, namely a neoclassical and a neo-Marxian theory (*Mensch*, Paper B). In the previous section we tried to sketch some major directions along which further integration of research could proceed. However, the main question, as posed by Mensch, is "Who integrates whom?" As far as we can see, there is no agreement on this matter.

According to the MIT group, further integrative research has to contain the following characteristics: a formal dynamic model, for which all assumptions are made explicit, endogenously generating long waves, and built on a structural–causal and not a correlative or econometric approach. For the MIT group it is essential that microstructures create the macroeconomic outcome. Small models have to be developed showing sufficient or necessary conditions for the long wave, or the amplifying role of some characteristics. Moreover, tests have to prove the adequacy and the robustness of the model structure, while generated data have to be compared with historical data (*Forrester et al.*). In other words, the starting point is the SDNM methodology, in which an active innovation process can be inserted.

From a phenomenological point of view, Mensch is near to agreement with the Forrester proposals, emphasizing that a post-Schumpeterian theory has to start from micro-foundations to show the macrodynamics. Indeed, these micro–macro models can remove the vague and impressionistic ways of research of Schumpeter and Marx, which caused a lot of skepticism as expressed by W. Baumol (***Mensch***, Paper B). However, Mensch is also convinced that his model is a good starting point for cooperation. Moreover, he observes the research frontier moving from data- to model-driven, and is already expecting the next phase transition, i.e. to instrumental research, prescribing economic activity in scenarios, and forecasting. He states that the long wave is the core area of the much larger field of disequilibrium dynamics, while he sees "much of our special theories already embedded in mainstream economics" (***Mensch***, Paper B).

However, in our opinion, to situate current long-wave research in this way is to exaggerate its present role. For van Duijn the aim of it becoming a part of standard economics is not so important. Schumpeter never has been regarded as a mainstream economist, while many scholars have read and used his interesting ideas. In van Duijn's view, all that counts is to do good research, and to avoid becoming a sect. Moreover, at this moment, we think that long-wave research is neither a full part of present economic research, nor the core of it, and it will require a long time to consider it as a new paradigm. Lastly, the methodologies of Forrester and Mensch are so different that it is likely that the former wants to integrate the depression-trigger hypothesis more than the consequences of the Schumpeter Clock approach. Consequently, the path to integration will be long and difficult, without clear "umbrellas" for the near future. Nevertheless, long-wave research inevitably has to follow that path, in order to deepen our understanding. In our view, conferences such as this one automatically widen the scope for further integrated research. The broad interest in the institutional aspects can only be proof of that.

A concrete example of integration of various approaches, and therefore one that is difficult to place in the scheme developed here, is the research carried out by ***Piatier***. Starting from the study of innovations and renovations, he integrates some ideas of Marchetti and Mensch. Being a business cycle analyst, he stresses the importance of the way in which the long cycle determines the Juglar, which he considers very useful for the analysis of turning points. However, he also has similar insights to the Sussex group and does not neglect the role of noneconomic variables. Indeed, he emphasizes the role of demand, the diffusion of microelectronics, and the economic, social, and political problems concomitant with this process. Not only is the whole production system forced to change, but also its environment: the managers, the educational system, the infrastructure, etc. In the short term, the effect on labor demand will be disastrous. While Piatier expects the next upswing at the end of our century, he believes that an adequate economic policy can shorten this period by a decade. However, this can only happen on one condition, namely that the financial problems postponing the recovery are solved, and not, it is hoped, with a ***Krach***, as happened in 1929. Such integrative approaches seem to be essential for our future research, but it is clear that at present only the first qualitative steps have been made in this direction.

A second major field of research has to be the design of an adequate economic policy. Following ***Tinbergen*** in his video message, it seems at least just as worth while to think about policy measures, given the insurmountable difficulties and the long time it will require to have a definite proof of the existence of the long wave. Also Freeman sees a gigantic task in this field in order to ease the enormously bad and possibly dangerous consequences for mankind. He quotes Keynes (1923) in this context, as follows: "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" (*Freeman and Soete*).

However, only a minority of the Conference papers dealt explicitly with the matter of economic policy, while the proposals made cover a broad range, from pure liberalism (Glismann) to international interventionism (Tinbergen). The growth-theoretical approach is rather silent on this matter. However, Silverberg (oral comment), following Forrester and Sinibaldi, raises the fundamental question: Have we to concentrate our energy to start the next long wave as quickly as possible, or to reach some kind of stationary state, i.e. to enjoy the fruits of economic development without instability pressures and unemployment threats? The former option seems inevitably to be implied by industrial capitalism, or, stated the other way round, the latter requires a radical reorganization of social and economic structures. Given the powerful economic and political pressures, it seems that the combination of permanent change and social cost will be chosen. Following this logic, then, Craig states that a primary goal of policy should be to minimize the disruptions associated with the transitions of social systems from one mode of stabilization to another (*Craig and Watt*). This suggestion is not worked out in more concrete terms, however.

Most researchers dealing with policy issues agree that the long wave is an international phenomenon, originating from unstable investment in the developed capitalist countries. The industrial planned economies would also show the same behavior but to a lesser extent, and this can be attributed to their own saturation of markets and to the linkage of international trade. Therefore, *van Duijn* concludes that it is first and foremost in the OECD countries that the problems are situated, and it is there that they have to be solved. Moreover, historically, innovations diffuse from the core to the periphery. Hence a massive transfer of funds from North to South is not the best solution. In contrast, capital shortage will be aggravated in the industrialized countries, and a recovery will be postponed further. According to van Duijn, this is not an argument for egoism, but the result of long-wave analysis that only the growth-center economies are able to be a locomotive for the peripheral economies. Moreover, the problems for the new industrialized countries (NICs) are not so enormous because historical research shows that after a country has taken off it is less affected by the next long-wave downswing. At the same time, a new upswing will create chances for new take-offs, transforming once again some less developed countries into NICs.

Other researchers cannot agree with van Duijn's policy advice. The MIT System Dynamics Group also situates the cause of the long wave in the industrial world because of the dominant role of self-ordering: the more capital there is engaged, the more serious the long wave. The disequilibrium effects are distributed over the whole world, but with different time lags. The downswing has an important function, namely the elimination of overbuilt capital, the latter being the result of the upswing. This excess capital, instead of van Duijn's shortage, can be removed in a slow or a catastrophic way. The latter solution has to be avoided, but the key to it lies not in the real, physical sector of the economy, but instead in the financial, attitudinal, and institutional aspects (*Forrester et al.*).

According to the MIT group, there are very few high-leverage policies available and, moreover, they can be pushed in the wrong direction or are subject to a tendency to overreact. Some policies can ease the impact of dislocations or reduce the severity of the downturn. However, it has absolutely no sense to look for a guilty person or group, as Glismann is doing for bureaucracy, because the instability was created by the interplay of all forces in society. What has to be found is 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 (*Forrester et al.*). In other words, this advice is a kind of Keynesian policy without inflation, and without investment incentives, given the massive excess capacity.

The MIT advice is basically built on a "passive" technological innovation, because Forrester is convinced that its role is overemphasized in the long-wave debate. In contrast, the Sussex group stresses the importance of the new technological paradigm at length, adding a post-Schumpeterian dimension to the rather Keynesian policy of the System Dynamics Group (*Forrester et al.*). Freeman is "going back to basics", i.e. to the original work of Keynes and Schumpeter. The latter was very hostile to government intervention, which he tolerated reluctantly. The basic lesson of Keynes, i.e. "the socialization of investment without public ownership" (*Freeman and Soete*), made him the architect of the new match between the prevailing technological paradigm and the social institutions. For Keynes, aggregate demand had an important role, while Schumpeter was more sectorally oriented because of the role of technology. Nowadays, we have to look for a new theory because none of the dominant theoretical paradigms (neoclassical, Keynesian, Marxist) can offer an answer to the question how to solve the growing mismatch between technology and the institutional environment.

From a neo-Schumpeterian point of view, Freeman is in favor of government policies encouraging a new wave of public and private investment, and offering incentives for the adaptation of social institutions (*Freeman and Soete*). The main goal is to achieve the maximum gain from the new technological complex with the minimum social costs. If private investment is too timid, public investment has to fill the gap. Anyhow, specific demand pressures and institutional changes have to be created to stimulate the diffusion of microelectronics. *Tinbergen* also calls for social changes and refers to the Japanese worker being very productive because of the high satisfaction gained from work, owing to more consultations involving workers and a less unequal income distribution than, for example, in the USA. Generally, the SPRU group is calling for more optimism and realism, and for avoidance of the creation of a "lost generation" (Freeman, oral comment). We only have to remind ourselves of the collective frustration of the 1930s and its concomitant social and political instability. Today, we can again observe growing tendencies of law and order, conservatism, and militarism (*Menshikov and Klimenko*). Tinbergen (in a written comment to the author) treats the intensive competition in armaments as the most urgent problem to be solved. One must be aware that these new tendencies are again trying to cope with the wrong problem.

Freeman and Soete further emphasize the crucial role of the technological–institutional match in an international framework. In fact, Soete in his research has shown that the new technology is more international in scope and requirements than anything that has preceded it. For newcomers it is easier to create new social institutions than to adapt old ones, as in the mature economies, while the capital-saving nature of microelectronics and the potential for small-scale applications are particularly favorable for the NICs. Moreover, it must be noted that the balance of economic and political power is changing in favor of the developing world. Thus, a very rapid international diffusion of the new technology is very likely, and therefore the need for a "matching" new international framework becomes very urgent. However, this new match is probably the most difficult challenge confronting the world economy. Indeed, as Freeman and Soete observe, "the national boundaries of decision making, the intensified international competition, the growth of protectionism, the re-emergence of Cold War attitudes and politics, and the persistent failure of North–South dialogues all serve to emphasize the great difficulties of re-establishing a new and more favorable international economic and political framework for expansion".

At this time, international solutions seem to be taking the place of the national ones of the 1930s, and are likely to become dominant in the next "match". However, at that time, nobody could propose with certainty the right policy that was needed. Goodwin (oral comment) reminded us of the policy of the Roosevelt administration, which tried a lot of valuable proposals until one proved to be successful. Indeed, we may state that the major merit of Hoover, the predecessor of Roosevelt, was that he showed at length that the classical deflationary solution, or the restoration of 19th century rules, was no longer possible. The dominant economic thinking of the time no longer had consistent solutions available, and this opened the way for positive policy experimentation. We have the feeling that we have arrived at the same situation again. *Tinbergen* claims that a good policy does not necessarily require knowledge of the right explanation. Consequently, he suggests spending far more energy in searching for good policy advice, instead of hoping to build the good theory first and then derive the right policy from it. It can work the other way round, as is illustrated by the development of Keynesian theory. At present, the most concrete and valuable policy proposals are those of the Brandt Report (Brandt 1980), and Tinbergen and the SPRU group are urgently asking for their implementation, in order to solve the acute social, political, economic, and financial problems on a world scale (*Freeman and Soete*, *Tinbergen*).

As a general conclusion, then, we may state that this Conference was an important step toward a better understanding of what is happening and what should happen in our world today. It was shown that the long-wave idea is very useful for this understanding, not least because it has to be seen as a multidimensional phenomenon. It has important economic features, while the social, political, and even cultural aspects cannot possibly be neglected. The notion that technological innovation creates structural instability, which forces institutional innovation, was one of the most interesting themes dealt with at length at the Conference. Because the long-wave idea is able to throw new light on neglected or even forgotten aspects of our industrial development, we are convinced that it deserves further research on empirical, theoretical, and policy levels.

REFERENCES

Authors' names are italicized where references are to Conference papers. Most of the Papers for which no further information is given are to be included in a book, based on the Conference, that IIASA is seeking to publish.

Adelman, I. (1965) Long Swings, Fact or Artefact? American Economic Review, pp.444–463.

Akerman, J. (1957) Structures et Cycles Economiques. Paris.

Bianchi, G., Casini-Benvenuti, S., and Maltinti, G. Italian Multiregional Development: Long Waves and Regional Take-Offs – Preliminary Findings.

Bieshaar, H., and Kleinknecht, A. Kondratieff Long Waves in Aggregate Output? An Econometric Test. Collaborative Paper CP-84-34, International Institute for Applied Systems Analysis. To appear in *Konjunkturpolitik*.

Boulding, K.E. (1978) Ecodynamics: A New Theory of Societal Evolution. Sage Publications, Beverly Hills, California.

Boulding, K.E. (1981) Evolutionary Economics. London.

Brandt, W. (1980) North–South, Program for Survival (Report of the Independent Commission on International Development Issues, under the Chairmanship of W. Brandt). Pan Books, London and Sydney.

Bruckmann, G. The Long-Wave Debate. In G. Bianchi, G. Bruckmann, and T. Vasko (eds.), Background Material for a Meeting on Long Waves, Depression and Innovation, Siena/Florence, October 26–29, 1983. Collaborative Paper CP-83-44, pp.1–4. International Institute for Applied Systems Analysis, Laxenburg, Austria. (This article first appeared in IIASA Options No. 2, 1983.)

Craig, P., and Watt, K. The Long Wave as Metaphor: Suggestions from Ecology.

Delbeke, J. (1981) Recent Long-Wave Theories. A Critical Survey. Futures 13:246–257.

Delbeke, J., and Schokkaert, E. The Interaction of Investment and Debt in the Long Wave.

van Duijn, J.J. Comments on Topics 1 and 5.

Dupriez, L.H. (1947) Des Mouvements Economiques Généraux. Louvain.

Dupriez, L.H. (1959) Philosophie des Conjonctures Economiques. Louvain.

Entov, R. Comment on Topic 1.

Forrester, J.W. (1977) Growth Cycles. De Economist 125(4):525–543.

Forrester, J.W., Graham, A.K., Senge, P.M., and Sterman, J.D. Implications for National and Regional Economic Policy.

Freeman, C., Clark, J., and Soete, L. (1982) Unemployment and Technical Innovation: A Study of Long Waves and Economic Development. London.

Freeman, C., and Soete, L. Comments on Topics 1, 4, and 5.

Glismann, H.H. Comments on Topics 1 and 2.

Goodwin, R. Schumpeter and Long Waves.

Gordon, D.M., Edwards, R., and Reich, M. (1982) Segmented Work, Divided Workers. Cambridge University Press, London.

Graham, A., and Senge, P. (1980) A Long-Wave Hypothesis of Innovation. Technological Forecasting and Social Change 17:283–311.

Haag, G. The Macroeconomic Potential.

Haag, G., Mensch, G., and Weidlich, W. (1984) The Schumpeter Clock (to be published).

Islam, S. Disequilibrium, Innovation, and Periodicity in Economic Development.

Keynes, J.M. (1923) Tract on Monetary Reform. Macmillan, London.

Mandel, E. (1980) Long Waves of Capitalist Development. Cambridge University Press, London.

Marchetti, C. On a Fifty Years Pulsation in Human Affairs: Analysis of Some Physical Indicators. Professional Paper PP-83-5, International Institute for Applied Systems Analysis, Laxenburg, Austria.

Mensch, G. (1975) Das Technologische Patt. Frankfurt.

Mensch, G., Paper A. A Bi-Equilibrium Model of Bi-Valued Technical Progress Embodied in Innovative Industrial Investment in US Industry between 1930 and 1934. In G. Bianchi, G. Bruckmann, and T. Vasko (eds.), Background Material for a Meeting on Long Waves, Depression, and Innovation, Siena/Florence, October 26–29, 1983. Collaborative Paper CP-83-44, pp.89–121. International Institute for Applied Systems Analysis, Laxenburg, Austria.

Mensch, G., Paper B. On Theory Integration: Towards Economies of Scope.

Menshikov, S., and Klimenko, L. On Long Waves in the Economy.

Millendorfer, J. Long Waves in a Larger Context.

Nijkamp, P. Long-Term Economic Fluctuations: A Spatial View.

Perez-Perez, C. Towards a Comprehensive Theory of Long Waves.

Piatier, A. Long Waves and Industrial Revolutions.

Prigogine, I. (1980) From Being to Becoming. San Francisco.

Rostow, W.W. (1978) The World Economy. History and Prospect. Macmillan, New York.

Schumpeter, J. (1942) Capitalism, Socialism, and Democracy. Harper, New York.

Screpanti, E. Long Economic Cycles and Recurring Proletarian Insurgencies.

Senge, P.M. A Long-Wave Theory of Real Interest Rate Behavior.

Silverberg, G. Embodied Technical Progress in a Dynamic Economic Model: The Self-Organization Paradigm. To be published by Springer-Verlag.

Sinibaldi, T. Discussion of Topic 4.

Slutzky, E. (1937) The Summation of Random Causes as the Source of Cyclic Processes. Econometrica 5:105–146.

Sterman, J.D. A Simple Model of the Economic Long Wave (1983 Working Paper D-3410, Sloan School of Management, MIT, Cambridge, Massachusetts, USA).

Tinbergen, J. Video Message.

Toffler, A. (1980) The Third Wave. New York.

Vacca, R. Elastic Mechanisms of Intercountry Attraction of Logistic Industrial Growth.

Weidlich, W., and Haag, G. (1983) Concepts and Models of a Quantitative Sociology. Springer-Verlag, Berlin (West).

Wold, H. On the Statistical Identification of Long Waves.

THE LONG WAVE AS METAPHOR: SUGGESTIONS FROM ECOLOGY

Paul P. Craig and **Kenneth E.F. Watt**

INTRODUCTION

> This is an economics blessed with an intellectual consistency, and one having implications that extend far beyond the realm of conventional economic theory. It is, in short, also a political philosophy, often becoming something approaching a religion.

[Lester Thurow (1983, p. xviii) commenting on equilibrium "price-auction analysis as the prevailing intellectual mode in economics".]

The long wave in socioeconomics has been intensively debated for over half a century. The idea has had continuing, but intermittent appeal. Despite many hints as to its existence, both the existence and the merit of the concept remain controversial. Today much of economic thinking has, as Thurow (1983) observed, been captured by a limited set of ideas as to how the world works.

While there are many reasons that can partially explain the current dominance of this single paradigm in economic thinking, one important factor is certainly the several decades of virtually uninterrupted growth that occurred from the end of the Second World War until about the time of the OPEC oil embargo in 1973. Today the idea of the continuous nature of economic progress is less obvious, and the need for new paradigms is becoming clearer. The metaphor of the long wave offers promise.

We approach the long wave as natural scientists. Our starting point is experimental. We emphasize an ecological perspective, with a focus on concepts of stability. We conclude, after examining both data and theory, that at the present state of knowledge the long wave offers a very promising world view for thinking about the future. At this time, however, long waves lie more in the realm of imagery than of established knowledge. The promise of this imagery is substantial, for it contains seeds that could lead to improvements in the way in which we manage our social systems. These seeds will require careful tending if they are to influence policy.

The long wave emerges from our analysis as a powerful metaphor for the idea – somewhat out of synchronism with the dominant paradigm of our time – that continuing progress should be viewed as normal. Long waves offer a larger perspective, and thus an element of needed caution.

We begin with a review of data supporting the long wave. From this review we conclude that the most compelling argument for a repetitive half-century cycle is found in financial, demographic and war data. The long-wave case is supplemented by processes of replacement of one technology by another. Though replacement processes clearly exist, we do not find market penetration data to be the most convincing of the evidence for long waves. These observations lead us to focus on ideas and beliefs, and specifically on the importance of optimism and pessimism as socio-demographic drivers. The Easterlin cycle in demography assumes an important role, as do ideas from the 1920s and 1930s about the importance of belief in gold as a bastion of stability in turbulent times (Warren and Pearson 1935, 1937).

We conclude with observations on ways of thinking about change in social systems, using as a focus generalizations from our review of the ecological literature (Watt and Craig 1985) applied to social systems.

WHAT CONSTITUTES EVIDENCE?

If the idea of long waves is to achieve broad acceptability it must be supported by concepts and by data. The concepts are likely the most important, but there is no substitute for firm data. Unfortunately little of this exists. To one trained in an experimental science, a good figure or diagram often proves far more convincing than thousands of words. The long wave literature contains remarkably few curves that we find convincing.

Much of the best of the published data on long waves is due to Kondratiev himself (1926). An early and extensive critique is due to Garvey (1943). The studies cut off before the depression of the 1930s, though they point clearly toward that event.

The Catalog of Cycles (Wilson 1964) includes figures of British Consol prices and US interest rates, including reference to the work of Kondratiev and others. In most cases only two cycles are reasonably clear to the eye, not enough to make a compelling case. Contrast this with, for example, the 18-year real estate cycle (précis 922). Here a full eight cycles are available from 1795 to 1945, each with about the same amplitude. A review of recent books on the long wave shows a conceptual curve in Mensch (1979, p. 73), and data on moving averages of dates of major scientific discovery in Freeman *et al.* (1982, p. 180). There is a striking peaking of "radical innovations in the mid-1930s and about 1960" (Freeman *et al.* 1982, p. 52).

The best graphical evidence for the long wave we have come across is the wholesale price relative to gold. This was used by Kondratiev (1926) in his original work, and has been frequently referred to since (e.g. Rostow, 1978). While some analysts believe "long waves in the price level are per se of no particular interest" (Glismann 1985) our observation is that price indicators offer the *only* long-wave data so compelling that a naive observer would easily notice a half-century cycle. We refer to data from the real world. Computer models easily generate cycles.

Figure 1 shows the US wholesale price index relative to gold. Referencing to gold is important, for reasons made clear by Warren and Pearson (1935), having to do with fundamental concepts of faith and value. Since all prices are relative it is equally correct to observe that wholesale prices are low, or that gold is highly valued. Failure to provide referencing causes a rapid increase in the value in recent years when the US dollar depreciated dramatically relative to gold. In Figure 1 there is an indication of cyclical behavior, but the eye is distracted by

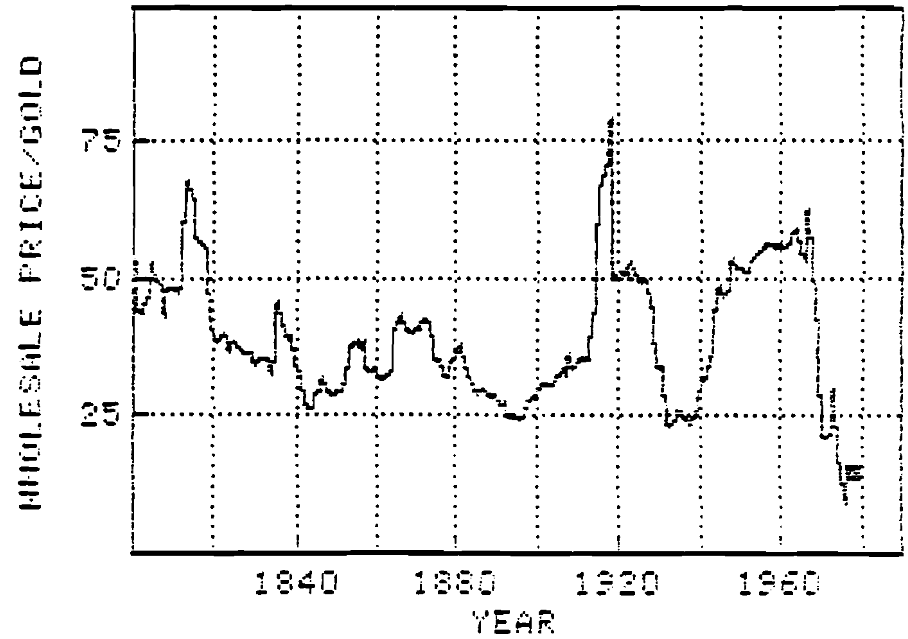

Figure 1 Wholesale price index for the United States, relative to gold. No averaging. It is difficult for the eye to extract the long-cycle peaks and troughs.

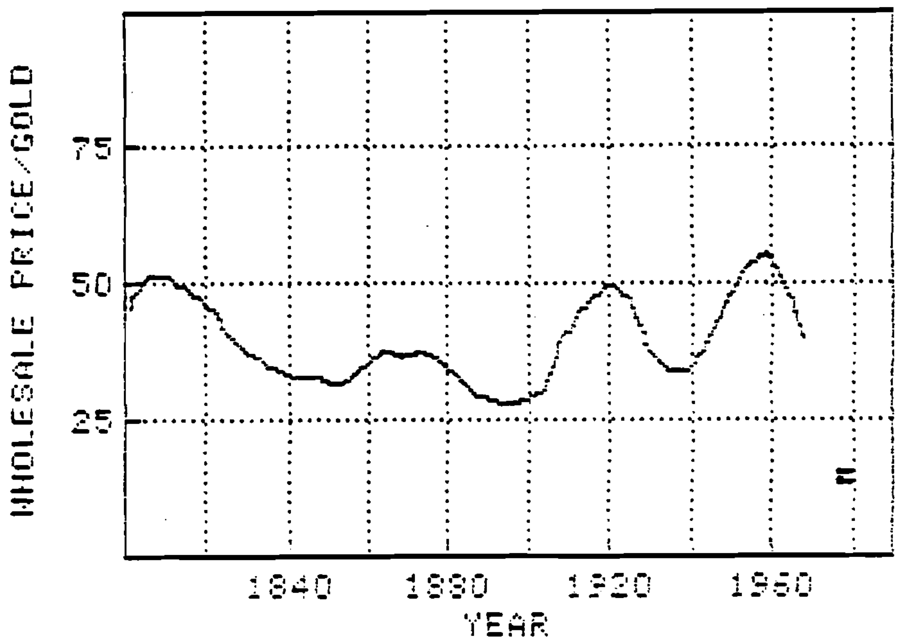

Figure 2 The data of Figure 1, but with 21-year arithmetic averaging. This Figure shows the four long waves more clearly than any other data of which we are aware. Peaks occur in 1813, 1869, 1919, and 1959; nadirs in 1846, 1895, and 1936. The square is for 1979.

short-term fluctuations and does not unambiguously extract the long waves.

The short-term fluctuations are removed in Figure 2, which uses a running 21-year average, plotted at the midpoint. This simple analytical approach was used by Kondratiev, and later by Kuznets. It has the great advantage of simplicity. A disadvantage is that each point is influenced by events a decade in the future as well as in the past, thus decreasing the utility for prediction. The square is the point for 1979, with no averaging. Maxima are found in 1813, 1869, 1919, and 1959, and minima in 1846, 1895, and 1936, in close agreement with general ideas on good times and bad.

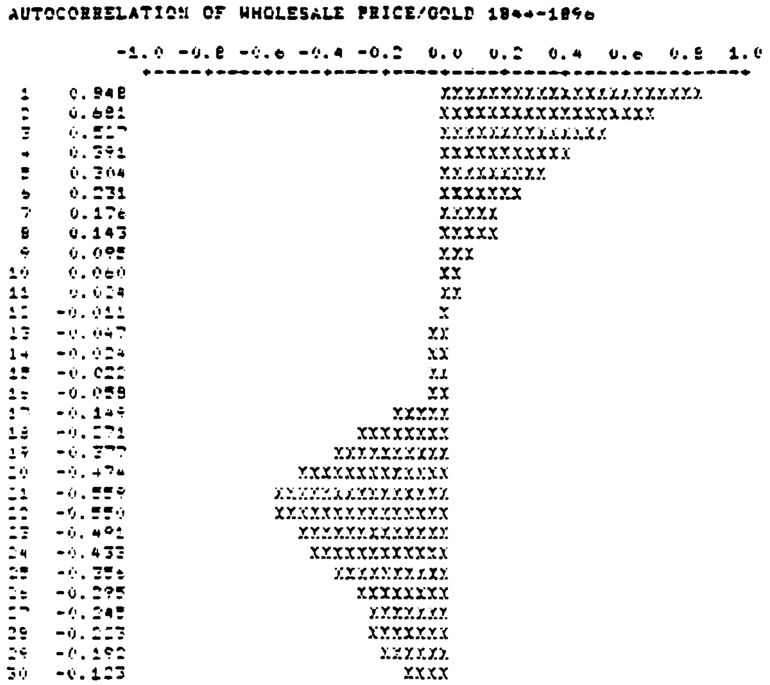

Figure 3 The autocorrelation of the data shown in Figure 1 for the period 1844–1896. Autocorrelation analysis clearly shows the 21-year half-period for this interval, but at the price of loss of insight. We believe it is a mistake to apply this type of analytical technique in situations where there is great uncertainty about the timing and phasing mechanisms involved.

To the best of our knowledge Figure 2 shows the clearest available direct evidence for the existence of the long wave. More sophisticated analytical techniques can be applied. Figure 3 shows the autocorrelation analysis of a portion of the data from Figure 1. A 32-year half-period is apparent. While cross-correlation and other analytical techniques may easily be applied, we believe this approach is a mistake. Long-wave analysis is in an early stage, and such analysis is more likely to mislead than instruct. For example, in the absence of sound theoretical reasons for fixed periodicity and phasing (in the mathematical sense of phase), there is no justification whatsoever for combining data from several waves in a single cross-correlation plot – even though the resulting curve is smooth and (apparently) elegant.

The connection of the long wave to wars has often been noted (e.g. Thompson and Zuk 1982, Mensch 1979, p. 79, Forrester 1979, p. 54). Craig and Levine (1984) have analyzed Richardson's extensive data base on wars, with the results shown in Figure 4. Richardson (1960a,b) estimated the number of persons killed in each of several hundred wars. The figure is produced by adding the number of persons killed in each year for all of the wars analyzed, then averaging the results arithmetically over a 21-year interval. The closed and open boxes show the maxima and minima respectively, from Figure 2. The visual correlation is striking, with the exception of the Second World War, which was two decades "premature". The economic data is for the USA, while war deaths are global. The long-wave period is quite slow enough that migration and economic interaction take place even prior to the advent of modern transportation and communications technology. This problem is discussed by Thompson and Zuk (1982).

The fact of a correlation visible as clearly as this presents, in our view, a major theoretical problem to anyone attempting to argue that there is *not* a causal relation between economies and war. On one side is the argument that wars generally lead to inflation; on the other side is the view that inflationary periods are conducive to war. A statistical analysis of these matters leads to the observations that while price increases tend to precede as well as succeed wars, the wars are a powerful reinforcing mechanism:

> Not only do major wars reinforce the Kondratiev upswing; they appear to be largely responsible for the fundamental shape of the Kondratiev wave phenomenon...
> Our findings suggest that were it not for global wars and the Civil War, the US and British price waves of the nineteenth and early twentieth century might also seem a bit like optical illusions. (Thompson and Zuk 1982)

A (very weakly) optimistic remark following from these observations is that if we are now in a long-wave downswing, we may have available some extra time to stabilize our world against the ever present threat of nuclear war.

Kuznets (1958), Easterlin (1980), Keyfitz (1972), and Samuelson (1976) examined various aspects of the relation between demography and long waves. A cycle two human generations long emerges in a very natural way. A particularly appealing aspect of the demographic argument is that it may become increasingly significant with increases in reproductive choice (entrainment). The argument is most easily expressed in the context of the current long wave.

In the depths of the depression of the 1930s there were few prospects for an improved future. Many couples elected to have small families. As these children grew up, they discovered they belonged to a small cohort and that their job prospects were excellent. They opted for large families. But a generation later these second-generation children had many contemporaries, poorer job prospects, and therefore decided upon smaller families. Since the average age of women bearing children is about 27 years, a two-generation cycle of 54 years emerges.

This demographic mechanism is powerful only when options for choosing the number of children are readily available, and socially acceptable. Only in recent decades has infant mortality dropped, and birth control technology developed to the point where one might expect the phenomenon to be important. Demography is thus an excellent candidate as a prime driver of the present and future waves.

Figure 5 presents data on the (log) birth rate in the US. The minima and maxima from Figure 2 are shown as closed and open boxes. The correlation since 1919 is obvious. In times of economic downturn women produce fewer children, and vice versa. Close inspection of the curve suggests that even in the last century a drop in the birth rate was roughly coincident with a peak in the wholesale price/gold ratio.

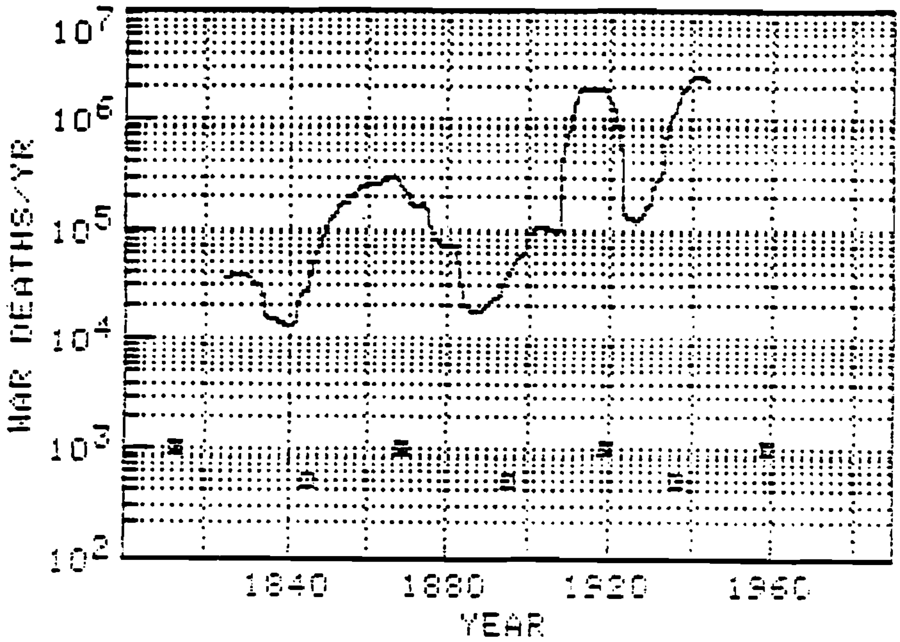

Figure 4 There is a correlation between the long cycle as it appears in the price/gold data (Figure 2) and deaths in wars based on Richardson's data. The minima and maxima from Figure 2 are shown as open and closed squares, respectively. Any successful theory of long waves should discuss this correlation.

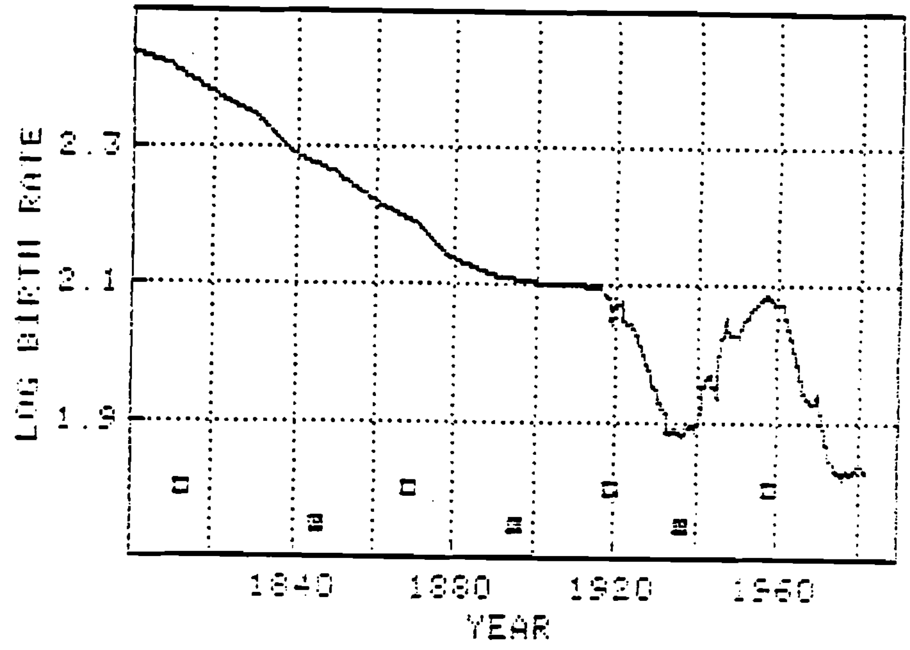

Figure 5 Logarithm (base 10) of the birth rate per thousand women in the USA. The minima and maxima from Figure 2 are shown as closed and open boxes. The correlation since 1919 is clear, and a close inspection reveals a correlation even in earlier years.

In order to examine this matter further we have differentiated the data of Figure 5. Figure 6 shows the results (shown is the derivative, less a linear background). The wholesale price/gold minima and maxima are shown as arrows. This graph is more complex than that of Figure 5, but shows more clearly the tendency for birth rates to rise after economic minima, and to fall after maxima.

If decisions on childbearing are based on individual perceptions of the future, then one might expect that wages would be a good long wave indicator. US wages relative to the consumer price index (CPI) are shown in Figure 7. The most striking features are the persistent rise in wages, punctuated by declines in the recessions of the 1840s and 1930s.

Figure 8 shows the same data on a logarithmic scale with 21-year averaging. Here a different message emerges. The curve breaks neatly into three parts: prior to about 1860; 1870 to 1920; and 1930 onward. The half-century long wave peaking in 1869 and 1919 is well confirmed.

MARKET SATURATION

Many investigators have focused on the innovation process as a key component to the long wave. Marchetti (1983) is the leading advocate of the inevitability of logistic growth. Freeman and Soete (1985) comment on the "agnostic" standpoint of van der Zwan that Long Waves consist "only of successive major structural crises of adjustment in the economy". This appears to us to be a striking understatement. If the most dynamic sectors of the economy are key drivers, their floods and ebbs must be highly correlated with other key indicators of long waves.

A critical point for long-wave theory is whether there are correlations with other indicators. Two examples suggest that there are. The growth of the railroads is a spectacular example of a technology meshing in growth with the long-wave periods obtained from price data. Figure 9 shows the penetration of train trackage in the United States. The indicator is the number of miles of railroad per capita. This is raw data – there is no smoothing. If smoothed with, say, an 11-year average, minor recessions are hidden and the data lead to a good Marchetti diagram. The growth fits well with the long-wave cycle having minima in 1846 and 1895. The long-wave peak in consumer price index of 1869 is clearly visible as a time of very fast growth, and the growth phase ended with the bust of the 1890s. (In more recent times the railroad industry entered a decline, and the number of miles per capita dropped.)

Figure 10 shows the mileage of railroad constructed annually per 1000 persons, with 11-year averaging. The railroads began with a high growth rate at the end of the depression of the 1840s. But the high growth rate in the mid-1850s is unexplained. The 1869 peak in wholesale price index is correlated with a spurt in railroad construction. But this spurt is no larger than that in the mid-1850s. Further, as the wholesale price index bottomed out in 1895, railroad construction began to take off again, though not for long. The burst of construction in the early 1880s likewise shows no correlation with other long-wave indicators.

While the railroad business in the USA boomed between two long-wave minima, the detailed correlation fails. It is in these details that one must search if one is looking for the kind of understanding that will lead to predictive capability.

Finally, the fact of saturation of railroad mileage, and especially the level of saturation which occurred in about 1890 (Figure 9), is in no way explained by the data presented here. The most obvious explanation is in terms of an imminent new mode of transportation – the automobile. Yet in the context of the times there was every reason to believe that the railroad business could have continued to expand for many decades.

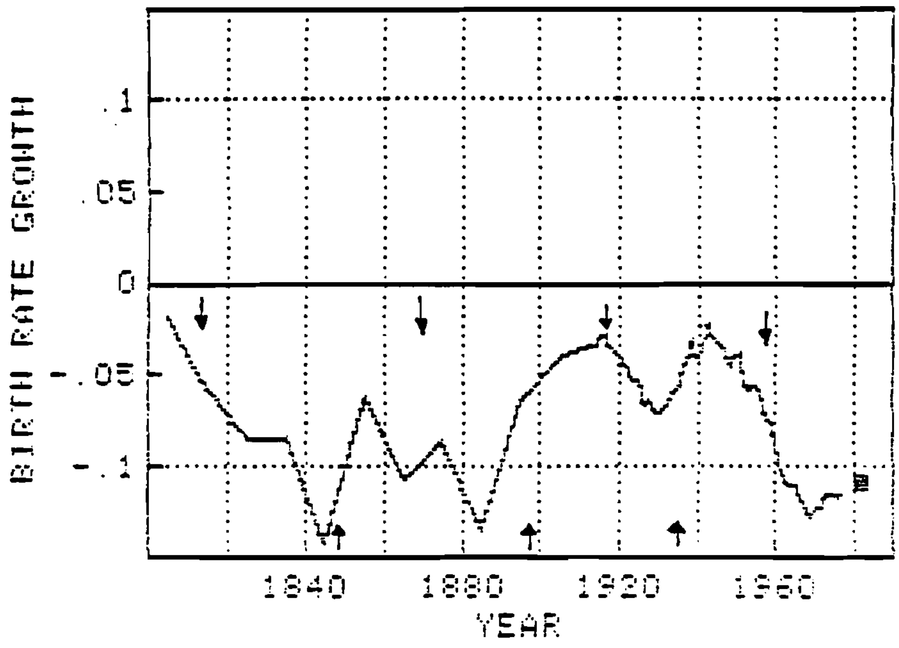

Figure 6 The derivative of the birth rate data of Figure 5, less a linear background correction. Maxima and minima from Figure 2 are indicated by arrows. There is a clear tendency for birth rates to drop in the vicinity of long-wave minima, and to rise near long-wave maxima.

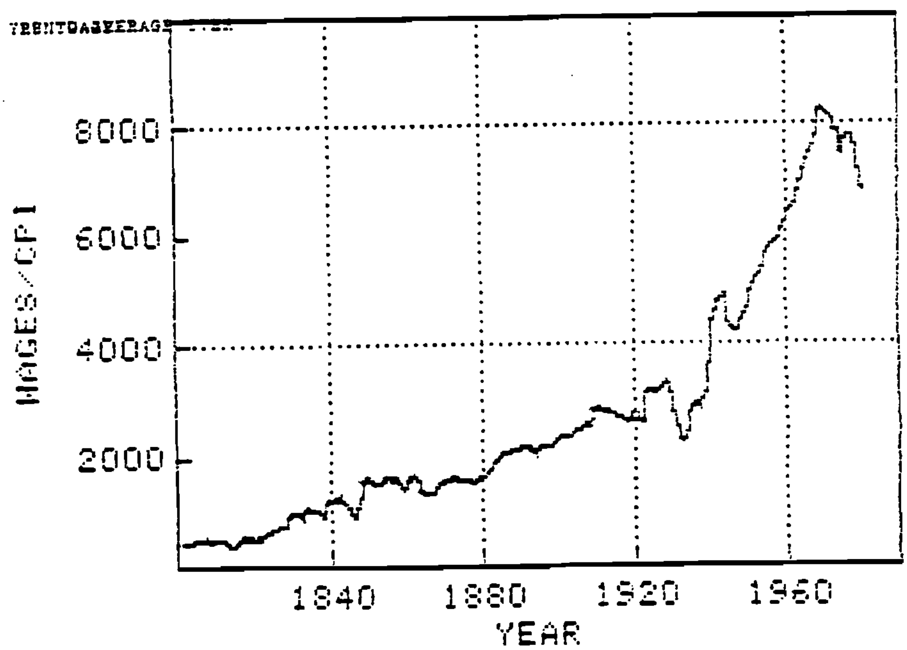

Figure 7 US wages relative to the Consumer Price Index. No averaging.

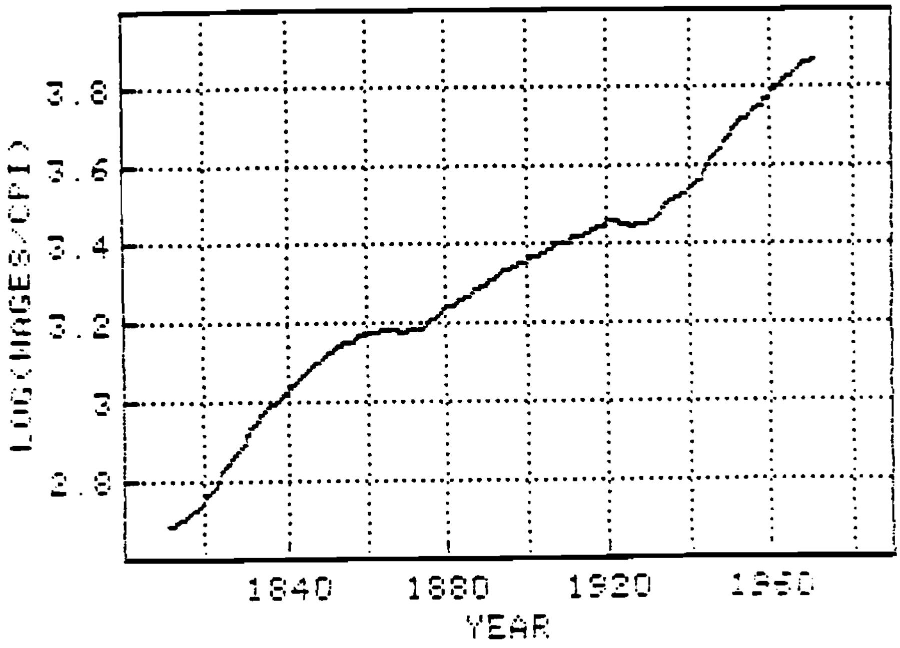

Figure 8 US wages relative to the consumer price index, logarithmic presentation with 21-year arithmetic averaging. The curve is clearly divided into three regions, with the middle region corresponding closely to the long wave of Figure 2.

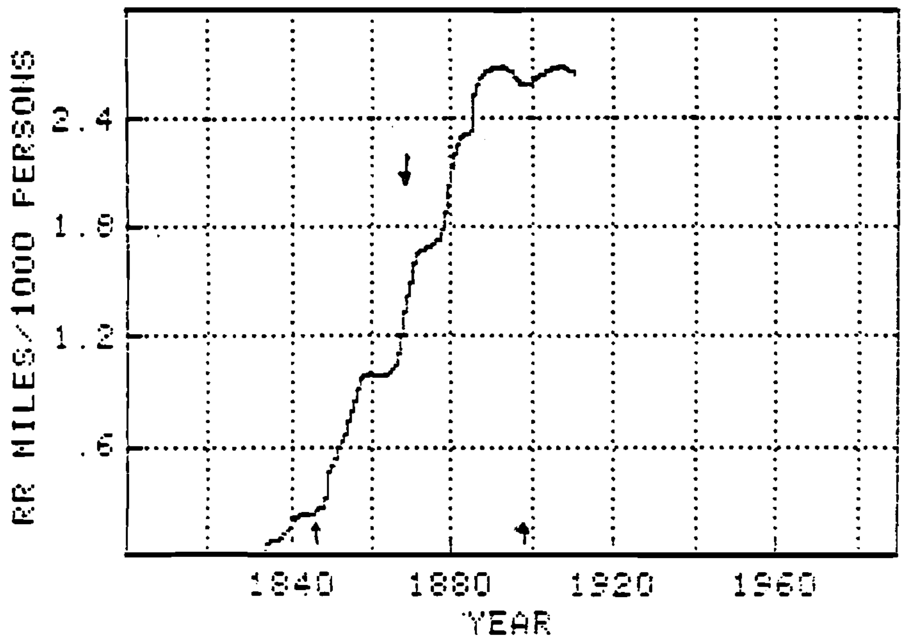

Figure 9 Penetration of trains in the USA the indicator is the total number of track miles per thousand persons. This penetration is well correlated with the third long wave. No averaging is used. After about 1895 trackage became constant, and later on declined.

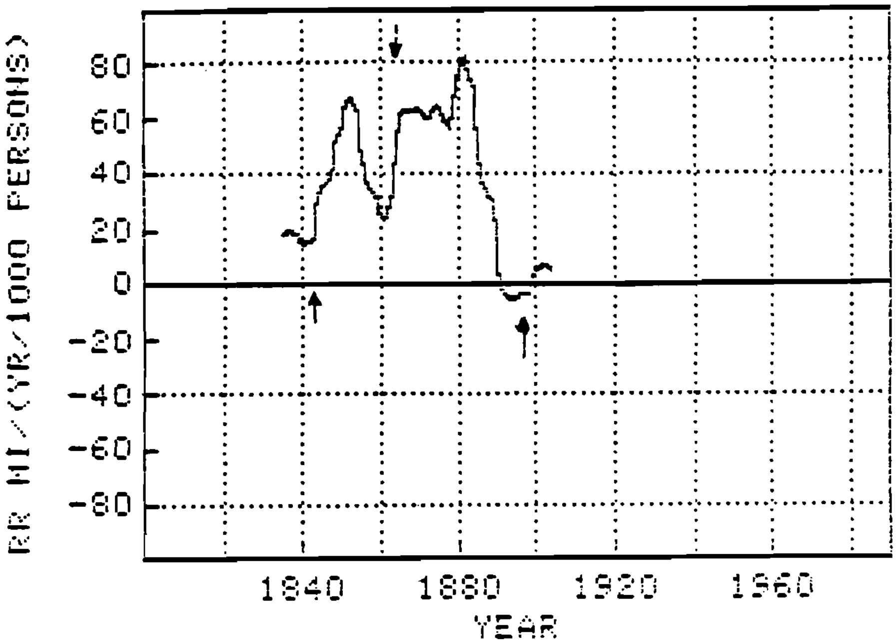

Figure 10 Miles per year of railroad track installed per capita. This is the derivative of the data of Figure 9, but with 11-year averaging. The beginning and the end of the growth phase are evident, along with the slowdown during the recession of the mid-1860s. The long-wave minima and maxima from Figure 2 are indicated.

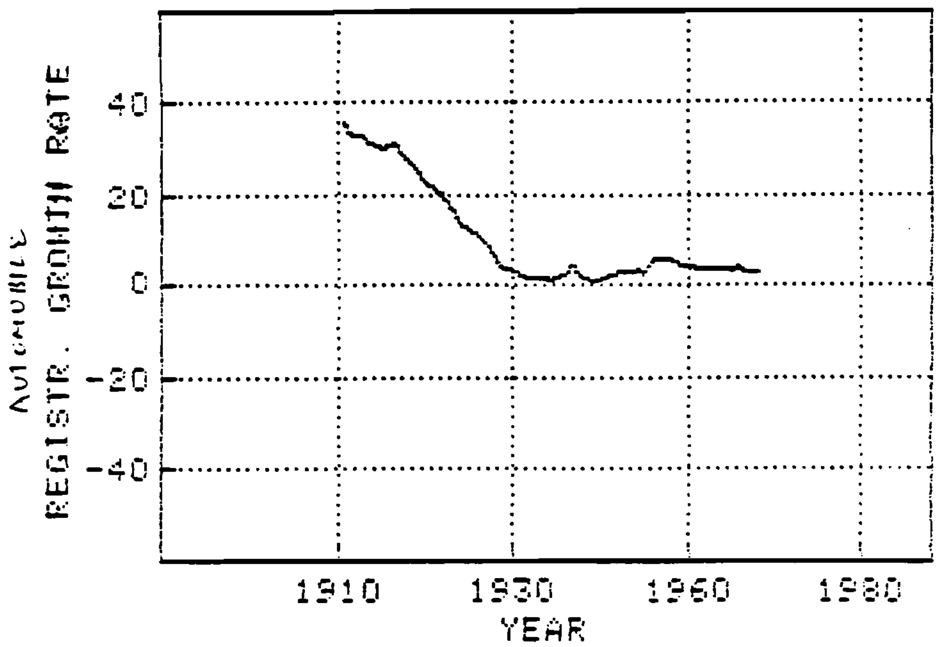

Figure 11 Automobiles were a dominant component of the US economy in the early twentieth century, with the major growth phase ending at the time of the long-wave minimum in the early 1930s. The figure shows the growth rate (in percent per year) of registrations (11-year averaging). A surprising conclusion is that the industry did not show rapid growth after the Depression.

Growth in the railroads is reflected in the experience of the iron and steel business, which provided the material for the rails. From the turn of the nineteenth century to the turn of the twentieth, business boomed. Steel production went from 5 ounces per capita to 285 pounds, and the proportion of iron refined into steel rose from 2% to 74% (Strassmann 1956; see also Singer 1958, Burke and Eakin 1979). The concurrent development of the machine tool industry with its spectacular series of inventions and innovations provided a driving force that could not be slowed. A detailed analysis here corroborates the discussion of rail growth, but does not provide good indicators for saturation.

The problem of saturation is especially severe for a Marchetti type of analysis, since the fit to logistic equations assumes one knows in advance what that saturation level is. At the time saturation actually occurs there seems often to be ample reason to believe that a great deal of growth still lies ahead. The automobile industry illustrates the same point. Figure 11 presents growth data for the automobile industry. The format is slightly different from that of Figure 9. The growth rate of registrations is shown rather than cumulative numbers of cars. At the time automobile registration was first required in the USA the growth rate was phenomenal; it fell until about 1930, and then leveled off. From the point of view of impact on the economy the automobile saturated at the beginning of the depression, and never recovered. Car sales were a key driver in the early years of this century, and a dynamic indicator of the state of the economy. Figure 12 shows sales per capita, with a rapid rise from the beginning of the industry until the collapse during the Depression, followed by a secondary rise after the Second World War. An 8 million car year corresponds (with the current population) to about 0.04 sale per capita, and this is about where the automobile industry may well remain for quite a while. The sales data thus fail to fit a Marchetti-type diagram, though the registration data would. While the number of cars per capita seems to have saturated, there is certainly ample opportunity, from a technical point of view, for further expansion.

These two examples from the transportation sector fit well with the long-wave dates for the last two cycles, as identified from wholesale prices measured relative to gold. Other sectors do not fit the model so well. Chemicals and oil, excellent candidates for the dominant sectors in recent times (prior to the OPEC embargo) measured as a fraction of industrial output, increased through the Depression of the 1930s (Figure 13). So too has total energy use and electrical energy use, which resumed rapid growth after the depression and maintained it until the mid-1970s, when growth virtually ceased. Theories based on swarming of innovation are appealing in the sense of a metaphor of progress, but little actual data that we have seen catch the eye convincingly. The best hope for sharpening the case lies, we suspect, in careful attention to identification of indicators for leading sectors, and in disaggregation.

STABILITY CONCEPTS: SUGGESTIONS FROM ECOLOGY

The previous section has examined empirical data supporting the idea of long waves. We found that evidence, while not abundant, is at least adequate to support the idea of the long wave as a metaphor for change. The evidence we found most compelling is in the areas of price, birth rate, growth and saturation of new industries, and war. We now turn to the matter of interpretation.

Our starting point is the observation that positive associations need not imply causality. In the approach to scientific investigation of Popper, a key concept is

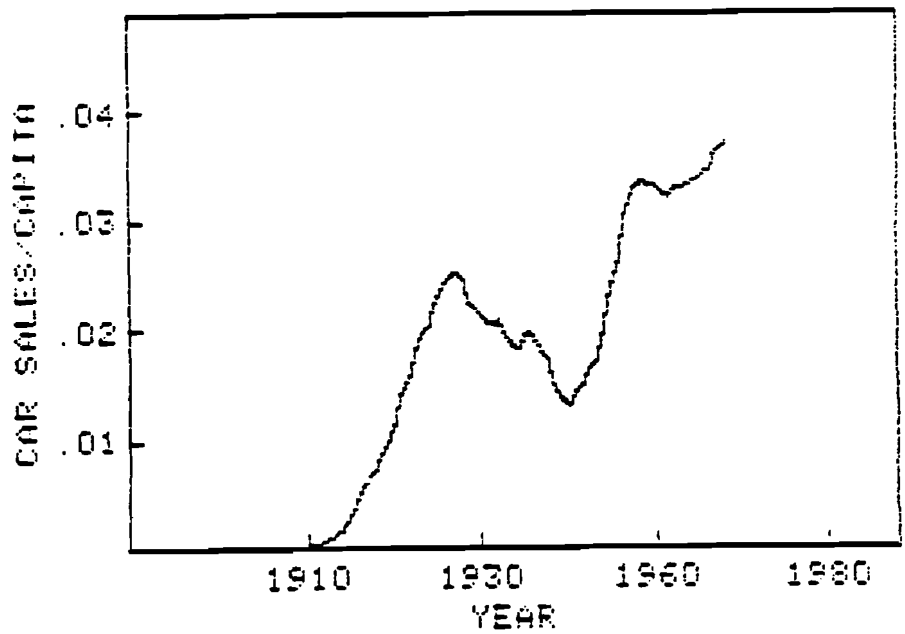

Figure 12 Automobile sales per capita (11-year average). Total sales per capita dropped during the Depression, then increased. The increase was not enough to lead to a sharp rise in registrations per capita.

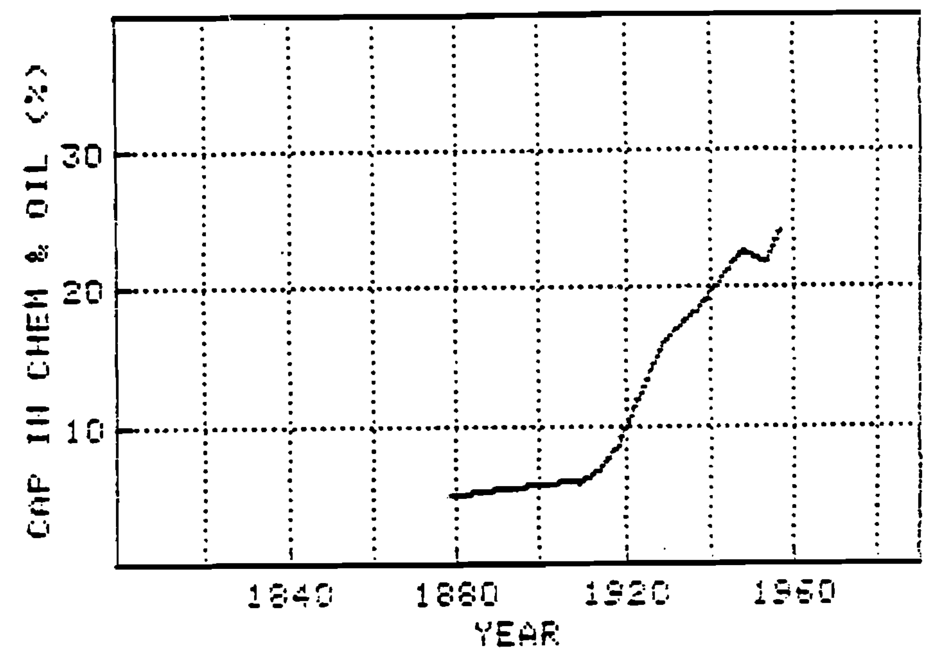

Figure 13 Capital in chemicals and oil, relative to total capital invested in US industry. These data illustrate the rise of a major sector even during the Great Depression of the 1930s. This sector presents a problem for long-wave theory.

that of falsifiability. According to this view, no theory can ever be proven true. However, to be acceptable, a theory must be subject to practicable tests which can prove it wrong. This is a difficult enough requirement in the laboratory sciences, where experiments can be repeated with changed conditions. The requirement is far more vexing when one is dealing with social systems for which repetition is not an option.

Yet thinking about the future is impossible without some kinds of models as to how the world works. Models, be they conceptual or mathematical, offer a simplified view of the world that allow the array of a broad spectrum of facts and observations about the world into a systematic structure having predictive content.

One potential source of guidance comes from non human living systems. This is the domain of ecology, the science which attempts to identify patterns in assemblages of living systems. Any proposal to generalize from non human to human systems must face the problem of self-awareness. There can be no totally convincing answer to this objection. Our view is that the same "laws of nature" that gave rise to all other living systems are also controlling for man (Miller 1978, Prigogine 1981). There is no escaping these constraints, any more than we can hope to escape from physical laws such as the law of gravity, or the universal speed limit – the velocity of light.

We reviewed concepts of stability as these have been identified in the ecological literature (Watt and Craig 1985). From this review we identified 13 principles. These principles illustrate that there are many different types of stability, and that what is perceived as stability from one perspective may very well be perceived as instability from another. The principles also help to clarify the observation that stabilization of a system is often not the goal of choice. This is particularly relevant in discussing social progress, where a typical goal is continuing advancement (e.g. of material wealth, or of knowledge).

A particularly vexing problem in the analysis of complex systems is the fact that many types of systems structures are of such a character that their behavior is exceedingly erratic, for reasons having to do with their structure, their environment, or both. This can be the case even with systems that are entirely deterministic: the nature of some systems is such that their evolution in time is exquisitely sensitive to the details of initial conditions, or to the values of parameters. The complexity of apparently simple systems was brought to general attention by May (1974, 1976), and there is now a large literature on the subject of catastrophe theory and of chaotic systems (Wilson 1981).

We analyzed the industrial revolution in terms of a transition from one type of stabilizing principle to another (Watt and Craig 1984). In this view the industrial revolution in England was characterized by stresses in the energy sector brought about by depletion of forests. The next energy resource tapped was coal, but trouble developed as shallow coal was depleted. The Watt steam engine provided the technology to mine deeper (since water could be pumped more efficiently), and to develop railroads. The Watt engine was a possible technology at least several decades before it actually developed as a commercial product. The resources to bring the technology to fruition could not be assembled before the need existed. Once the new technology became available, many applications emerged that could hardly have been imagined only a few decades earlier.

These ideas can be expressed in the language of several of the general principles of stability. Reliance on wood (and later on coal) as a primary fuel is stabilization based on high-flux use of a single resource (monoculture). Systems can stabilize by high throughput, but are then highly vulnerable to shortage of that resource. An alternative strategy based on diversity of resources may be less efficient when times are good, but has higher survival value when key resources are in shortage. This stability principle is captured in the folk adage "don't put all your eggs in one basket".

As transportation and communications systems improve, the economies of the world are becoming increasingly tightly coupled. This is leading to the reduction of stabilization mechanisms associated with isolation – the "patchiness" principle. This has several effects. A positive effect is that good ideas are rapidly propagated. An adverse effect is that trouble developing in one area is rapidly communicated elsewhere. The depression of the 1930s was more intense in the USA than in Europe, due to the relatively loose economic coupling that then existed. To what extent are the tighter and faster couplings that exist today leading to a more vulnerable world?

In order to begin to test these ideas we explored the degree to which key indicators can be explained in terms of the variation of a hypothesized lead sector. We focused on energy as a driver, using the ratio of the price of a market "basket" of fossil fuel energy to average spendable family earnings as an indicator. In the period 1957 to 1966 only 29% of year-to-year variance in the durable goods sector of GNP could be explained in terms of this ratio. In the period 1967 to 1973 the explainable proportion of the variance increased to 38%, and in the 1974-80 period 80% of the variance could be explained. Analysis with long-term trends removed lowered the variance to 69%.

This approach emphasizes the identification of key driving variables appropriate to any given era. It emphasizes simplification, following our belief that if the results are to prove broadly convincing the models used must be simple, a lesson we believe is one of the most important messages from the history of large-scale modeling. As instabilities inevitably develop, the social system makes transitions from one mode of stabilization to another. A primary goal of policy, we believe, should be to minimize the disruptions associated with these transitions. Work is in progress to develop this approach in detail.

REFERENCES

Burke, J.G., and M.C. Eakin (1979) Technology and Change. Boyd and Fraser Publishing Co., San Francisco.

Craig, P.P., and M.D. Levine (1984) Lewis Richardson and the Analysis of War. Chapter in the American Physical Society Arms Race Study. APS Conference Series, NY.

Easterlin, R.A. (1980) Population, Labor Force, and Long Swings in Economic Growth, The American Experience. Columbia University Press, NY, in Birth and Fortune, Basic Books, NY.

Forrester, J.W. (1979) An Alternative Approach to Economic Policy: Macrobehavior from Microstructure, in N. Kamvany and R. Day (eds.), Economic Issues of the Eighties. John Hopkins University Press, Baltimore, Maryland, USA.

Freeman, C. and L. Soete (1985) Comments on Topics 1, 4 and 5. This volume.

Freeman, C., J. Clarke, and L. Soete (1982) Unemployment and Technical Innovation: A Study of Long Waves and Economic Development. Greenwood Press, Westport, Conn.

Garvey, G. (1943) Kondratiev's Theory of Long Cycles. Rev. Econ. Statistics v25, 203-220.

Glismann, H.H. (1985) Comments on Topics 1 and 2. This volume.

Keyfitz, N. (1972) in Population Dynamics, T.N.E. Grenville (ed.) Academic Press, NY.

Kondratiev, N.D. (1926) Die Lange Wellen der Konjunktur. Archiv für Sozialwissenschaft und Sozialpolitik 56:573-609.

Kuznets, S. (1958) Proc. Amer Phil. Soc. v102, 25.

Marchetti, C. (1983) Recession: Ten More Years to Go? IIASA Options. (in Background Material, Bianchi *et al.* 1983).

May, R.M. (1976) Simple Mathematical Models with Very Complicated Dynamics. Nature v261, June 10, p.459.

May, R.M. (1974) Stability and Complexity in Model Ecosystems. Princeton University Press.

Mensch, G. (1979) Stalemate in Technology: Innovations Overcome the Depression. Ballinger Publishing Co.

Miller, J.G. (1978) Living Systems. McGraw-Hill.

Prigogine, I. (1981) From Being to Becoming. W.H. Freeman and Co., San Francisco.

Rostow, W.W. (1978) The World Economy: History and Prospect. University of Texas, Austin.

Samuelson, P.A. (1976) Population Studies, v30, 243.

Singer, C., E.J. Holmyard, A.R. Hall, and T. Williams. A History of Technology (7 Volumes) Oxford, Clarendon Press. Especially Volume V (The Late Nineteenth Century) 1958 and Volume VI (The Twentieth Century). 1978.

Strassmann, W.P. (1956) Risk and Technological Innovation: American Manufacturing Methods During the Nineteenth Century. Cornell University Press.

Thompson, W.R., L.G. Zuk (1982) War, Inflation and the Kondratiev Long Wave. J. Conflict Resolution, v26, (4), 621-644.

Thurow, L.C. (1983) Dangerous Currents. Random House, NY.

Warren, G.F., and F.A. Pearson (1935) Gold and Prices. John Wiley, NY.

Warren, G.F., and F.A. Pearson (1937) World Prices and the Building Industry. Wiley, NY.

Watt, K.E.F., and P.P. Craig (1985) Surprise, Ecological Stability Theory and A Reinterpretation of the Industrial Revolution. Chapter in "The Anatomy of Surprise", C.S. Holling (ed.).

Wilson, A.G. (1981) Catastrophe Theory and Bifurcation: Applications to Urban and Regional Systems. University of CA Press.

Wilson, L.L. (1964) Catalog of Cycles . Part I – Economics. Foundation for the Study of Cycles. Inc. 124 S. Highland Ave., Pittsburgh, PA 15206.

THE INTERACTION OF INVESTMENT AND DEBT IN THE LONG WAVE

Jos Delbeke and Erik Schokkaert

INTRODUCTION

The present long-wave discussion is rather confused. Most economists do not accept the theoretical and empirical relevance of the concept. Within the small circle of long-wave researchers, many theories are competing, each of which claims to give the basic cause of the Kondratiev. The main starting point of this paper is that this confusion can only be resolved if long-wave researchers try to build an integrated theoretical framework in close contact with standard economic theory. This framework should offer an endogenous explanation for the long-wave phenomenon. These basic starting points are sketched in Section 1.

Such a macroeconomic framework should describe the conditions under which innovation will take place. In Section 2 we argue that the financial sector may be important in this respect and has been relatively neglected in recent research. We present a simple model that can explain the long wave through the interaction of investment, debt and the cost of credit. In Section 3 we enlarge somewhat the approach and analyze the role of innovation, of prices and of the multiplier-accelerator mechanism. In each case we simulate our model for reasonable values of the parameters and show that it generates cycles with a periodicity of about 50 years.

It is certainly not our intention to describe or explain the economic development since the industrial revolution. Our approach remains purely deductive and theoretical. We want to show that some simple economic mechanisms may generate long waves and deepen our understanding of the relative importance of these mechanisms and of their interaction.

1. THE NEED FOR A MACROECONOMIC FRAMEWORK

In general one can state that there are two main streams in the long-wave literature; the same holds for recent research in the field. The first, and larger, group of researchers is mainly empirically oriented. Economic historians collecting data about sectors and regions over a long period observe in most cases fluctuations of different length and amplitude. With the help of a whole range of statistical methods the trend and all short-run fluctuations are eliminated. On the basis of the resulting series they conclude to accept or reject the so-called long-wave hypothesis. In other words, the fluctuation in a number of series is confronted with the best known conclusion of Kondratiev (1926), i.e. the existence of a ± 50 year fluctuation.

Given the present state of the theory on the long wave, such empirical data collection undoubtedly is an essential job. However, one can ask if it is meaningful to follow further this way of research with practically all means. Have we not passed the point where the marginal returns of more investment in the same direction are rapidly declining? Of course, not all problems have been solved: the data problem is enormous and the filtering is critical. Yet it seems fair to conclude that most authors agree about the existence of long-term fluctuations. The crucial question which has remained open, however, is "whether these long-term variations are more than the outcome of a summation of random events, and further, whether they exhibit recurrent temporal regularities that are sufficiently well-behaved to call them 'long waves'" (Rosenberg and Frischtak 1983, p. 146).

The answers to these questions cannot be found by empirical research alone. Therefore, a small but growing group of researchers takes a more deductive starting point. They try to formulate the mechanisms, that could generate a long-wave phenomenon. They want to *explain* the possible existence of long waves. It is clear that the results of the first group are a necessary precondition for this theoretical work. However, it is only a first step: fruitful empirical research in science is possible only on the basis of theoretical insights. It is therefore not surprising that the best known authors on long waves must be situated in this second group: if they arrive at reasonable explanations, these appeal also outside the small circle of long-wave researchers (prominent examples have been Schumpeter 1939, and Dupriez 1947, 1959).

Until now, most authors have been looking for one strategic variable, that could be considered as the fundamental cause of the 50-year fluctuation. To a certain extent we will also follow that approach in this paper. However, we are convinced that this is only a first step. A complete explanation should take into account the general interdependence, that is such an important feature of the economic system. More concretely, a review of the literature (Delbeke 1981) shows that the different theories of various authors are to a large extent complementary. The Schumpeter (1939), Mensch (1975), Kleinknecht (1979), and van Duijn (1979) hypotheses about the clustering of innovations are compatible with the labor approach of Freeman *et al.* (1982), with the declining-profit hypothesis of Mandel (1980), the fluctuating fixed capital of Forrester (1977), or the scarcity of primary goods suggested by Rostow (1978). The same can be said for the more sociologically inspired theories of Simiand (1982) and many recent authors. Essentially, the monetary theories (e.g. Dupriez 1947) can also be reformulated to fit into the general macroeconomic framework.

The acceptance of such an interdependent approach throws a new light upon some actual problems in long-wave research. One of these is the difficulty of measuring and dating the long waves. Is it reasonable to claim one turning point or year for a 50-year cycle? We suggest that this is not the case, because the timing depends on what variable is considered as essential. If we allow for a turning period, let us say a decade, many different explanations can be reconciled. The pattern of leads and lags can give us important insights into the economic fluctuations, along which the adaptive mechanisms have to break through numerous inertias.

The quest for one basic factor seems to have biased the long-wave research. The older approach (before the Second World War) is using primarily price data. Nowadays most of the researchers prefer the analysis of real data, because they want to avoid the constant rise in prices since the 1930s. As a consequence of this choice, the majority of long-wave research is based on the Schumpeterian hypothesis. Enormous efforts are made to analyze empirically the historical pattern of the outcome of basic innovations. It need not be stressed how difficult such a task is, given the fact that new products are only classified or registered when the quantity produced becomes of some importance. The innovative act is so narrowly connected with the entrepreneur who wants to protect his secret, that the sample of available statistics is likely to be biased towards successful stories. Only when the entrepreneurial function is institutionalized, i.e. during the last long wave, is this situation likely to be remedied to some extent.

We do not claim that the Schumpeterian hypothesis is useless, just the opposite, but we doubt that further empirical investigation can offer us a definitive proof. We think that it would be more fruitful to study more actively the role of the macroeconomic environment in the innovation process. Today, almost nobody doubts the need for basic innovations. Even people who have never thought about the long wave agree with this opinion. On the other hand, many people are disappointed about the small scale on which the innovation process starts and about the many negative short-run effects. A better understanding of these questions can only be obtained within a complete macroeconomic framework.

In this view, the choice between real, price or monetary data becomes irrelevant, because their interdependence is the rule in economic life. Indeed, the continued prices rise (since the 1930s) and the transition of a metal to a fiduciary monetary standard create problems for the study of the long wave. Within the macroeconomic framework, however, these problems become neither insoluble nor irrelevant. On the contrary, the integration of such phenomena is one of the main research objectives.

2. A STOCK–FLOWS MECHANISM IN THE FINANCIAL SPHERE

At present, the study of the macroeconomic interdependence of real and monetary variables in a long-wave perspective still is a neglected area of research. In a prevous paper (Delbeke 1983) we tried to draw a first sketch of a relevant macroeconomic framework. It is obvious that the construction of a complete macroeconomic model, which could give an endogenous explanation for the existence of long waves, is the ultimate purpose of the research. However, it is often difficult to see clearly the mechanisms that are working in such a huge model. In the present state of the art, it seems interesting to gain additional theoretical insights through the construction of simple models. The main purpose of these models must be the *explanation of the endogenous creation of turning points*.

The prototype of such a simple model is the multiplier-accelerator model, the success of which can largely be explained by its combination of simplicity and intuitive appeal and its capacity to generate fluctuations in a purely endogenous way. It is to be noted, however, that the cycles generated by the multiplier-accelerator mechanism are much shorter than 50 years for reasonable values of the unknown parameters. In this section, we propose an alternative dynamic mechanism, which is also able to create a long wave, but is situated in the financial sphere of the economy. Section 2.1 gives a short description of the model and some references to the literature. The bare essentials of the model are analyzed mathematically in Section 2.2. We will illustrate the working of the model with a simple simulation exercise.

2.1 Financial Factors in the Long Wave

The simple fact that the long wave seems to be typical for an advanced capitalist economy already points at the potential importance of the financial system. More especially, the banking system, being a private business with no policy responsibilities, might play an important role.

The analysis of Minsky (1964, 1975) seems to offer an interesting starting point. He agrees with the (almost) universal point of view that the instability of investment is the crucial factor for the unbalanced growth path of the economy. Financially, investment can be interpreted as one of the fundamental speculations of capitalist society: the entrepreneur is hoping that the future (uncertain) cash flows originating from an investment will be greater than the payment commitments due to the liabilities. Moreover, a decision to invest can be considered as a portfolio decision because it is a decision to emit liabilities or to decrease liquidity.

Investment decisions are dominated on the one hand by the cost of capital and credit and on the other hand by the discounted value of the expected yields of the capital assets. By its nature, this expected yield is easily influenced by waves of optimism and pessimism, causing an exaggerating behavior of investors. Behind these changing states of confidence, the degree of fragility of the financial system is crucial. The system is developing towards fragility as the cash payments increase relative to the cash receipts and as units possess ever less liquid assets. Indeed, after a depression and with the beginning of recovery, the supply curve of finance is very elastic. The innovative investments are more profitable than expected and give rise to an ever growing wave of investment. Internal financing is more and more replaced by external financing, and a whole structure of debts is built up on one foundation: the prospective yields on investment projects.

However, the expansion cannot continue. When the first signs of saturation become discernible, and competition is growing, it becomes clear that the debt structure is based on an overoptimistic evaluation of the yields from investment projects. Economic units will be short of liquid assets, and will be forced to sell more and more assets, because bankers are not willing to grant new credit lines. The decline of income and production will confront more and more economic units with payment problems.

Some economic units will not be able to fulfill their payment commitments: they will fail. This development can create severe domino-effects, as is well documented for the Great Depression of the 1930s (see e.g. Bernanke 1983). Because debts are expressed in nominal terms, problems become still more dramatic when prices start to decrease. The debt deflation process leads to a downswing with low incomes and high unemployment, during which the new recovery and boom are prepared. Disinvestment occurs, but the financial position is rebuilt. Expectations again become more confident as the subjective repercussions of the debt deflation wear off, and new profitable investment opportunities are created by innovation.

We can add two remarks to this story. In the first place, it may be dangerous to overemphasize the irrational aspects of the banker's behavior and to resort to vague ideas of "optimism" and "pessimism" to explain the turning points. It has indeed been argued (by Bernanke 1981, 1983) that the disruption of the financial sector by the debt crisis raises the real cost of intermediation between lenders and borrowers. Therefore it is completely rational for banks to increase the rate that they charge borrowers and to strengthen the conditions for risky loans.

Secondly, the preceding story almost exclusively focuses on investment behavior by firms. At least since the thirties a completely analogous story can be told about consumer expenditure. Here the effect of the financial crisis works via the wealth effect in the consumption function and the liquidity effect in consumer durable and residential housing expenditures. A convincing illustration of these effects as given by Mishkin (1978).

Of course, we are quite aware of the fact that our analysis remains very limited and partial. Nevertheless we feel that it helps explain at least some features of the long wave. In Section 3 we will comment on the links between our financial model and the real and monetary sectors of the economy. Note indeed that the roles of the price system and of the innovation process were only casually mentioned until now. Before we try to indicate how the model could be improved however, let us first deepen our understanding with a mathematical illustration.

2.2 A Simple Linear Dynamic Illustration

In analogy with the popular multiplier-accelerator model we can construct a model that illustrates the basic features of our apporach. We will show that for reasonable values of the parameters the model generates cycles of about 40-50 years.

The basic ingredient of course is an investment function. We noted earlier that crucial variables here are the profit expectations and the cost of credit and we therefore write:

$$I_t = I^0 (z_t^I) + \alpha_1 R_t = \alpha_2 P_t^* \,, \tag{1}$$

where I_t = investment in period t

I^0 = autonomous investment

R_t = cost of credit in period t

P_t^* = expectation of profit in period t

and $\alpha_1 (< 0)$ and $\alpha_2 (> 0)$ are parameters. The first term on the right-hand side in (1) gives "autonomous investment". Because we want to emphasize that our model is only part of a larger approach, we explicitly write autonomous investment as a function of other (perhaps very relevant) variables z_t^I. Here the superscript I of course refers to investment.

The most difficult variable is the expectation of profit, which indeed is to a large extent a psychologically determined factor. For our purposes, however, we only need to capture the simple idea that there may be "waves" of optimism and pessimism, i.e. that a psychological climate in a certain sense perpetuates itself if there are no changes in other variables. A straightforward way of translating this argument is to relate profit expectations to past investment:

$$P_t^* = P^0 (z_t^P) + \beta I_{t-1} \,, \tag{2}$$

where $\beta > 0$. Again we introduce a vector of unspecified variables z_t^P to show the partial character of our model.

The cost of credit is an essential building block of our approach. This cost will be influenced by the situation on the capital market and therefore by the relationship between saving and investment. There is some indication that one might discern a long wave in saving behavior (van Duijn 1983). However, the basic idea of our approach is that the difference between the "safe" interest rate and the cost of credit for risky investments also is a consequence of the behavior of the economic agents and follows a long-wave pattern. The basic determinant of this pattern is the debt (D_t) position of the economy:

$$R_t = R^0 (z_t^R) + \gamma D_t \quad , \tag{3}$$

where $\gamma > 0$. Relationship (3) is convincingly demonstrated for the Great Depression by Bernanke (1983). We noted already that the same author argues that (3) may follow from perfectly rational banking behavior.

Finally, we write the following equation to describe the formation of debt:

$$D_t = \delta_1 D_{t-1} + \delta_2 I_{t-1} \quad , \tag{4}$$

where both δ_1 and δ_2 are between zero and one. The interpretation of these parameters is obvious. The fraction of debt repaid each period is given by $1 - \delta_1$, while δ_2 gives the share of external financing of investment. We argued in the previous section that this share is increasing during the upswing of the long wave, but for the present purpose we keep δ_2 constant as a first approximation. Equation (4) is true by definition and it therefore is not necessary to introduce an "autonomous" component.

We could analyze the dynamic properties of this simple model as such, but it is easier to concentrate on the investment equation. Inserting (2) and (3) in (1) yields:

$$I_t = I^0 (z_t^I) + \alpha_1 R^0 (z_t^R) + \alpha_2 P^0 (z_t^P) + \alpha_1 \gamma D_t + \alpha_2 \beta I_{t-1} \tag{5}$$

and, transforming (5), and denoting the sum of the first three terms on the right-hand side by $C^0(z_t)$ to simplify the notation,

$$D_t = \frac{I_t}{\alpha_1 \gamma} - \frac{\alpha_2 \beta}{\alpha_1 \gamma} I_{t-1} - \frac{C^0(z_t)}{\alpha_1 \gamma} \quad . \tag{6}$$

Using (6) to substitute for D_t and D_{t-1} in (4) we get, after some algebraic manipulation:

$$I_t - (\alpha_2 \beta + \delta_1 + \delta_2 \alpha_1 \gamma) I_{t-1} + \delta_1 \alpha_2 \beta I_{t-2} = C^0 (z_t) - \delta_1 C^0 (z_{t-1}). \tag{7}$$

It is now possible to analyze the dynamics of investment (and hence of debt and cost of credit) in our simple model. To simplify the notation, we introduce the following symbols:

$$\alpha_2 \beta + \delta_1 + \delta_2 \alpha_1 \gamma = a \tag{8a}$$

$$\delta_1 \alpha_2 \beta = b \tag{8b}$$

$$C^0 (z_t) - \delta_1 C^0 (z_{t-1}) = C^0 \tag{8c}$$

Dynamic analysis (see e.g. Chiang 1974) then shows that (7) will endogenously generate a cyclical movement of investment if $a^2 < 4b$. This movement will be explosive if $|b| > 1$ and damped if $|b| < 1$. The length of the cycle is of course crucial to see whether we can generate *long* waves with our model. If we define

$$\cos \varphi = a / 2b^{1/2} \quad , \tag{9}$$

then we can derive the length of the cycle as $2\pi / \varphi$.

Let us now apply these formulae for our model. Consider first the parameters in (8b). The coefficient δ_1 is related to the fraction of debt repaid each period. It is not unreasonable to give it a value around 0.90, which would imply that all kinds of risky loans have on average a term of 10 years. For our simulation exercises we assumed δ_1 to be equal to 0.92 (average term of risky loans 12.5 years). The values of α_2 and β depend in our linear model on the units of measurement of investment and "expected profitability". For the dynamic analysis, however, only their product matters and it can be seen from (5) that this product links present to past investment. As a first approach, let us put $\alpha_2\beta$ equal to 1, which means that changes in investment have to be explained by the autonomous component and the debt position. In that case $|b|$ clearly is smaller than one and the cycle is *damped*. Note in fact that $\alpha_2\beta$ has to be larger than about 1.1, if we want the movement to become explosive.

Let us now turn to the analysis of the length of the cycle. If we keep to the values assumed for δ_1 and $\alpha_2\beta$, this length is determined by the product of δ_2 and $\alpha_1\gamma$. These parameters are crucial in the model and reflect both behavioral and institutional considerations. The first parameter gives the fraction of debt in total financing of investment. For Belgium its average over the period 1964-79 has been 0.38, but the coefficient will have another value for countries with a different institutional structure. The second parameter is the product of the interest effect on investment (α_1) and the influence of debt on the cost of credit (γ). It is difficult to define *a priori* values for these parameters but it seems reasonable to locate the value of the product between 0.01 and 0.05.[1]

In Table 1 we give the results of a kind of sensitivity analysis and relate the length of the endogenously created cycles to the values of δ_2 and $\alpha_1\gamma$ (given the values for δ_1 and $\alpha_2\beta$ mentioned previously). It is obvious from the table that a long wave of about 40–50 years can be generated by our model for reasonable values of the parameters. Note that the length of the wave increases if the fraction of debt financing becomes smaller. It decreases with the absolute value of the effect of debt on the cost of credit.

$\delta_1\gamma$	δ_2		
	0.25	0.50	0.75
-0.01	213	107	81
-0.02	107	67	53
-0.03	81	53	43
-0.04	67	45	37
-0.05	59	40	32

Table 1: Length of Cycle

The dynamic process is illustrated by Figure 1, where we simulated the model for the following values of the parameters: $\delta_1 = 0.92$, $\delta_2 = 0.50$, $\alpha_2\beta = 1.00$, and $\alpha_1\gamma = -0.04$.

We start from an initial stable situation where $I = 500$, $C^0 = 125$ and therefore $D = 3125$. In period 5 we give an exogenous shock to C^0, raising it to 300. The damped cycle of about 45 years can be clearly seen in the figure. First investment and debt increase, until debt (and hence the cost of credit) becomes too high. At that moment investment starts to decline and it keeps on declining for a long period, because it takes time to return to a normal level of debt.

[1] The interest elasticity of the demand for credit in Belgium has been estimated to be about 0.10 (see Verheirstraeten 1977, Dombrecht 1979). In 1974 gross investment was about 500 milliard Belgian francs. This figure implies that for an interest rate of 10%, α_1 would be about minus 5. Total credit to the private sector in 1974 amounted to about 1400 milliard Belgian francs. (Government debt was about 1200 milliard Belgian francs.) Values for γ between, 0.002 and 0.01 seem not unreasonable, *a priori*. The product $\alpha_1\gamma$ then is situated between -0.01 and -0.05.

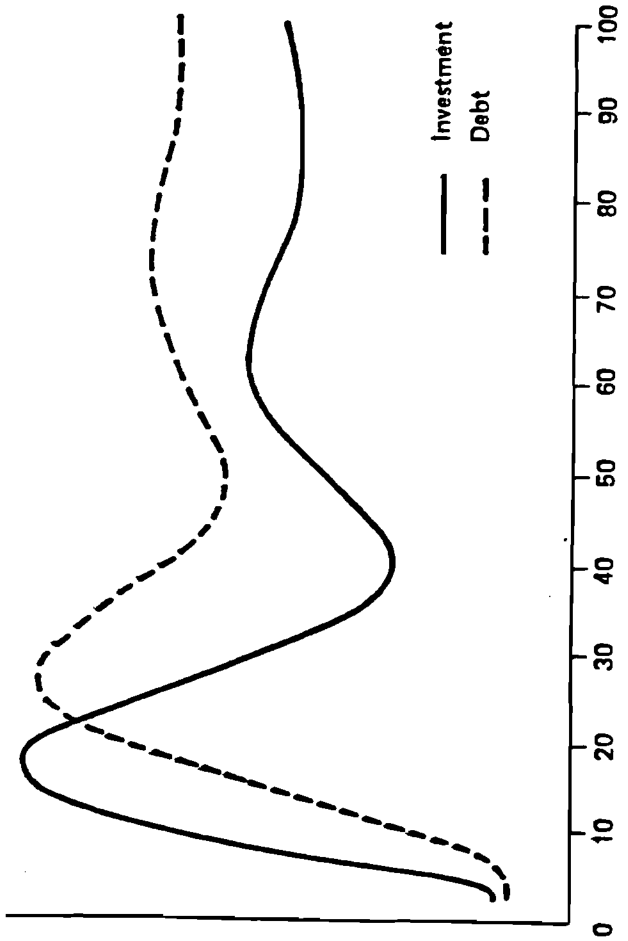

Figure 1

Of course, the model is really very simple as it stands now. It is interesting to see, however, that even such a simple model is already able to generate the turning points of a long wave *for empirically reasonable values of the parameters.* On the other hand, because of its damped character, it cannot explain the recurrence of the long-wave phenomenon. At the present stage of the work, it is tempting to conclude that recurrent exogenous shocks are necessary to explain the long-waves of the past. Before drawing this conclusion, however, let us first see how the dynamic behavior of the model changes if we try to make it somewhat more realistic.

3. TOWARDS AN INTEGRATED MODEL

We noted already many times that the final purpose of the research must be the construction of an integrated model. We certainly do not have the pretension to claim that our financial variables are the final explanation for the phenomenon of the long wave. In this section we show the possible relevance of other approaches and try to find out how they can be related to the model of Section 2. We will treat innovation, the price system and the multiplier-accelerator scheme successively.

3.1 Innovation and Our Financial Model

In their critical appraisal of the relationship between innovation and long waves, Rosenberg and Frischtak (1983) give the following overview of the conditions under which long cycles become an historical necessity:

1) The availability of an elastic supply of inventions, at a time when risk-return combinations appear propitious for innovation;
2) The formation of a cluster of innovations at the base of the upswing;
3) The reaching of an upper turning point of the technologically driven cycle due to increasing macro economic instability, as well as forces that deter the introduction of substitute technologies;
4) The arrival of the economy at a technologically fertile ground, after an appropriately extended period of time.

And in the same paper they also write: "Technologically driven long waves can be made to appear plausible only if macroeconomic factors can be shown to play a dominant role in shaping and disciplining the timing of the introduction of innovations."

We quote the paper rather extensively because these quotations clearly illustrate that there is no contradiction between our financial mechanism and the innovation approach. Quite to the contrary, for the innovation theory to make sense from an economic point of view, it needs some macroeconomic underpinning. The dynamics of investment and debt may be an important part of such a macroeconomic background. It is obvious that there will not be many innovations in the upswing, because the existing technology is profitable enough. During the downswing no capital is available in our model, especially not for risky innovation investments. In the trough, however, when the normal debt position has been restored, the risk premium is small and the conditions are almost ideal for innovation to take place.

In this description, innovation may seem to play a purely passive role. We can give it an active and crucial role in our model, however, if we interpret it as the main generator of the exogenous shocks setting the system in motion. Note in this respect that the model in Section 2 is damped and can only generate recurrent long waves if it gets recurrent exogenous shocks.

This idea also is illustrated with a simulation exercise. Assume C^0 follows the patterns given by Figure 2. There are some "clusterings" of innovations (in periods 4, 19, 40–46, 70 and 85–91), leading to an increase in the autonomous part of investment. For the rest, the system is completely the same as the one leading to Figure 1. The new dynamic behavior is sketched in Figure 3: we now see indeed a recurrent long wave, as could be expected.

3.2 Prices in our Financial Model

The main defect of the model in Section 2 undoubtedly is the neglect of prices, which implicitly are treated as constant. To introduce prices in an adequate way, it seems necessary to work out a monetary sector. Indeed, one could say that price changes are induced by the variable money creation of the banking system. Some first ideas, largely inspired by Dupriez (1947), are sketched in Delbeke (1983). In this paper we will not follow this track: we do not want to explain price changes, but only concentrate on the consequences of prices within our financial model.

Let us therefore postulate the following short-cut expression for price changes:

$$p_t = p_{t-1} + \varepsilon \, (I_t - I_{t-1}) \; . \tag{10}$$

where p_t refers to the price level. Equation (10) implies that prices increase and decrease together with investment. It is an easy way to introduce the idea that prices increase during the upswing and decrease during the downswing. We now rewrite our basic model (1)–(4) as follows:

$$I_t = I^0 \, (z_t^I) + \alpha_1 R_t + \alpha_2 P_t^* \tag{11}$$

$$P_t^* = P^0 \, (z_t^P) + \beta \, I_{t-1} \tag{12}$$

$$R_t = R^0 \, (z_t^R) + \gamma \, (D_t \, / \, p_t) \tag{13}$$

$$D_t = \delta_1 D_{t-1} + \delta_2 \, (p_{t-1} I_{t-1}) \tag{14}$$

Equations (11) and (12) are the same as (1) and (2): we assume that investment decisions are influenced mainly by real considerations. The financial debt, however, is expressed in nominal terms: in (13), we therefore transform it into real terms using our (endogenous) price index. While investment is expressed in real terms, the external financing of investment is a nominal concept. This explains the difference between (4) and (14).

The main purpose of this section is to capture the idea of debt deflation (see e.g. Fischer 1933). During the upswing prices increase, which makes it more profitable to contract nominal debt. Then comes the (unexpected) downswing, however, and prices tend to decrease: this raises the real value of debt and makes the necessary repayments more difficult. It may seem that this explanation does not hold for the recent experience. However, taking into account inflationary expectations during the upswing, a decrease in the rhythm of price increases (i.e. inflation) during the downswing may have the same debt-deflationary effects.

Model (10)–(14) now is not linear any more. However, simulation will reveal its dynamic properties immediately. We keep all parameter values identical to

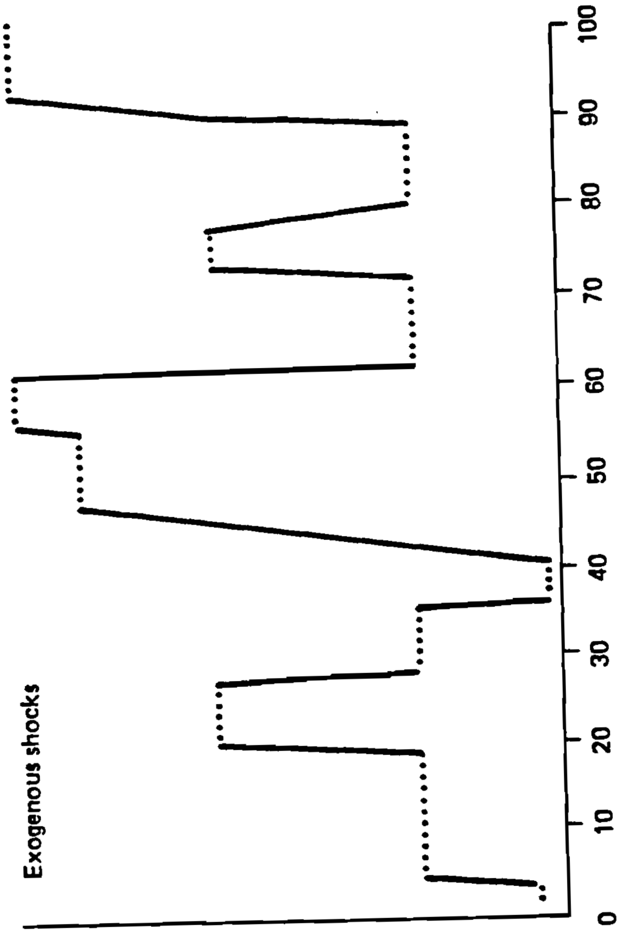

Figure 2

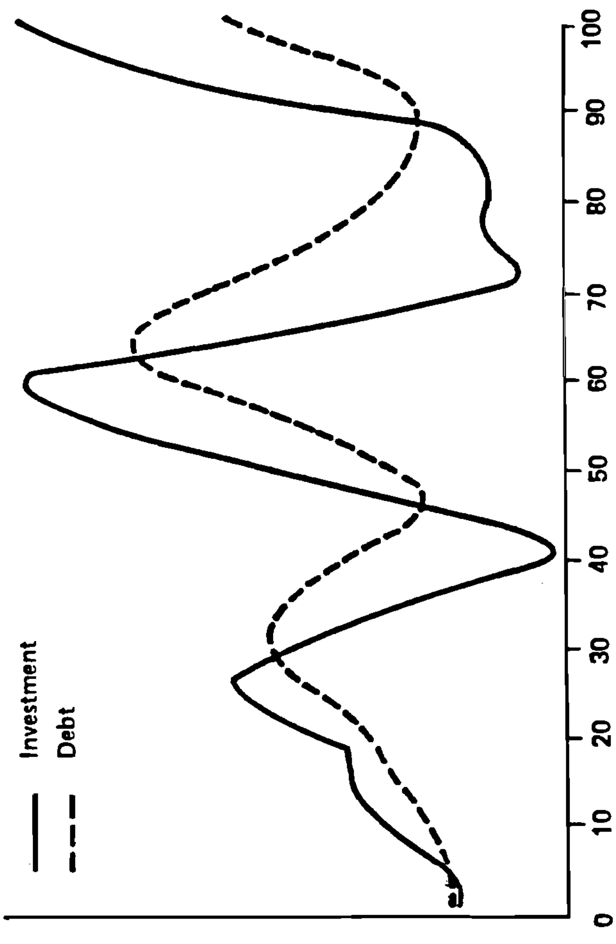

Figure 3

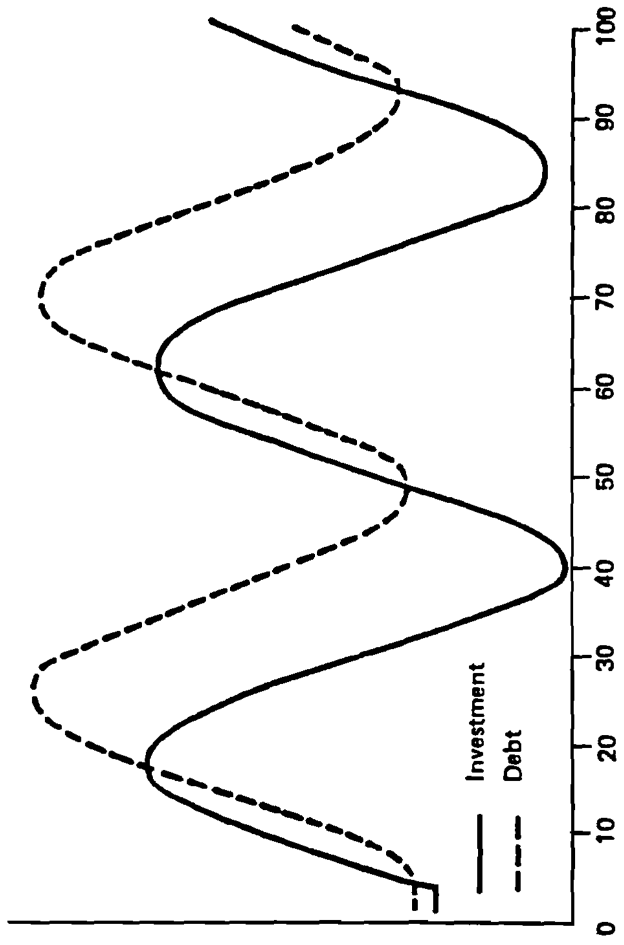

Figure 4

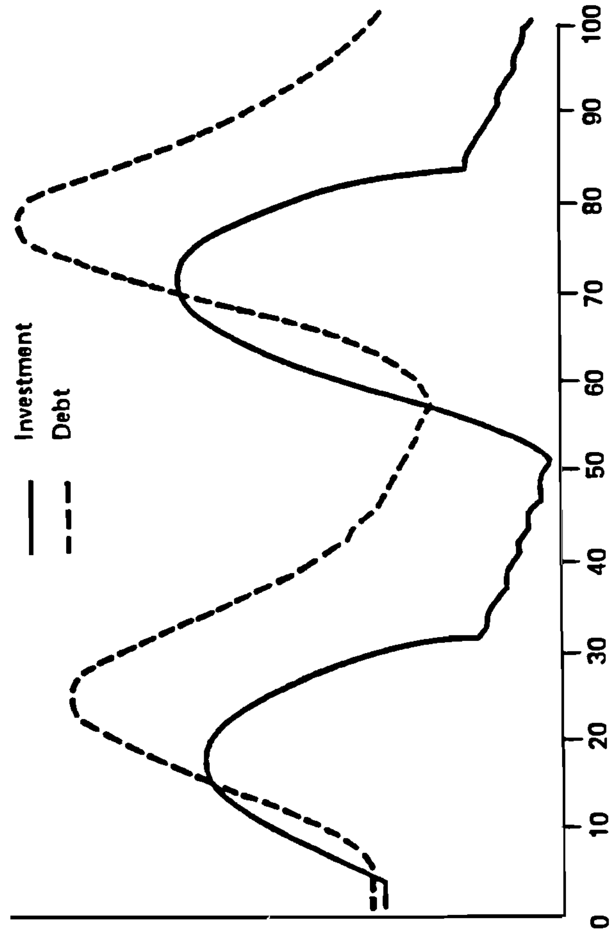

Figure 5

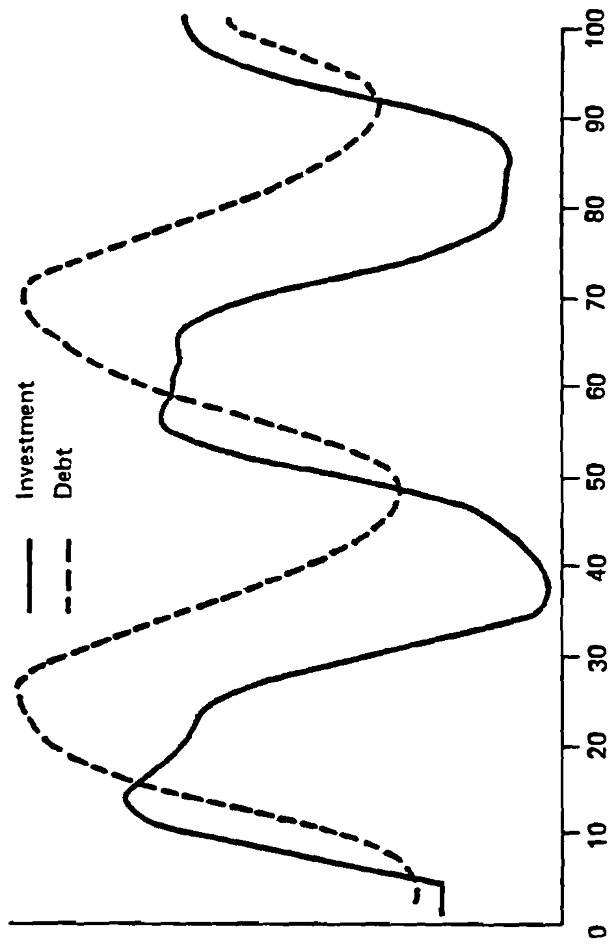

Figure 6

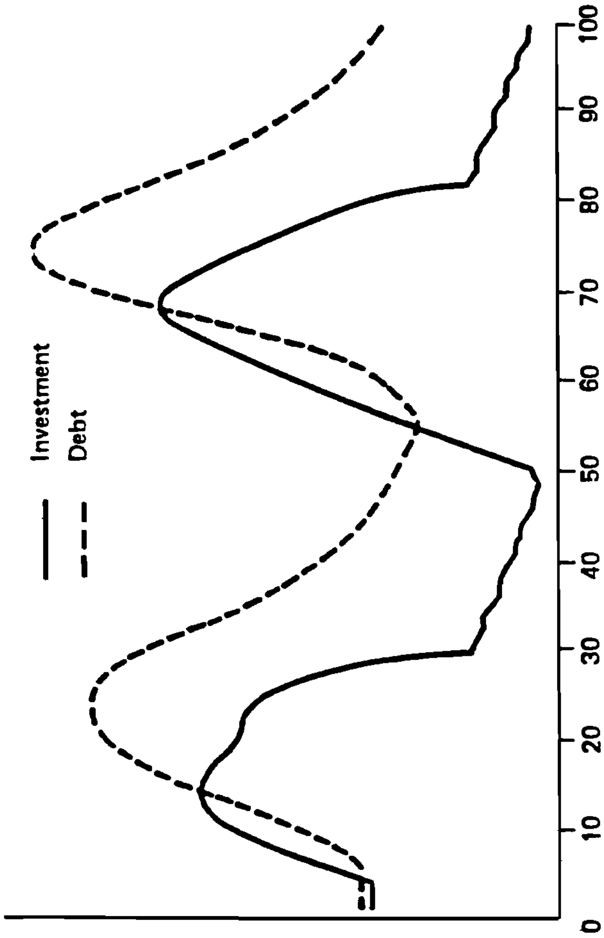

Figure 7

those used in Section 2.2 and start from the equilibrium price index $p=1$. We give the system the same exogenous shock, by increasing C^0 from 125 to 300. The behavior of the model crucially depends on the value we choose for ε. In Figure 4 we give the results for $\varepsilon=0.0003$. We get a nice long-wave pattern with a periodicity of 40 years. Note, moreover, that the strongly damped character has disappeared: the long cycle, generated by the model, now is a recurrent phenomenon. It could be argued, however, that our value of ε is too low, since the variation of the simulated price index is constrained in the range 0.78 to 1.50.

Raising the value of ε to 0.0005 considerably increases this variation: it now covers the range 0.16 to 2.04, which seems a better description of reality. The complete simulation results, presented in Figure 5, are remarkable. In the first place, we again find a recurrent long wave, with a periodicity of about 50 years. More interesting, however, is the shape of this long wave, which has changed because of the nonlinearity in (13)–(14). The waves in Figure 5 have a sharp peak, but a long trough of about 14–20 years. Again, this seems to give a more realistic picture of the historical facts in the Western world.

These simulation results suggest that the integration of a monetary sector with our financial model may be a very promising track. In the first place we get a better description of reality. Moreover, we do not need any exogenous shocks to make the long wave a recurrent phenomenon. This does not imply that there have been no exogenous shocks in the past: they obviously have been important. Nor does it imply that innovation does not play any role in the process. New technologies determine the character of the upswing and are essential elements in the complete model, which also would explain long waves in the labor market and in consumption behavior.

3.3 The Multiplier–Accelerator Model

The multiplier–accelerator model could have been an alternative dynamic mechanism to explain the phenomenon of long waves. However, we noted already that this mechanism generates shorter cycles for reasonable values of the parameters. What happens to our model if we introduce a kind of business cycle?

To answer this question we simulated the model of Section 3.2 under the assumption of a 15-year cycle in C^0. After the initial shock (from 125 to 300) it follows the following pattern:

300	320	340	360	340	320	300	
280	260	240	220	240	260	280	300

The results for $\varepsilon=0.0003$ and $\varepsilon=0.0005$ are given in Figures 6 and 7, respectively. These figures do not give us many additional insights and do not change the basic long-wave pattern found in Section 3.2. However, we get a more attractive picture with accelerations and decelerations of growth along the fundamental long wave-path.

CONCLUSION

In this paper we have argued that an integrated macroeconomic approach is necessary to understand the empirical phenomenon of the long wave. Although the construction of a large model is the ultimate purpose and may be already worthwhile now, simple models may be useful in the present state of the art to deepen our understanding of the basic mechanisms. Of course, such simple models can never be rich enough to explain the historical facts. They can give some indication, however, about the importance of different theories and about the possible interrelationship between these theories. Mathematical formalization can be a useful instrument to check for consistency and to get some feeling for the empirical conditions needed to generate long waves. We have to make explicit our assumptions; both about the structure of the model and about the values of the parameters. In this way, scientific discussion can become more fruitful and less speculative.

We showed that a simple stock–flow mechanism in the financial sphere can generate long waves for reasonable values of the parameters. If we add the phenomenon of debt deflation, the cycles in our model become permanent: their periodicity is about 50 years and the shape of the generated long wave seems to offer an attractive picture of reality.

Of course, we do not claim to have discovered the basic cause of the long wave. On the contrary, we think that the quest for one basic cause is a bad research strategy. In the first place, many theoretical questions remain open. We completely neglected, for instance, the potential role of relative prices and of labor shortages. A model of the monetary sector also is lacking. This should replace the primitive solution that we now have chosen to explain the behavior of prices. We also have specified an oversimplified equation for the expected profitability of investment: a more complete theory should introduce here the notions of saturation and of the life cycle of industries. Another important problem is to determine the exact role of innovation in the framework. In this respect we argued that it is necessary to explain the macroeconomic conditions under which innovation will take place and that our model can be an important cornerstone of such an explanation. It still is not clear, however, whether innovation is necessary to generate long waves or only colors them.

In the second place, it must be emphasized that theory is only interesting insofar as it gives a hint to understand the empirical reality. Some indications of the possible relevance of our model are given by Delbeke (1983), who shows, for instance, a clear long-wave pattern in the Belgian money base multiplier. Yet much more work remains to be done. Note, however, that theory is necessary to guide empirical research and that a carefully specified model is an ideal starting point for this research. We plan to go further in this direction in the near future.

In fact, our ambition in this paper has been very limited. In the first place, we wanted to illustrate that the construction of simple models may be an interesting research strategy, which leads to consistent thinking and more fruitful discussions. In the second place, we wanted to emphasize the potential importance of the financial sector for the explanation of the long wave. In recent research, the financial mechanisms and the interaction between debt, credit and investment have been relatively neglected. A macroeconomic framework is necessary, however, if we want to give an endogenous explanation for the Kondratiev. Only in such a framework does it become possible to integrate different existing theories and, more especially, to formulate the conditions under which the innovation process can generate long waves.

REFERENCES

Bernanke, B.S. (1981) Bankruptcy, Liquidity and Recession, *American Economic Review (Papers and Proceedings)*, 71, 155-159.

Bernanke, B.S. (1983) Nonmonetary Effects of the Financial Crisis in the Propagation of the Great Depression, *American Economic Review*, 73, 257-276.

Chiang, A.C. (1974) *Fundamental Methods of Mathematical Economics*, McGraw-Hill Kogakusha.

Delbeke, J. (1981) Recent Long Wave Theories: A Critical Survey, *Futures*, 13, 246-257.

Delbeke, J. (1983) *The interdependence of real and monetary factors in a long wave perspective*, Postgraduate Workshop on Quantitative Economic History, Leuven and Vlaamse Economische Hogeschool, Brussels.

Dombrecht, M. (1979) *Financial markets, employment and prices in open economies*, Acco, Leuven.

Dupriez, L.H. (1947) *Des Mouvements Economiques Généraux*, Louvain.

Dupriez, L.H. (1959) *Philosophie des Conjonctures Economiques*, Louvain.

Fischer, I. (1933) The debt-deflation theory of great depressions, *Econometrica*, 2, 337-357.

Forrester, J.W. (1977) Growth Cycles, *De Economist*, 125, 544-575.

Freeman, C., J. Clark, and L. Soete. (1982) *Unemployment and Technical Innovation: A Study of Long Waves and Economic Development*, Frances Pinter, London.

Kleinknecht, A. (1979) Basisinnovationen und Wachstumsschübe: das Beispiel der westdeutschen Industrie, *Konjunkturpolitik*, nr. 5/6, 320-343.

Kondratiev, N.D. (1926) Die langen Wellen der Konjunktur, *Archiv für Sozialwissenschaft und Sozialpolitik*, 56, 573-609.

Mandel, E. (1980) *Long Waves of Capitalist Development*, Cambridge University Press.

Mensch, G. (1975) *Das technologische Patt*, Frankfurt a/Main.

Minsky, H.P. (1964) Longer Waves in Financial Relations: Financial Factors in the more severe Depressions, *American Economic Review*, 54, 324-335.

Minsky, H.P. (1975) *John Maynard Keynes*, New York.

Mishkin, F.S. (1978) The Household Balance Sheet and the Great Depression, *Journal of Economic History*, 38, 918-937.

Rosenberg, N., and Frischtak, C.R. (1983) Long Waves and Economic Growth: A Critical Appraisal, *American Economic Review (Papers and Proceedings)*, 73, 146-151.

Rostow, W.W. (1978) *The World Economy. History and Prospect*, Macmillan, London.

Schumpeter, J.A. (1939) *Business Cycles*, McGraw-Hill, New York.

Simiand, F. (1982) *Les Fluctuations économiques à longue durée et la crise mondiale*, Paris.

van Duijn, J.J. (1979) *De lange golf in de economie*, Assen.

van Duijn, J.J. (1983) *Long Waves and Saving Behavior*, Graduate School of Management, Delft, mimeo.

Verheirstraeten, A. (1977) *Geld, krediet en intrest in de Belgische financiële sector*, Acco, Leuven.

DISEQUILIBRIUM, INNOVATION, AND PERIODICITY IN ECONOMIC DEVELOPMENT*

Saiful Islam

There is, it seems to us,
At best, only a limited value
In the knowledge derived from experience.
The knowledge imposes a pattern, and falsifies,
For the pattern is new in every moment
And every moment is a new and shocking
Valuation of all we have been. We are only undeceived
of that which, deceiving, could no longer harm.

[T.S. Eliot in *East Coker*]

Disequilibrium is a precondition for the existence, orderliness and preservation of dissipative structures. Human societies are, among others, resource-converting systems. Human economic activity can also be described as a dissipative system that functions by utilizing information and by the transformation and exchange of resources, goods, and services.

The information content of a dissipative structure changes with time, so that such structures are inherently indeterministic. The information content of a system at one time is in general insufficient to predict the state of the system at later times (Poincaré, 1892). Industrial capitalism is relatively new. We are not involved with very large time scales in the study of the capitalist economies. Since our knowledge about the exact functioning of a system as complex as an economy is relatively meager, it would be unwarranted to predict the development of the capitalist economies very far in the future. Historical data, however encourage us to predict the short-run behavior of an economy. Careful analysis of such data might be useful in understanding the present state of the capitalist economies. But we have to keep in mind the warning of Schumpeter (1942): Analysis, whether economic or other, never yields more than a statement about the tendencies present in an observable pattern. And these never tell us what *will* happen to the pattern but only what *would* happen if they continued to act as they have been acting in the time interval covered by our observation and if no other factor intruded.

*This work was supported by the following Swedish organizations: the Council for Planning and Coordination of Research, the Commission for Energy Research and Development, and the Science Research Council.

Kondratiev (1926) first observed that from industrial revolution onwards, capitalist economies went full cycles in terms of prosperity, recession, depression, and recovery in about every 50 years. I have tabulated the Kondratiev cycles below:

Name of Cycle	Prosperity	Recession	Depression	Recovery
Textile	1787–1800	1801–13	1814–27	1928–42
Railway	1943–57	1858–69	1870–85	1886–97
Electricity/ chemical	1898–1911	1912–25	1926–39	1940–52
Control	1953–66	1967–79	1980–89	1990–2000
Information				

Table 1 The Kondratiev Cycles.

The last cycle has not yet started. The dates for different periods in different cycles may not be exact. It would be pedantic to enter into a debate on this issue. It merely helps us to see that there is some periodicity in the development of the capitalist economies.

I have named the cycles according to the main source of impulse of that cycle. The fourth cycle is the controls Kondratiev since in this cycle we produce better motor vehicles, better aircraft, computers, and spacecraft by learning to control rather complex systems. The fifth Kondratiev will definitely be a cycle of versatile automatic systems and biotechnology – a revolution in understanding the modes of information transfer and information processing in living and non living systems.

Capitalism, according to Schumpeter (1942), cannot be a stationary affair. From its very nature, capitalism is evolutionary. The main forces keeping capitalism in motion are the introduction of new consumer goods and the mass production of already existing goods. This requires advancement in technology – both embodied and disembodied.

Capitalists know that the markets will be cleared only in the short run. They always have to keep on guard to introduce new goods or utilize new production processes. Economic development is thus primarily a process of reallocation of resources between industries. This leads to structural changes and disequilibrium.

We know from thermodynamics that things happen only in disequilibrium. In major economic crises R&D activity increases and/or the firms apply already patented technology in production processes. The economy starts recovering. It is not a peculiarity pertaining only to the capitalist economies. All self-organizing systems operate in the cycle of becoming, growing, changing and decaying (Prigogine 1980).

When the demand rises in an economy working at full capacity, the firms react by increasing consumer prices, the proceeds of which are used to create new capacity. If the capacity of the economy was low to start with, it will grow with a mild inflation. On the other hand, if the economy is already working at near full capacity and if the markets are satiated to a large extent, in the absence of innovation, stagnation is the only viable outcome.

The reaction of the policy makers in the present stagnation was to reduce the liquidity, which in my opinion is wrong. If the liquidity is reduced, the firms react by increasing prices and producing less, thereby underutilizing capacity and increasing unemployment. Devaluation and trade restrictions will not solve the problem either. It will at best prolong the depression, at worst it would lead to armed conflicts. When the leaders of the depressed economies think that the only way out of stagnation is to invest in the armament industry, the tendency toward using force increases. Trade restrictions curtail the exchange of normal merchandise. For weapons there is always a market. It is for this reason that the nations should not indulge in trade restrictions. Trading in normal merchandise should continue even at the price of less national welfare in the short run, and in the meantime we have to innovate.

In a book of remarkable scholarship, Mensch (1975) convincingly argues that the encouragement of innovation is the best way out of stagnation. He classifies innovation in three categories:

(1) Basic Innovation

(2) Improvement Innovation

(3) Product Differentiation *(Scheininnovation)*

Basic innovations are those which open up a new field of activity and create new jobs for a number of people. Nontechnical basic innovation generates new cultural activity, new types of public administration, and novel social services.

Improvement innovation in the industrial sector brings new products into the market that are better in quality and reliability, inflict less damage on the environment, and need less raw material and human labor in their production. It remains a seller's market because the consumers want to buy qualitatively better products. But after that comes a stage when a product cannot be made better, at least not at a price acceptable to the normal consumers. This is a consequence of the large-scaie production processes, which they are difficult to modify. Most of the production processes are, at least in the short run, of the putty-clay type. The elasticity of substitution being very low (Hildenbrand 1981, Islam 1980), they have to operate with obsolete technology or continue to produce goods for which the demand has declined.

At this stage the producers indulge in an activity classified by Mensch as *Scheininnovation*. Something is packed better, given a shiny color. But this does not help. The seller's market has become a buyer's market. The market is saturated. When the industry was expanding it neglected research. Now it cannot break open into a new market.

In economic crises goverment should encourage R&D activities. These should not only be restricted to technical innovation. Tinbergen (1981) rightly points out that it is questionable whether only technical innovation can bring about large-scale economic recovery. We have to, among many other things, innovate in the finance sector, we have to innovate mechanisms that would reduce international and intranational disparities. Unequal distribution is a major source of armed conflicts among the nations and within a nation.

We need organizational and intellectual innovation that will enable us to avoid major economic crisis. Enhanced research activity is needed in many sectors. Let us take the example of climatology. Our knowledge about how the global climatic system will react to increased industrial activity is insufficient (Kandel 1981). The Mycenaean civilization is said to have been destroyed by erratic climate (Bryson *et al.* 1974). Homer in the *Iliad* described the Mycenaean decline as an act of the Olympian gods. Although the present destructive capacity of the superpowers (and smaller powers) will make the Olympian (and the Himalayan) gods blush, a vast amount of money and intellect is being spent to increase this destructive capacity. If resources were diverted from the military sector, we could at least hope for a better and safer future.

The best policies to follow are, in my opinion:

(1) To lower the trade barrier, so that purchasing power can be generated in the less developed countries. This will speed up the diffusion of modern technology.

(2) Biotechnology is going to be a major component of the next phase of development. Most of the biotechnology research is done to produce expensive pharmaceuticals. More resources must be allocated to the food and agricultural sector. Better agriculture will help the poor countries to save a considerable amount of foreign exchange needed to import technology. The problem of getting people out of poverty is not how to feed them. Poor countries need technology to produce their own food.

(3) It is true that different societies have different capabilities to gain from technological development but certain economic activities generate more inventiveness (technical and nontechnical) than others in a given society. The way to development is to identify and pursue economic activities that make people more inventive.

I have not filled up the row for the fifth Kondratiev in Table 1, anticipating that the present cycle is the last one. I hope that we will innovate mechanisms to avoid major disequilibria, which, of course, presupposes an equitable distribution of wealth and opportunities. Inequality makes the system not only inequitable but also inefficient. It is as true of intranational as of international distribution of income, wealth, and opportunity.

REFERENCES

Bryson, R.A., H.H. Lamb, and D.L. Donley (1974) *Antiquity*, 48, 46-50.

Hildenbrand, W. (1981) *Econometrica*, 49, 1095-1125.

Islam, S. (1980) *On the Connection Between Generalized Pareto Distribution and Cobb-Douglas Production Function*, Discussion Paper no.70, Economics Department, University of Bonn.

Kandel, R.S. (1981) *Nature*, 293, 634-636.

Kondratiev, N.D. (1926) *Archiv f. Sozialwiss. und Sozialpol.*, 56, 573-609.

Mensch, G. (1975) *Das Technologische Patt*, Umschau, Frankfurt am Main.

Poincaré, H. (1892) *Les Méthodes Nouvelles de la Mécanique Céleste*, Gauthier-Villars, Paris.

Prigogine, I. (1980) *From Being to Becoming*, Freeman, San Francisco.

Schumpeter, J.A. (1942) *Capitalism, Socialism and Democracy*, Harper, New York.

Tinbergen, J. (1981) *Futures*, 13, 258-263.

ON THEORY INTEGRATION: TOWARD ECONOMIES OF SCOPE

Gerhard O. Mensch

INTRODUCTION: WHERE DO WE STAND?

In March 1983, I had the pleasure of meeting with several of you either at the Long-Swing Conference in Paris (organized by the Maison de Science de l'Homme), or at the Growth Cycle Conference in Siena (organized by the Instituto di Economia). We should be grateful to IIASA for bringing both lines of theorizing together now, and again here in Siena. My delight in meeting with you here again is heightened by two facts.

First, the circle has become more representative by joining the representatives of the empirico-inductive majority with the representatives from the various logico-deductive quarters . Into the latter group I would count my collaborators, Gunter Haag and Herman Wold, and myself. Since I consider us logico-deductive types still to be a minority in the long-swing hypothesis research field, I am particularly looking forward to meeting here again with Richard Goodwin, the pioneer in the non linear multiplier—accelerator modeling field, who has inspired large numbers of students and textbook writers with his explanations of growth and stability as spurts of investment; and with Jay Forrester, whose system dynamics approach to capital formation still provides the most direct method for studying long swings from the phenomenological point of view. Of course, accelerated investment multiplier effects and cumulative capital formation processes are considered the core of dynamic economics by both Western and Eastern mainstream economists of neoclassical, Keynesian, Schumpeterian, and Marxian leanings. Therefore, I am especially grateful to IIASA for giving me an opportunity to meet with our colleagues from the Soviet Union. For us the Russian names of Kondratiev and Slutzky stand synonymous for both the unresolved question of whether long waves do really exist, or whether long waves are just a statistical illusion (a Slutzky Effect). Furthermore, it should be mentioned that those of us who work on mathematical theory of dynamic economics usually work with the classical Russian textbooks. They still represent the state of the art in the West. We are, of course, curious to learn from the disciples of our teachers.

A second very important fact is highlighted by our gathering here. In terms of mathematical sophistication and econometric modeling capability, this gathering represents a level of achievement comparable to the accomplishments of mathematical economists in Walrasian and non-Walrasian invisible colleges. In terms of practical significance, however, I would like to conclude that *we are now representing here a major section of the current research frontier in dynamic economics.*

REFLECTIONS ON THE MOVING RESEARCH FRONTIER

My point now is this. Over the last few years, several individuals and research groups in our field have taken an important emancipatory step by advancing from the purely descriptive to partly deductive reasoning. These researchers have designed and developed a family of partial models that formalize some important aspects of the dynamic economic process. In fact, there exist so many partial models at this time that I fear I would miss a few if I tried to list them now. In other words, our "long-term research" ("Kondratiev") field has recently progressed from a state of so-called *exploratory research* to the advanced state of *explanatory research*. In so advancing, our small field has become a core area of the much larger field of disequilibrium dynamics, which has become known in the economics profession as Schumpeterian economics.

I am thus saying that the research frontier in our field has recently taken a jump. For clarification, let me briefly state the criteria that separate the exploratory from the explanatory phase in a research agenda. Exploratory research usually means descriptive, historiographic, empirico-inductive (data-driven) work directed at formulations of tentative hypotheses and tentative assumptions. Explanatory research usually means analytical, econometric, logico-deductive (model-driven) work directed at mathematical hypothesis testing, and that is where the research frontier stands now.

Usually, the phase transition from the data-driven, exploratory research to the model-driven, explanatory research implies two concurrent emancipatory steps. At one end, the penetration of a new, largely extended intellectual territory usually generates accelerated returns to effort; and at the other end, the competition between alternative hypotheses, which often took the form of personalized rivalry between data-assisted points of view, gives way to a nonpersonal, formalized simultaneous testing of all model-assisted theories. I maintain that is where the action is now, and in future years.

In order to double-check the accuracy of this observation, I should like to invite you to look around in this room. Here we are in the good company of several authors of partial models that fit the criteria of advanced explanatory special theories. *Ergo*, as a group we undoubtedly have already entered the analytical phase, which consists of testing mathematically formalized hypotheses.

What will happen during the analytical phase? Judging from the experience of other theory groups, there will be a theory evolution from several specific theories toward a few more general theories. In this regard, again, it seems we are right on target. To see how, take a word from J. Niehans, our colleague from Berne, who recently detracted from the theoretical value of Schumpeter's vision by saying:

> "However, 'vision' is not enough. The essential step is to formalize it into an analytical model. This is what makes the idea communicable to others, a potential contribution to economic doctrine. *Schumpeter* was a tragic figure in the history of economic analysis because he was unable to transform his vision of innovation into an analytical model" (*Kyklos* 1983, p. 175).

Clearly, we are far away from having found a unified, *the* unified Schumpeterian analytical model. All we have is a family of partial models; but we also have some notions of their integrability into two or three distinctive clusters of matching theories that may be regarded as candidates for two or three somewhat more general theories, which—to be sure—in the end will be distinguished by differences in degree of generality, and by differences in degree of usefulness for specific purposes.

For example, long-wave theories with built-in gradualism of economic motion can be expected to yield a smaller spectrum of formalizable scenarios than can be expected from discontinuity theories with built-in possibilities of saltatism (jerky motions). An example of discontinuity theory is my Metamorphosis Model.

For another example, theoretical approaches and calculation techniques that allow for a deeper level of disaggregation will eventually out perform other models when the task consists in analyzing company-level or industry-level developments. Since my Metamorphosis Model is grounded in the notion of strategic investments of competing firms, it is able to perform analyses down to the business unit level of disaggregation.

Thus, it is safe to assume that our theory group will sooner or later undergo another phase transition. If the research frontier keeps moving, it will enter the instrumental phase. In fact, some of the available models may have already reached readiness for venturing into prescriptive activities, such as formulation of alternative scenarios, evaluating them numerically, and actually computing specific forecasts.

At the same time, we may safely assume that the research activities that tend to consolidate the explanatory basis of the whole field will greatly increase in importance. For example, model-based assessment of the validity and the explanatory power of alternative partial hypotheses will become a rewarding activity, whereas judgmental statements on the mere plausibility of special data-induced long-swing hypotheses will be found less frequently in the scholarly journals. By the same token, systematic model-driven data gathering will continue to yield higher returns to scope than what Koopmans calls "measurement without theory".

Summing up my reflections on the likely motions of the best-practice research frontier in our field during the years to come, I would like to stress *theory utility* as a separate issue of validity and reliability. My claim is that post-Schumpeterian microfoundations (incorporating entrepreneurial innovation, strategic investment, etc.) and post-Schumpeterian macrodynamics will prove very useful to business leaders and policy makers. Currently, there seem to exist only three such micro–macro models: the Swedish (IUI) model, the Nelson–Winter Model, and our Schumpeter Clock model (Mensch *et al.* 1984). Of course, these models still have to prove their value. Until that has happened, most mainstream economists would probably still agree with William Baumol's skepticism,

> "Neither Marx nor Schumpeter was a narrow specialist. Schumpeter has been described (by one who himself has grounds to claim the title) as 'perhaps the last of the great polymaths'—one of those giant intellects whose understanding and erudition permits them to roam widely among the many disciplines. History, sociology, political science, and other fields of knowledge all make their appearance in the works of both these writers.
>
> "But, perhaps to make room for this wealth of source materials, they had to pay a price. The dynamic systems of the Marxists and Schumpeter leave us with a sense of frustration because they are so vague and impressionistic. We are left feeling that their tale might just as easily have been given a different ending. Even if we were to accept their premises, we are under no obligation to go along with their conclusions!" (Baumol 1951, pp. 34-35).

Therefore, the quest for theory utility seems to mobilize forces that press for theory integration that increases predictive relevance.

REMARKS ON THEORY INTEGRATION

At this juncture, I would like to briefly address the issues of integrability of available special theories of long-term growth and development. In principle, integration may take place along the lines of greater explanatory power (generalizability), greater computational precision ("parameter accuracy", "predictive relevance"—Herman Wold), or better match to user needs. Of course, the benefits of integration would be greatly increased if it improve theory on two or all three of these dimensions.

I am happy to learn that Forrester considers our two theories as candidates for integration. I agree. For lack of specific experimental knowledge, though, I cannot now compare generalizability, precision, or ultimate utility of their respective individual or combined output. But the prospects are certainly worth exploring.

Likewise, I am unable now to indicate to you any perceptions I have on ultimate integrability and generalizability of other approaches in the field.

However, only in regard to my Metamorphosis Model, which is operationalized by the bi-equilibrium approach, can I venture a statement of integrability and generalizability. As I perceive it, it is already part and parcel of mainstream economic theory.

As I have explained in my bi-equilibrium paper (Mensch 1981), I consider my theory a constructive specification of a general theory of change. My theory of *disaggregate discontinuous disequilibrium dynamics* (4-D theory) I regard as an extension of the formal theory known as (non-Walrasian) General Equilibrium Dynamics (GED); all it takes to integrate my work into the neoclassical framework is to remove the Inada condition of uniqueness.

The extension of GED then is straightforward. Since GED permits the situation where both the equilibrium condition and the stability condition are violated (structural instability), many economic motions then become admissible. Based on years of experience with innovating and planning companies, I postulate that industrial companies' investment behavior is bifocal. Consequently, in the aggregate, the Postulate of Bifocal Investment Behavior leads to a bounded nonequilibrium motion of the whole economic system, such that the following bistability holds:

(i) the economy is always out of equilibrium; there exist two equilibria, so the economy is always out of one, and moves relative to both;

(ii) the economy moves in both an equilibrating and a disequilibrating fashion almost all the time, usually approaching one while moving away from the other.

This nonequilibrium motion can be approximated with the bi-equilibrium model, which perceives of the economic system as shifting back and forth from one equilibrium pole to the other. The shifts from one equilibrium pole to the other may occur gradually, and steadily, as in the long-wave analogy, or they may occur discontinuously (seldom, but then suddenly), as in my Metamorphosis Model.

Incidentally, Schumpeter's Process of Creative Destruction (PCD) can now be seen as a special case of extended GED. In terms of qualitative change,

(i) the flow of creative and destructive effects is (nearly) always imbalanced,

(ii) economic activities are nearly always both creative and destructive at the same time,

and the imbalance in simultaneous creative and destructive changes may shift gradually or suddenly.

Likewise, Forrester's capital good –consumption good –capital transfer model seems to me a constructive specification of the two-sector model of Uzawa (1962, 1963), from which the Inada condition of uniqueness has been dropped, with the result that capital productivity and capital intensity move over time as discussed by Solow (1963).

I feel that the bi-equilibrium approximation represents the observable facts sufficiently well. In the accompanying bi-equilibrium paper, in which theoretical estimates of US industry data for 1900–34 are compared with observations, an r^2 value greater than 0.75 attests to a satisfactorily high explanatory power of the Postulate of Bifocal Investment Behavior. Therefore, I am seeing many of our special theories already embedded in mainstream economics.

Therefore, I have selected as a concluding remark a quote from Philip H. Wicksteed. Wicksteed, like me, wants "...to convince professed students of Political Economy that any special or unusual features in the system thus constructed are not to be regarded as daring innovations or as heresies, but are already strictly involved, and often explicitly recognized, in the best economic thought and teaching of recent years." (Wicksteed 1967, p. 2).

CONCLUSIONS

As a postscript, I should like to add to the above disclaimer of originality another humbling thought. When eight months ago, in Siena, Richard Goodwin and I reflected upon the short reach of even the best known of our economic theories, he offered a simple and direct reason: "We do not have what natural scientists have, reliable constants to work with."

REFERENCES

Baumol, W. (1951) Economic Dynamics. Princeton University Press, New Jersey.

Mensch, G. (1981) A Bi-Equilibrium Model of Bi-Vlued Technical Progress Embodied in Innovative Industrial Investments in US Industry Between 1900 and 1934. Working Paper No. 53.

Mensch, G., G. Haag, and W. Weidlich. (1985) The Schumpter Clock. Ballinger, Cambridge, Massachusetts. (forthcoming).

Solow, R.M. (1964) Capital Theory and the Rate of Return. New York: Random House.

Uzawa, H. (1962) On a Two-Sector Model of Economic Growth. Review of Economic Studies, 29:40-47.

Uzawa, H. (1963) On a Two-Sector Model of Economic Growth II. Review of Economic Studies, 30:105-118.

Wicksteed, W. (1967) The Common Sense of Political Economy. Kelley, New York.

ON LONG WAVES IN THE ECONOMY

S. Menshikov and L. Klimenko

1. THE SUBJECT OF STUDY

The recent spread of long-wave theories is no doubt due to the incidence in the 1970s and 1980s of deeper recessions, slower growth of productivity, and overall stagnation in growth rates of the capitalist economies. However, long-wave theories should not be used to explain all major phenomena in the current economic situation, which is rather a combination of cyclical (periodic) processes and long-term structural, but not necessarily repetitive, crises.

Thus the energy crisis, which symbolizes the termination of the era of cheap energy, has no precedent in the 1920s and 1930s (the time of the previous long depression). It is also a powerful manifestation of the crisis of the old international economic order, which belongs only to our times.

Another prominent feature of the current long depression—"stagflation"—is not simply a repetition or modification of previous inflations. The upward price inertia based in the oligopolistic structure of the economy is clearly a modern feature. The new mechanism, which makes recession and inflation appear simultaneously, and feed upon each other, is also completely new.

If one wants to lump together all structural phenomena, then it is useful to treat them as a totality of features and processes characteristic of the current stage of the general crisis of capitalism, as a socio economic system.

However, it is possible and necessary to distinguish symptoms of long-term periodicity among current economic phenomena. These relate primarily to oscillations in overall growth rates of economic output and in technical progress.

This paper concentrates on long fluctuations in *material production*. In attempting to identify long waves it takes up such aggregate indicators as gross domestic product (GDP) or industrial production (IP) where national accounts statistics are not available. In attempting to single out an *endogenous* mechanism of long-term fluctuations in material production it also turns to indicators explaining the behavior of GDP or IP, namely investment, fixed capital stock, the capital—output ratio, labor productivity, profit and profitability. Indicators of distribution and circulation, such as trade, prices, interest, money stock, etc., are left out intentionally. Granted that all these processes are important, 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 such fluctuations in which the downward movement periodically leads to crises, i.e.

absolute contractions of material production for not less than half a year (in monthly or quarterly series) and 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 AND THE CURRENT LONG RECESSION

Do long waves of 50 years' duration really exist? There is no unanimity in the literature either on empirical evidence of their existence, or on their underlying theory (van Duijn 1983, Forrester 1981, Freeman *et al.* 1982, Kuczynski 1980, Mensch 1979, Rostow 1980). Neither are we aware of convincing arguments for their theoretical impossibility.

As mentioned above, the contemporary discussion of the subject has been revived by the crises of 1973–75 and 1980–82, as well as by the pronounced slowdown of economic growth in the 1970s and early 1980s. If, in the history of the cycle, one singles out crises that are deeper or longer than their neighbors, then, it is claimed, they are the crises of 1872–75, 1929–33, and the two latest cases. 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 USA was weaker than both 1892–94 and 1907–8; in addition it occurred on the crest of a long upswing rather 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 identification 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 (J. 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 longer 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 various kinds. However, in some cases–namely, when the dispersion of long fluctuations is smaller than or approximately equal to the dispersion 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 that 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 all 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 USA (1889–1982), IP series for the USA (1864–1982), the FRG (1860–1982), and Japan (1900–1982); and 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 up-crosses, 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' duration) are clearly discernible around an astonishingly stable secular exponential trend of the first degree. A periodicity close to 50 years is very weak in this case and is manifested in deviations from super-long waves. It was identified by using both high- and low-frequency filters.

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 USA, the FRG, and Japan). Here we clearly observe in the *manufactory* (prefactory) *period* (1700–1780) a major dependence of super-long waves on growth rates of the population, but later on the successive phases of the *Great Industrial Revolution*. The upswing in industrial output of consumer goods started in 1780 and continued until 1860 (80 years), and in the output of producers goods it lasted from 1818 to 1883 (65 years). 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 USA, the FRG, and Japan the upswings of the 50-year wave are clearly associated with the ***massive spread 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 in these countries: the age of railroads and steel (in the USA also of petroleum): 1870–1910 in the USA, 1870–1913 in Germany, 1900–1919 in Japan; the age of chemistry, electronics, aviation, and in the FRG and Japan also of the automobile and petroleum: 1935–1970 in the USA, 1950–1973 in the FRG, 1955–1975 in Japan.

As to the "great crises", they may have reflected the superposition of three shorter waves and of the downswing in the long wave. But, obviously, other factors have played a major role, including socioeconomic 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 intervention caused by stagflation and the growth of transnational corporations, and the underlying necessity of a transition to international coordinated economic policies.

Such transformations cannot be explained only on the basis of long waves in economic life. They are associated rather with consecutive stages and substages in the evolution of the capitalist system, and these stages do not neatly coincide with long waves.

However, it remains true that any long recession accelerates a search for new forms of capitalist organization, methods of management, forms of relations with the working class, etc. Crises in general serve as accelerators of socioeconomic change.

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 socioeconomic reasons – or whether we are in fact observing a transition to a slower secular growth trend, cannot be determined without additional qualitative analysis.

A large array of factors – economic, social, and political – act as determinants in this case. The current period of long recession is characterized by increased activity on the part of right-wing and conservative forces. The crisis of government economic intervention and of the welfare state has created widespread disillusionment in reformist policies. Mass unemployment and conservative economic policies have helped weaken trade unions. In a number of countries militarism is on the rise. The question of how to overcome the long depression is acute, and the suggested approaches are drastically different.

The ***conservative*** approach, exemplified by Reaganism and Thatcherism, ignores the very existence of the long crisis and puts an accent on higher military expenditure, and lower social appropriations, stimulating capital investment by tax privileges for big business and the wealthier families. In practice this policy calls for sitting out the crisis, for leaving the mechanism of the long recession to work its own way. It also means avoiding social upheaval by a new rearmament drive and more international tension. It is a dangerous policy, and will certainly delay the oncoming of a new technical revolution.

The *reformist* approach recognizes the existence of the crisis, but does not necessarily consider it long-term and structural. It calls for a return to Keynesian recipes (in combination with other theoretical approaches) and coordination of national economic policies. But it is hardly implemented anywhere and in any way, and in a number of countries has been sabotaged by right-wing forces. International economic coordination does not work, since the conservatives refuse to follow this line.

The *progressive* approach calls for efforts to overcome the structural, long-term, and not simply the cyclical crisis. It suggests stimulating technical progress, however not of any kind, but of large-scale new directions, which could lead the economy on to the road to a new technical revolution. It puts an accent on measures to support investment in creating new employment, new jobs. It advocates reallocation of resources from armaments to research and development in major civilian needs, to the solution of global problems, such as energy, environment, and reducing the gap between developing and developed countries. It also shows the necessity of social and institutional reforms, diminishing the influence of the military-industrial complex and transnational corporations, and the spread of democratic methods of managing the economy.

Each of these approaches means absolutely different directions of socio-economic change. The choice of the direction will deeply affect the outcome of the current long depression.

3. A THEORY OF LONG WAVES

Long-term fluctuations of material production should have a material prime cause, 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 producers' durable equipment;
- for the "construction wave" (18—20 years)—fluctuations of fixed capital in producers' structures.

The common feature in all three is that waves of different duration are associated with the different durations 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.

Capitalist 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"—such as the labor force, as well as constant capital. Therein lies the material foundation of *periodic economic crises* under capitalism.

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

Long waves (of 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.*

Technical progress is not associated exclusively with the long wave, but has a lot to do with the shorter economic cycles as well.

One should distinguish between changes in *generations* of technology based on the same basic discovery (with an average length of 10 years), and the change in *directions* of technology. The latter are implementations of basic discoveries and, when lumped together in a space of a few decades, are tantamount to technical revolutions on a macroeconomic scale (an average length of these in the current century is about 50 years). One change in direction of technology embraces a few (5 or 6) shorter changes in generations of technology.

In the course of the major economic cycle with the change of fixed capital there occurs, as a rule, a change from one generation of technology to another in at least a number of important, leading industries. However, from time to time a qualitatively new technology is introduced, new products appear, and new industries are born. At first, i.e. in their first generation, their expansion is slow, but later on it quickly gains speed. In this period, which may take 2 or 3 major cycles, labor productivity rises faster than capital intensity, therefore the capital—output ratio falls and the average rate of profit increases. This lays the foundation for a long-term upturn interrupted by relatively weak business recessions. In the course of the long upturn there is a general transformation of the economy to a new technological base, new kinds of output, and a new interindustry structure.

However, after a few generations of the new technology have been introduced, further changes and improvements of the same basic discovery begin to bear diminishing economic returns. The rise in productivity lags behind capital intensity, the capital—output ratio increases and the average profit rate falls. The aggregate growth of the economy decelerates, and the period of the long recession starts. The regular business crises become longer and deeper.

Some authors have had difficulty in finding an endogenous explanation of the lower turning point of the long wave. But in fact this is not a great mystery. The continuous long-term fall of the average profit rate causes a speed-up in the development of new basic technological *directions*. The lower the rate of profit from the old technology the less risk there is in introducing basic innovations. The first to be implemented are those which lead to *cost saving*, more often labor cost saving but also energy and materials saving. This happens in the course of the long downturns. For example, the conveyor belt was first widely introduced in the 1920s and 1930s: robots and energy-saving equipment have spread in the late 1970s and early 1980s.

New cost-saving technological directions, as such, do not generate a new long upturn. For a while they even help escalate unemployment and dampen effective aggregate demand. But step by step old fixed capital is written off, old technologies are rejected, stagnant wages and other cost savings help turn the tide in profit rates. Once these start rising, the signal is given for implementing other new technologies, not necessarily cost saving, as such, but associated with new products and the creation of new industries. Then comes the time for a new long upturn.

At the macroeconomic level technical revolutions are evidenced by large oscillations in growth rates of fixed capital, investment, labor and capital productivity, the capital—output ratio, and the rate of profit. Underlying these fluctuations is the uneven rate and change in direction of technical progress, as it applies to production.

A theoretical explanation of these processes has been given by Marx in *Das Kapital* and *Theories of Surplus Value* (Marx 1960–1963), though 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. Given a constant amount of surplus value the profit rate would tend to fall in the long run, since the value of constant capital would increase in relation to the wage bill. However, Marx identified a number of counteracting factors, such as an increase in the rate of surplus value and, most importantly, the economy on costs of constant capital. These factors may bring about long periods when the profit rate is stable or even rises. In fact, Marx identified two such periods in England: 1797–1813 and from the mid-1830s to the mid-1860s.

Thus, for all practical purposes, Marx laid a theoretical foundation for understanding long-term perodicity in economic behavior under capitalism.

4. SOME STATISTICAL EVIDENCE: LEADING AND LAGGING INDICATORS

Let us look at statistical evidence related to the oscillatory nature of technical progress in the capitalist economy. US time series (in real terms), 1890–1982, have been collected (Kendrick 1961, Kuznets 1961, Historical Statistics of the United States 1975, Economic Report 1983) for gross private domestic product, man-hours worked in the private economy, gross stock of fixed capital (excluding residential structures), and compensation of employees in the private economy. These have been transformed into series of labor productivity, capital intensity (the capital–labor ratio), the output–capital ratio, the profit rate (the profit–capital ratio), the share of profits in domestic product, and the profit–labor ratio. All series have been smoothed by 9-year moving averages. They are plotted in Figures 1–5 against their respective log–linear trends, while in Figures 6–10 they are shown as deviations from these trends.

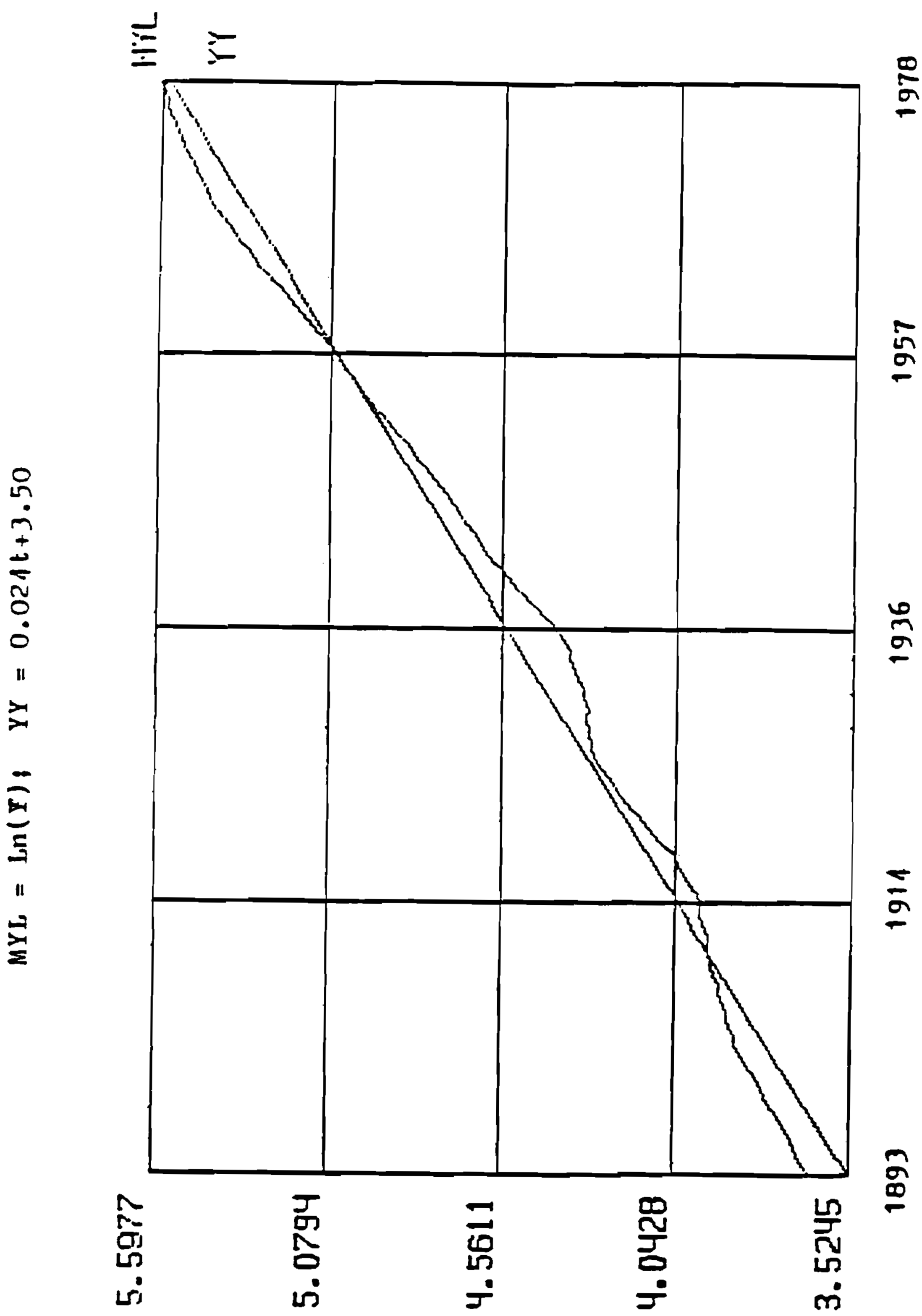

Figure 1 Labor productivity (actual and trend).

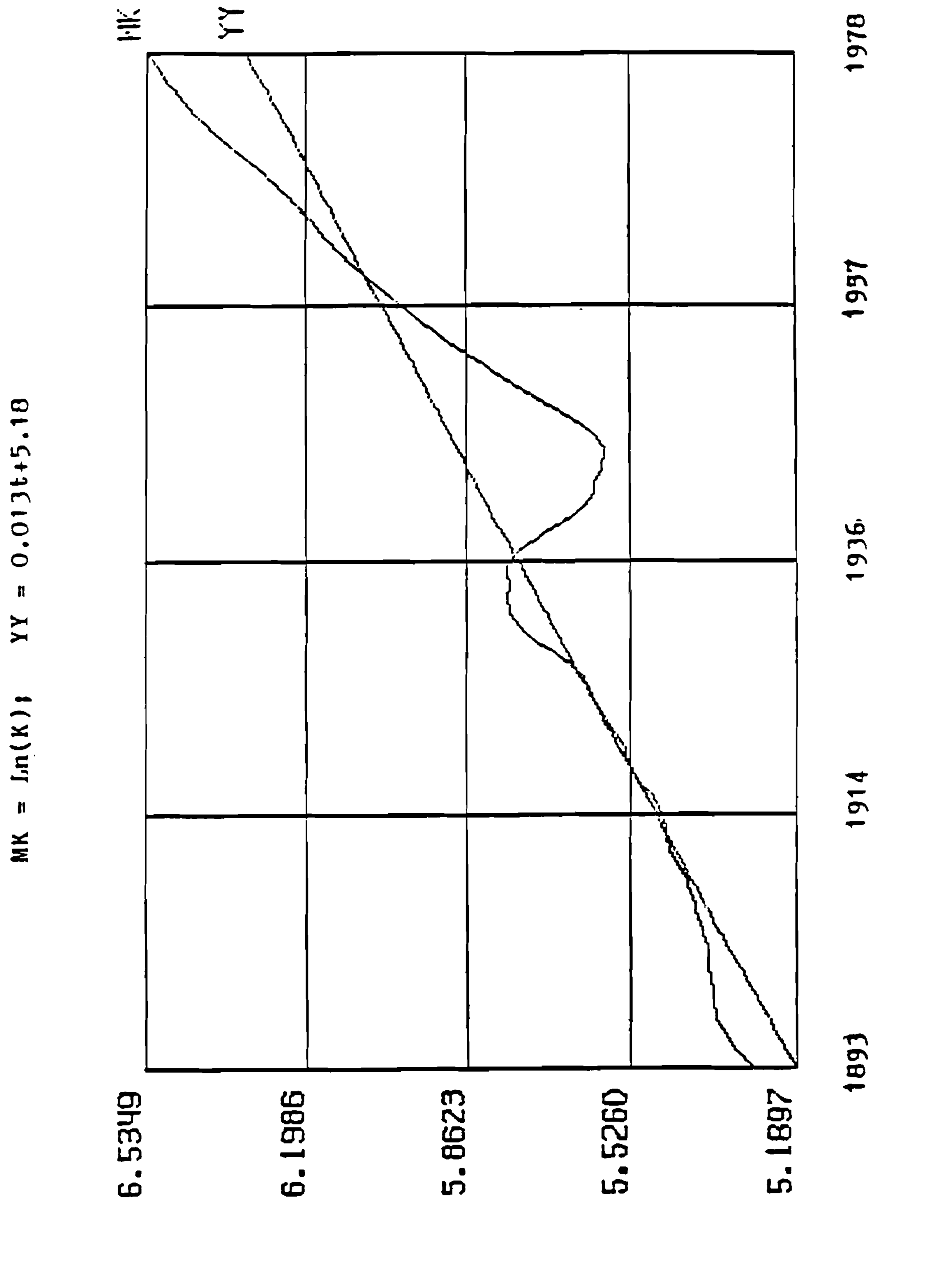

Figure 2 Capital intensity (actual and trend).

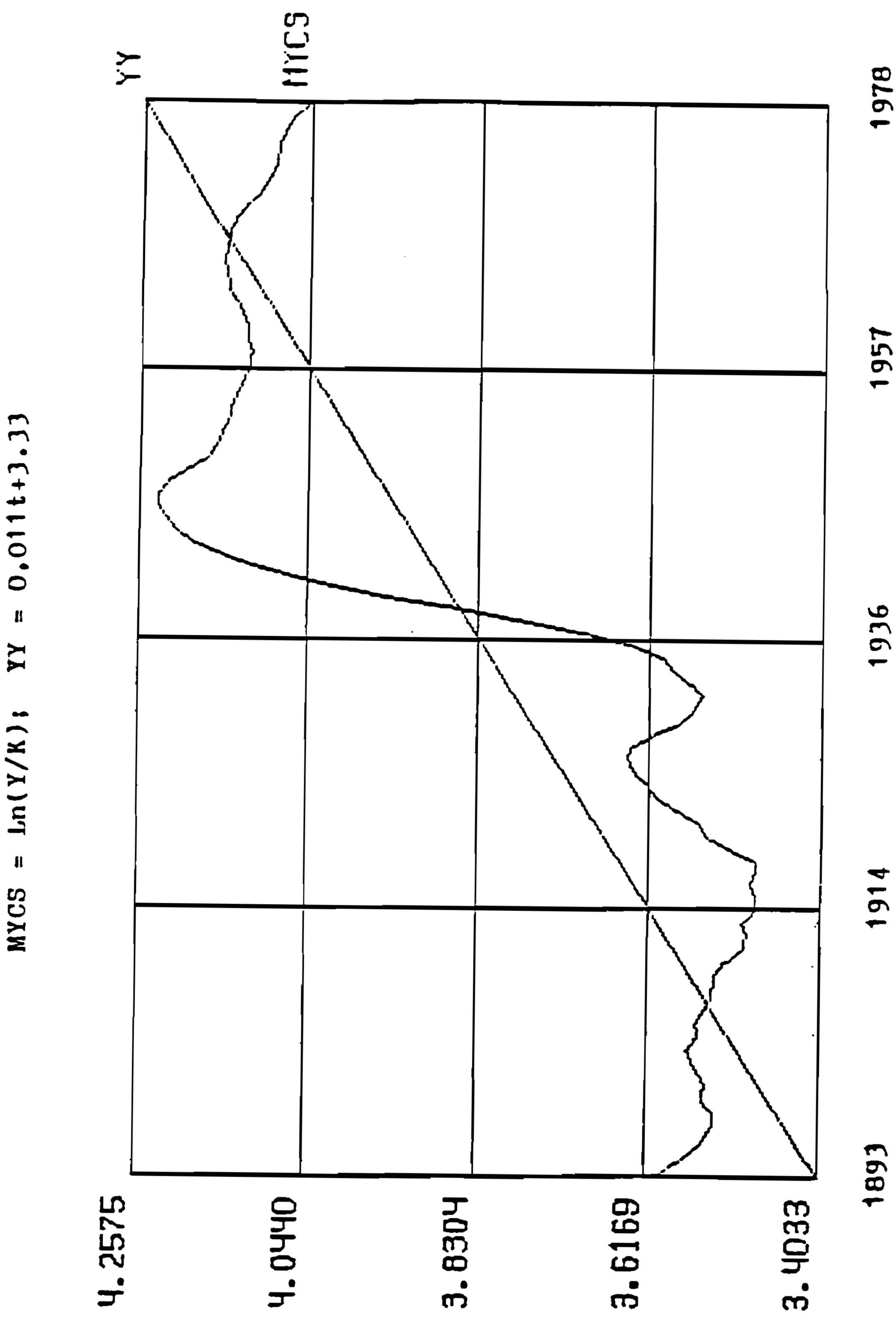

Figure 3 Output—capital ratio (actual and trend).

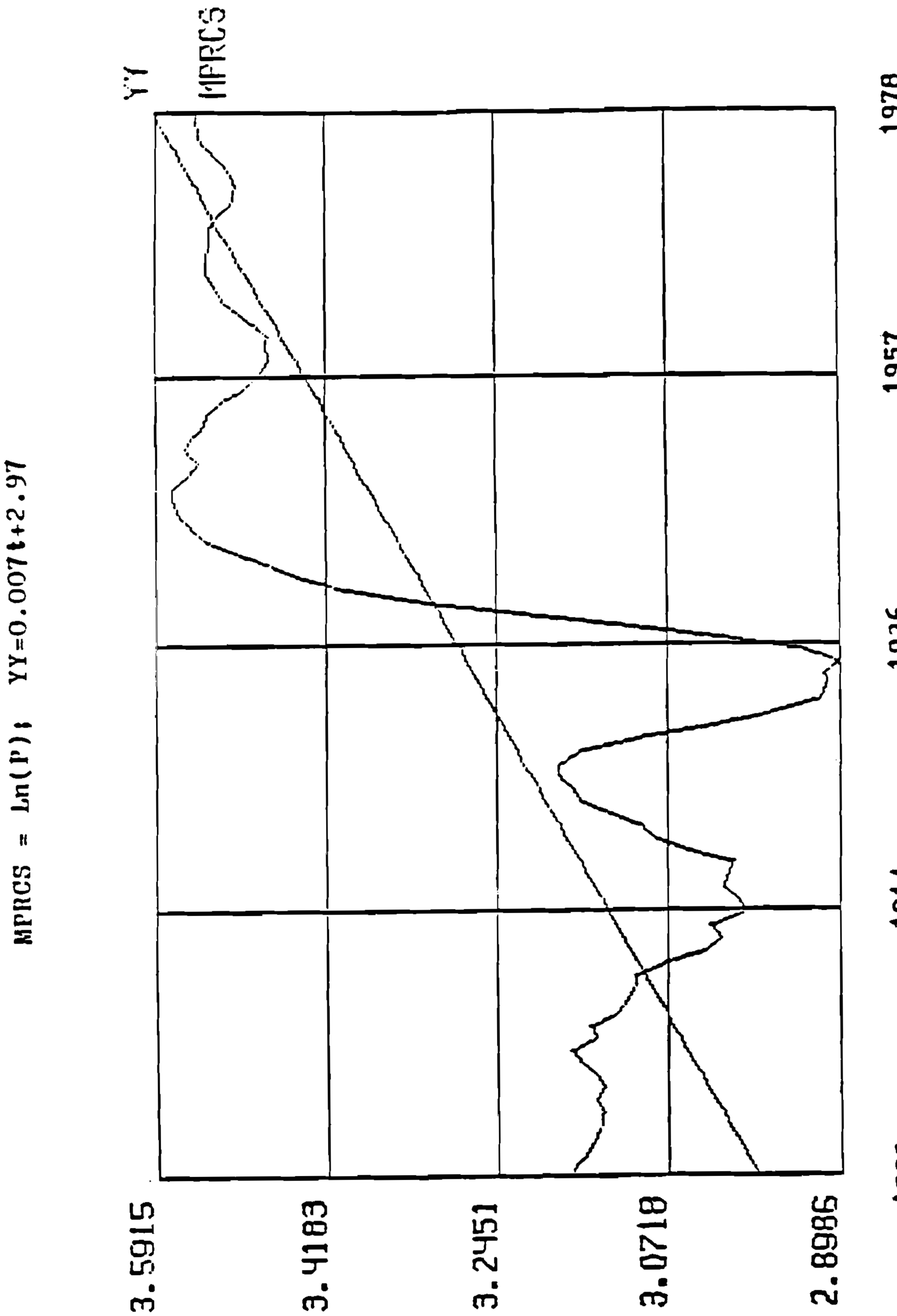

Figure 4 Rate of profit (actual and trend).

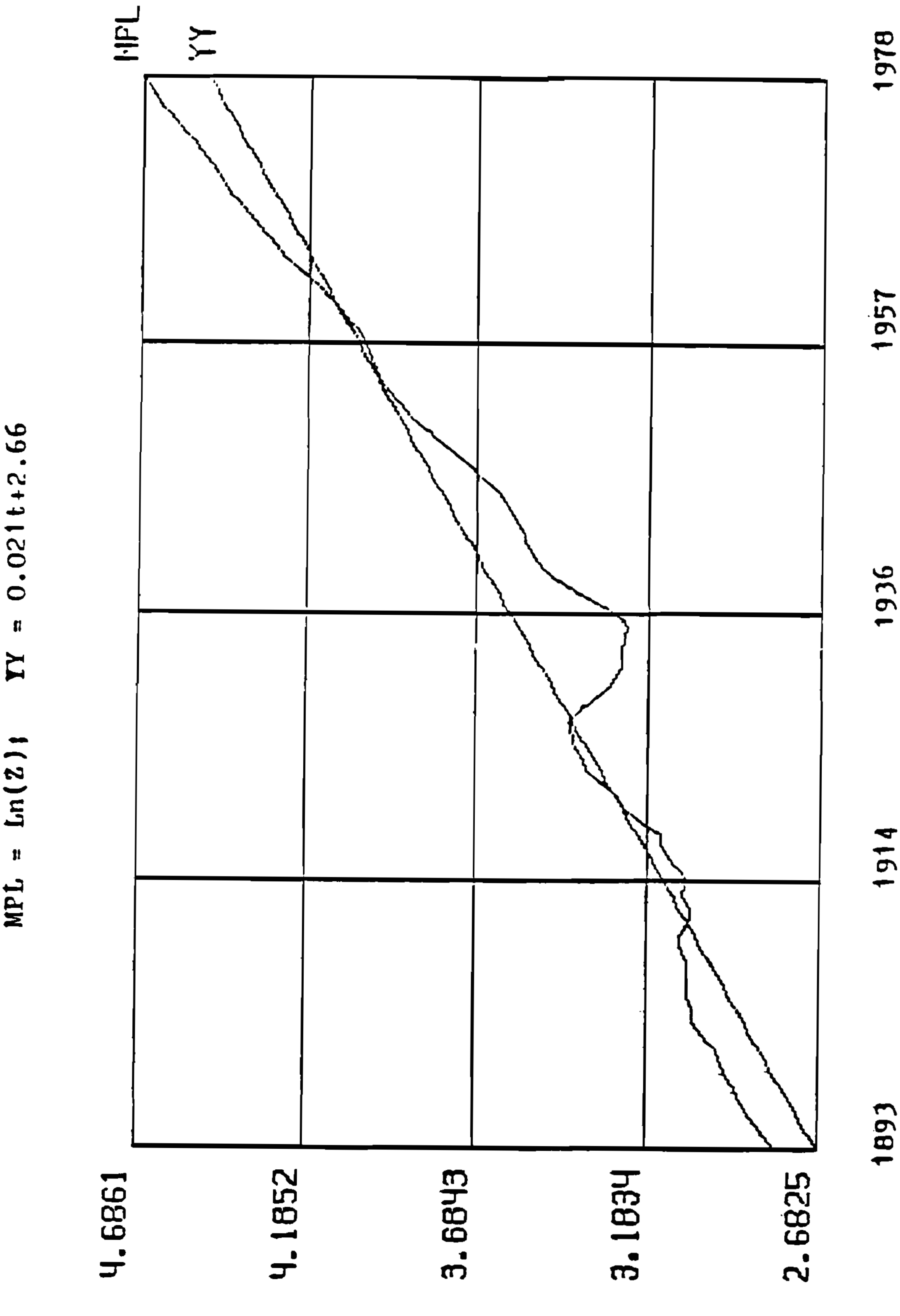

Figure 5 Profit per man-hour (actual and trend).

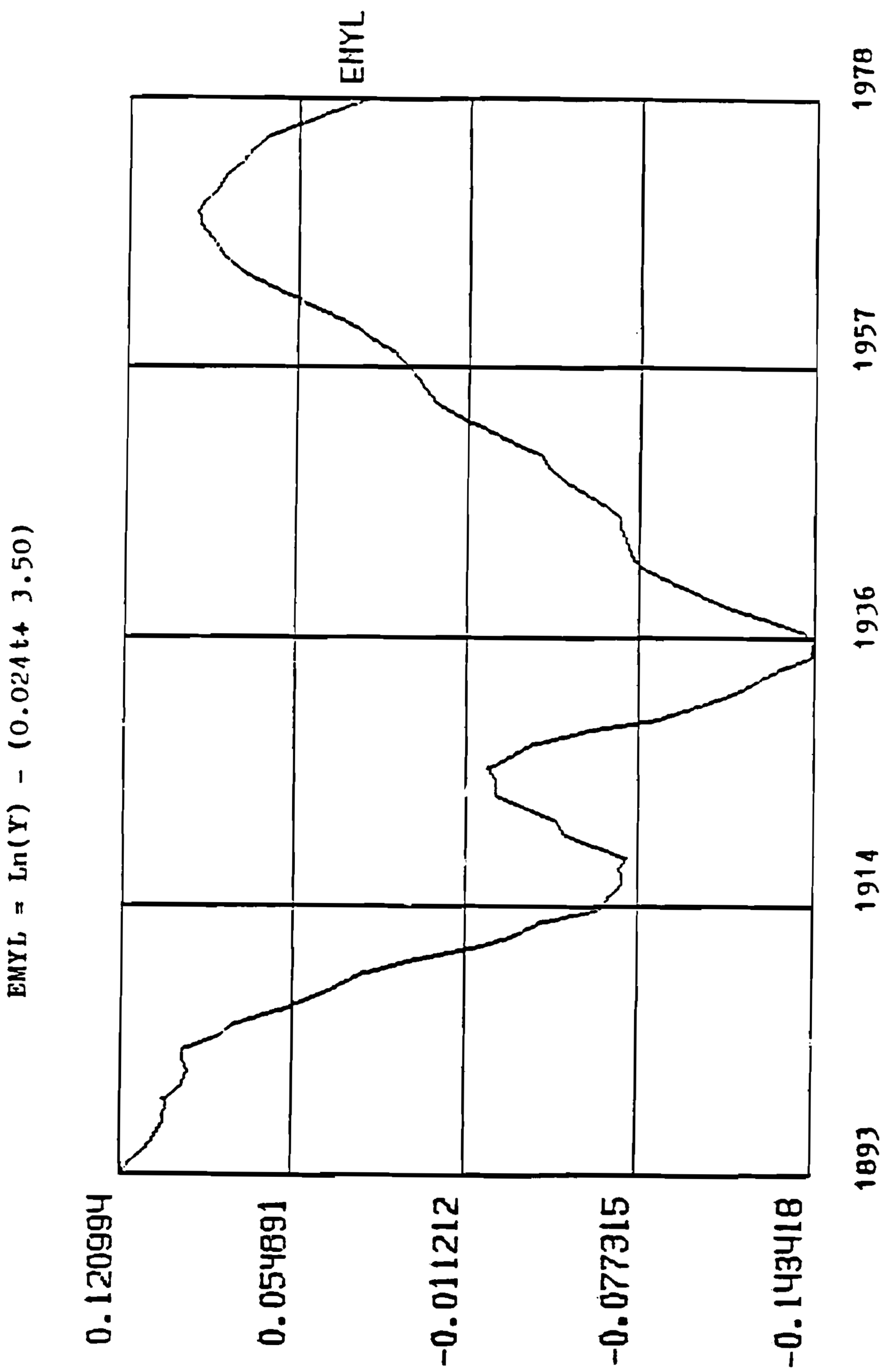

Figure 6 Labor productivity (deviation from trend).

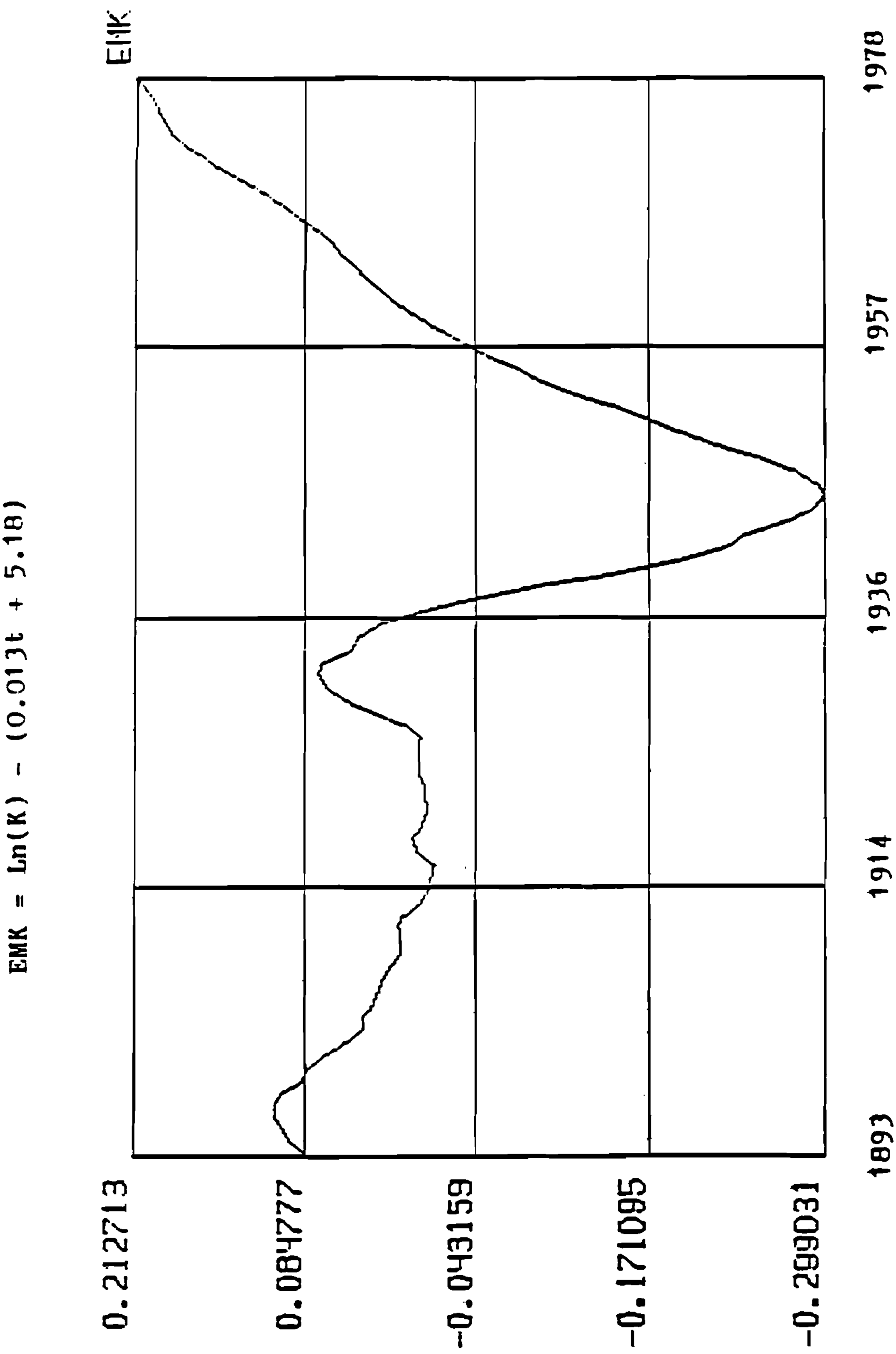

Figure 7 Capital intensity (deviation from trend).

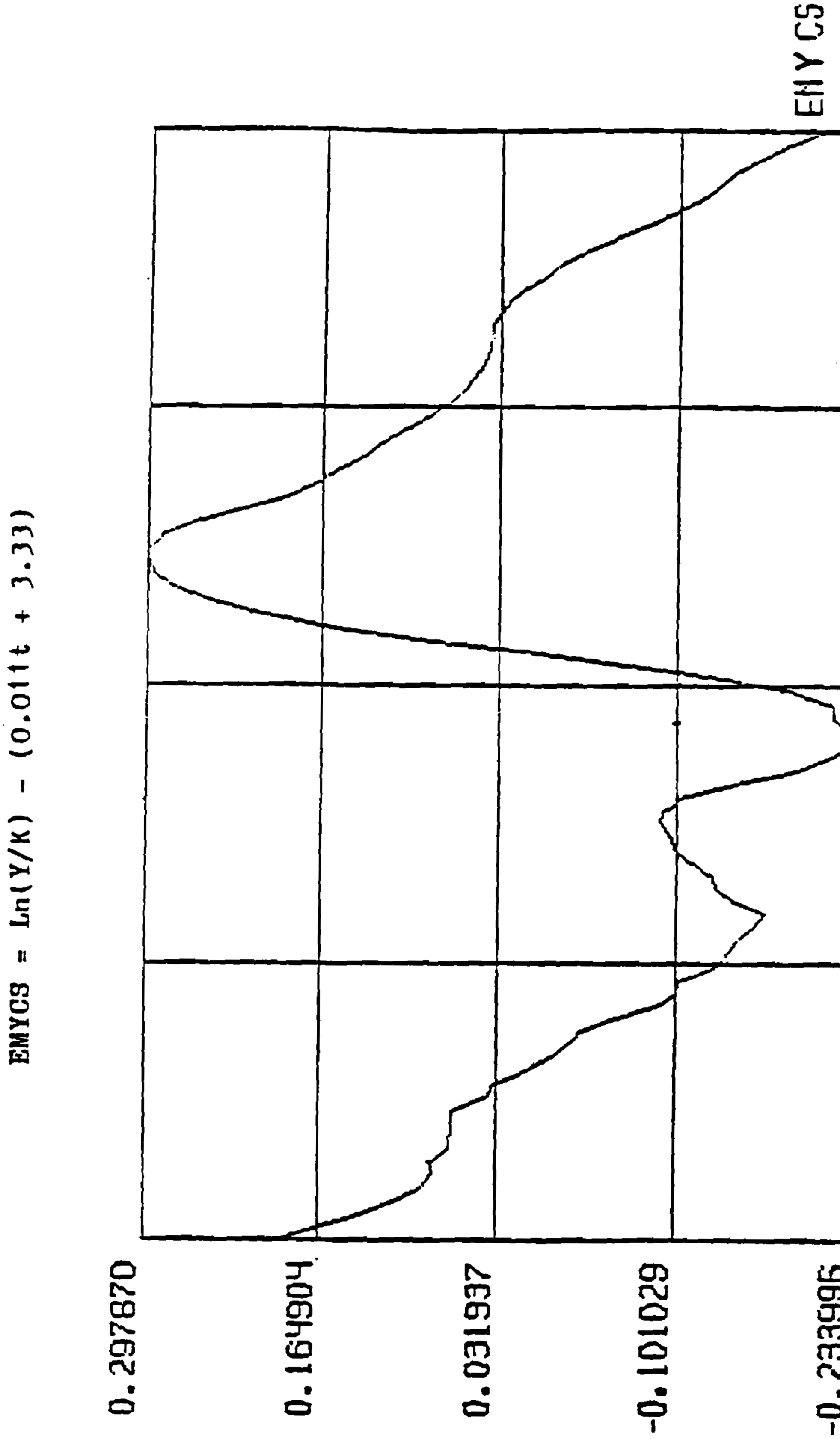

Figure 8 Output–capital ratio (deviation from trend).

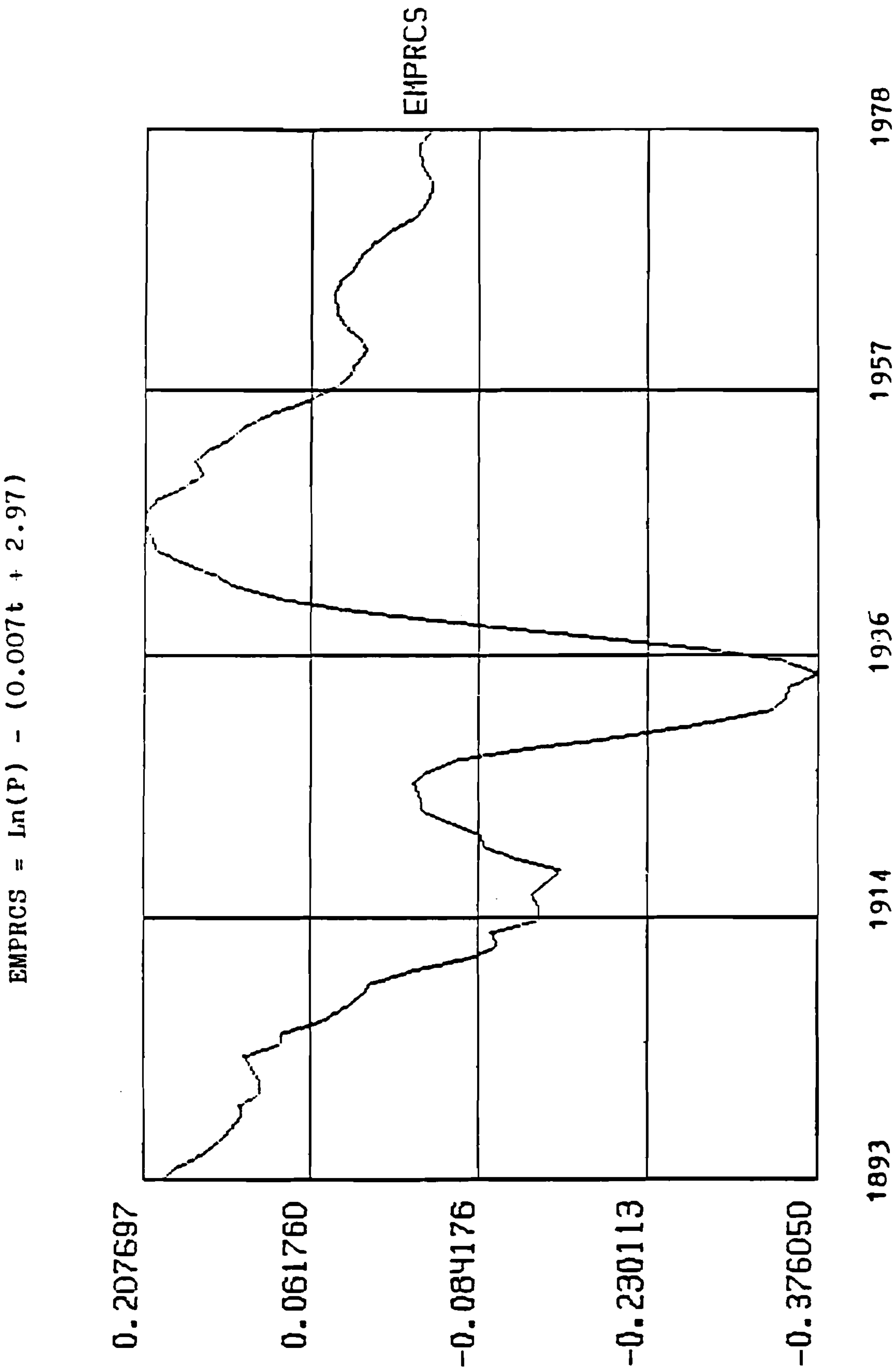

Figure 9 Rate of profit (deviation from trend).

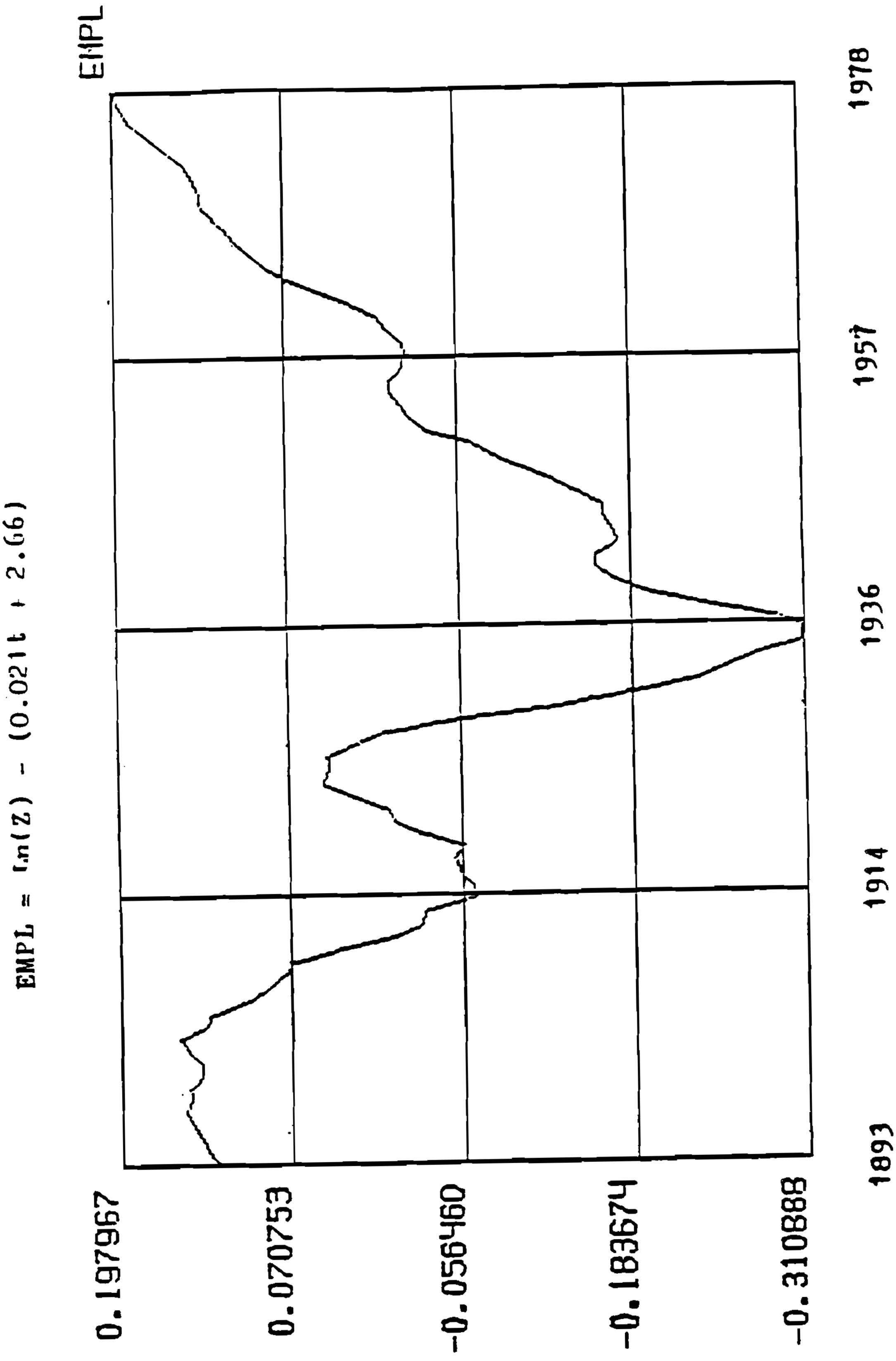

Figure 10 Profit per man-hour (deviation from trend).

The long wave is evident in all series, but particularly in those directly related to labor productivity and the output–capital ratio.

For purposes of comparing the various series we shall distinguish the following four consecutive phases in the long wave.

(1) *upturn:* from the time when the deviation upcrosses the trend to the time when it reaches its peak;

(2) *downturn:* from the peak to the downcross;

(3) *depression:* from the downcross to the trough;

(4) *recovery:* from the trough to the upcross.

The reader should be reminded that since there is a distinct upward secular trend in most indicators, the downturns and depressions of the long wave do not necessarily signify absolute decreases, but rather, as a rule (though with some notable exceptions), decelerations of growth. However, when deviations from trends are considered, then one can rightfully talk about downturns and decreases. In the following analysis we use these terms in their latter sense.

The two underlying indicators are labor productivity and capital intensity.

Labor productivity (deviation from trend) was falling at the starting point of observation (1893). With variations, including a short-lived "hump" in the 1920s, it continued to fall until 1933. The downcross occurred around 1910, a full 23 years before the trough was reached. It started rising in 1935, passed the upcross in 1953, and reached a peak in 1970. The new downturn did not hit the downcross within the period under observation (ending 1978).

Capital intensity was rising until 1898, and then started a very long fall, interrupted by relative stability in 1914–25 and a short increase in 1926–30. The secular trend line was reached as early as 1914, but a definite downcross occurred no earlier than 1936. Capital intensity continued to fall until 1946, long after the depression of the 1920s was over. Thereafter there was a continuous increase uninterrupted at the end of the period.

A direct comparison of the two indicators shows that labor productivity was apparently leading. The lead time at the trough was no less than 14 years, and it may have been as long at the peaks. A combination of both yields another important indicator – the output–capital ratio (or capital productivity).

Capital productivity followed labor productivity in the long fall from 1893 to the end of the 1920s, but thereafter tended to go with capital intensity. It reached a trough in 1929 (only a few years before labor productivity), but a new peak occurred as soon as 1946, a full 24 years in advance. The downcross wad reached in 1967, and at the end of the observed period (1978) the deviation of the output–capital ratio was close to its previous trough.

In the long upswing there were definitely two different periods. In the first, labor productivity was on the increase, while capital intensity continued to fall. This was also the time of the rapid rise in capital productivity. In the second period labor productivity was still on the rise but capital intensity was increasing even faster, bringing down capital productivity.

In the long downturn the fall in labor productivity was more pronounced than that in capital intensity, so that capital productivity declined. However, within the long depression phase a period could be observed when changes in labor productivity were fairly close to changes in capital intensity, so that capital productivity was relatively stable and even showed a tendency to grow. This is clearly seen in the chart for absolute values of the output–capital ratio, which even in the 1930s was higher than in the 1910s.

The chart also demonstrates the peculiar movement of capital productivity, which tended to make small gains in the depression phase, sharp gains in the recovery, and then to slowly slide downwards towards a new depression. To what extent this is true of other countries or of the USA before 1890 remains to be explored.

The movement of the output–capital ratio is translated into the movement of the average profit rate after adjusting for the share of profits in gross domestic product. We are considering gross profit (rather than corporate profit), which includes all non-wage and non-salary factor incomes in the economy, as well as depreciation of fixed capital. The gross profit rate tends to follow the output–capital ratio with a short lag of 1–4 years. The difference is caused by the fact that long-term turning points in profit occur somewhat later than in gross product. Compare, for example, the movement of labor productivity and profit per man-hour. The latter continued to rise while the former was already falling in both long downswings observed in the charts.

A turn in capital productivity and the profit rate tends to take place long before serious changes occur in the overall growth rate of the economy. In 1898–1907 gross product was in its upward phase, while capital productivity was already falling. The downward phase in gross product (1907–1928) started only after capital productivity passed its downcross. In 1928–1935 gross product was in depression, whereas the output-capital ratio was showing signs of recovery. The recovery in output (1935–1946) coincided with a sharp upturn in capital productivity. The upturn in the economy (1946–1969) went ahead, while the output-capital ratio resumd its downward slide. And, finally, the new downturn in output (since 1969) came on the heels of a depression on capital productivity (since 1967).

On the basis of this experience one would expect a new recovery in growth rates of the economy at large to occur only after a preceding recovery in the output–capital ratio. This, then, is the principal indicator to watch in the coming years.

5. A MODEL OF THE LONG WAVE

Causal relationships between variables described in the preceding section can be expressed by the following generalized model:

$$\dot{y} = -a(y - bk) \quad (1)$$

$$\dot{k} = -c(k - dp - \bar{k}) \quad (2)$$

$$p = z - k \quad (3)$$

$$\dot{z} = -e(z - fy) \quad (4)$$

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;

$\dot{y}$, $\dot{k}$, $\dot{z}$ = changes in the growth rates of y, k, z;

a, c, e = speeds of reaction, or adjustment;

b, d, f = coefficients.

Growth rates rather than absolute values are used in the model mainly for substantive reasons. All variables show secular growth over the observed period. Equations describe deviations from long-term dynamic stability conditions. The model thus combines growth and fluctuations. When expressed in terms of growth rates it is reduced to a linear differential system, which is easier to analyze theoretically. It is obvious that definition (3) holds for small rates of growth.

Equation (1) is derived from the general production function with embodied technological progress. The capital-to-product elasticity of this function is normally smaller than unity. This contradicts actual performance, where labor productivity may rise faster than capital intensity both in secular trends and in the upward phases of the long wave. Equation (1) allows for both possibilities if coefficient b is not substantially different from unity. Since b is expected to represent the ratio between average long-term values of k and y, it (in the case of the USA for the observed period) should be somewhat higher than 1.0. When y becomes larger than bk, $\dot{y}$ is negative, and a downward adjustment of y is affected with speed a.

Equation (2) is a derivation of the investment function, assuming a constant growth rate of labor. When the profit rate is stable at its long-term mean (p = 0), $k = \bar{k}$, i.e. capital intensity is moving along its average growth path. However, when the profit rate is changing, k with a certain lag deviates in the opposite direction (d < 0). This looks like a paradox, but it is not.

Assume that variables are closely following sinusoidal curves around their mean values with k fluctuating in counterphase to p. But P (the rate of profit, rather than its percentage change) lags behind p by a quarter of a cycle. When p reaches its peak P is only at its upcross. While p is falling P first rises to its peak, then falls back to its downcross. As a result k rises while P is higher than average, and falls while P is below average. Thus investment per unit of labor *positively* follows the deviation of the rate of profit from its mean, though it is *negatively* correlated with the relative change.

The negative influence of p on k has also certain substantive reasons. In a long depression, when a negative p is driving down the profit rate, there is both involuntary accumulation of fixed capital and inventories, and a strong drive to save at the expense of labor – with or without investing in labor-saving equipment. These influences keep k up. In a recovery more labor is needed in order to fill up unutilized capacity, and k may fall while p is rising. When the profit rate is higher than average, there is less compulsion to save labor, and labor-intensive technologies are used more readily.

Equation (2) is, perhaps, the driving force of the long wave. It is crucial in explaining both turning points of the wave: minimum and maximum.

Equation (4) determines oscillations in the share of profit (surplus value) in national product. Coefficient f indicates the historical mean of $\bar{z} / \bar{y}$, i.e. the relation between the average growth rates of profit per labor unit and productivity of labor. In capitalist countries f should be either close to or slightly higher than 1.0.

Definition (3) shows that the average profit rate is stable in the long run if $\bar{z} = \bar{k}$, and, since $\bar{z}$ is close to $\bar{y}$, if $\bar{y} = \bar{k}$. It follows that, when $\bar{k} > \bar{y}$, the profit rate is falling. This is just another formulation of Marx's law of the declining profit rate. If $\bar{k} < \bar{y}$, however, the counteracting factors are strong, and the operation of the law is frustrated, or "paralyzed", to use Marx's own expression.

Coefficients b and f thus have an important politico-economic value: b

governs the dominating trend in the organic composition of capital, and f indicates the trend in the rate of surplus value. Their product (bf), determines the mode of operation of the law of the declining profit rate.

The dynamic properties of (1–4) are determined by the roots of the characteristic differential equation:

$$mx^3 + nx^2 + qx + s = 0 \tag{5}$$

where:

$$m = cd - 1$$

$$n = cd\,(2e + 1) - 2e - c - abcdef$$

$$q = cd\,(e^2 + 2e) - e\,(e + 2c) - 2abcdef$$

$$s = ce^2\,(d - 1) - abcdef$$

To simplify matters assume that $z = y$, so that the share of profit in national product is constant. Then the model generates periodic fluctuations subject to conditions:

$$c/a < (b + 2)/2; \tag{6}$$

$$c/a - 1 - b - c/ag < d < c/a - 1 - b + c/ag, \tag{7}$$

where:

$$g = b^2 + 2b - 2bc/a.$$

There are no fluctuations if $d > 0$, and b is within the expected range $0 < ; < 2$. However, fluctuations are generated if d is negative, but not too small. Thus the importance of equation (2) in generating the long wave receives additional support.

Given these conditions, the length of the wave depends upon the speeds of reaction a and c. According to (6) c should not be much larger than a. Assuming that they are equal, and that $b = 1$, (7) becomes:

$$-2 < d < 0 \tag{8}$$

A 52-year regular oscillation is generated with coefficient values:

$a = 0.12$

$b = 1.0$

$c = 0.12$

$d = -1.88$

It is easier to study the properties of the model when fluctuations are not dampened. As seen in Figures 11–12 (representing results of a machine simulation) the leading variable is p. Its turning point precedes the change in k in the opposite direction by 7 years, and 6 years later comes the turn in y. It takes another 13 years for p to reach its peak or trough. This particular sequence is determined by the structural equations and does not depend on the initial conditions of the simulation. The latter do, of course, affect *absolute* amplitudes of variables, but *not relative* amplitudes. Thus the amplitude of k is 1.37 larger than that of both y and p irrespective of initial conditions. The relative amplitudes are conditioned by the model's structure.

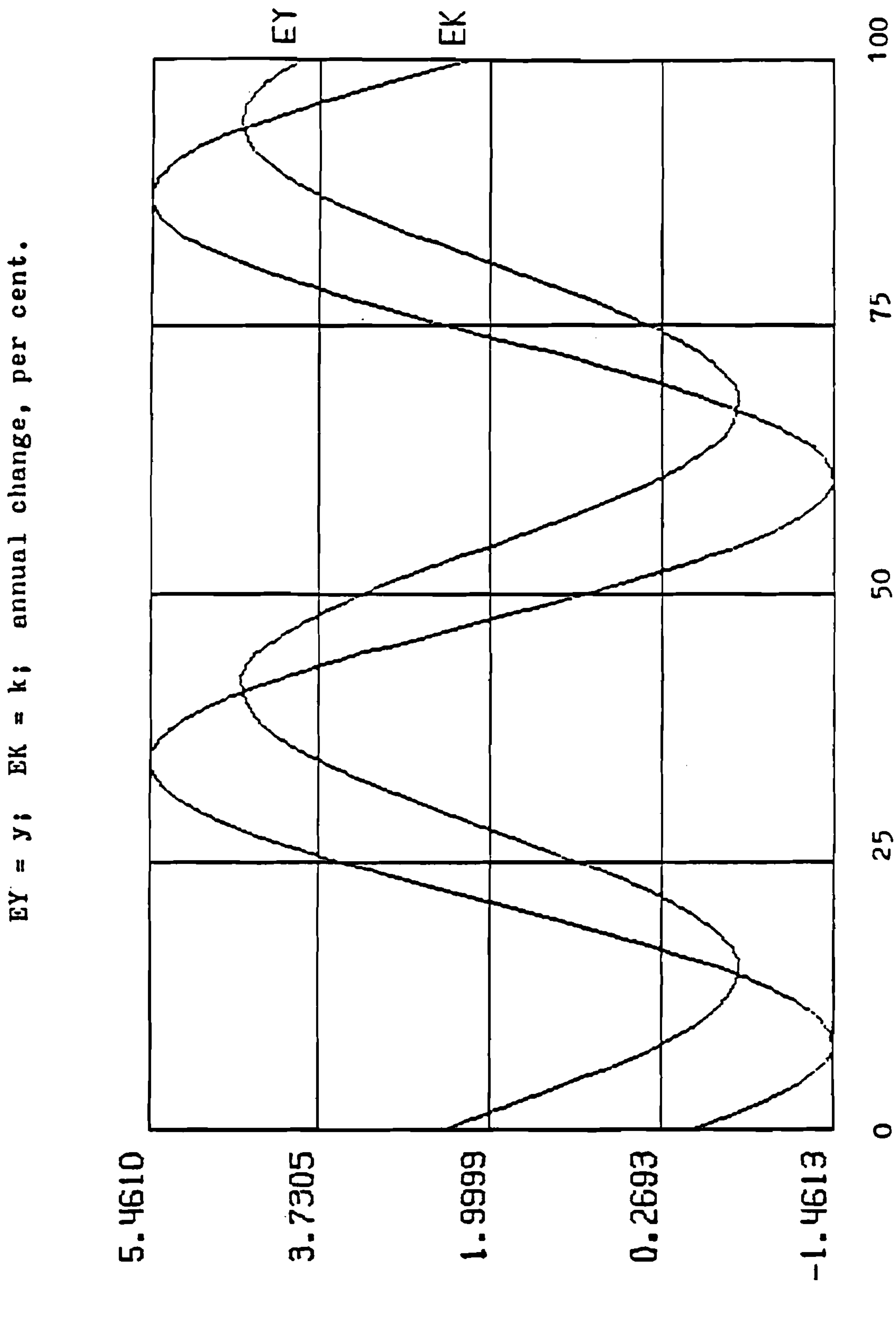

Figure 11 Theoretical model simulation (y and k).

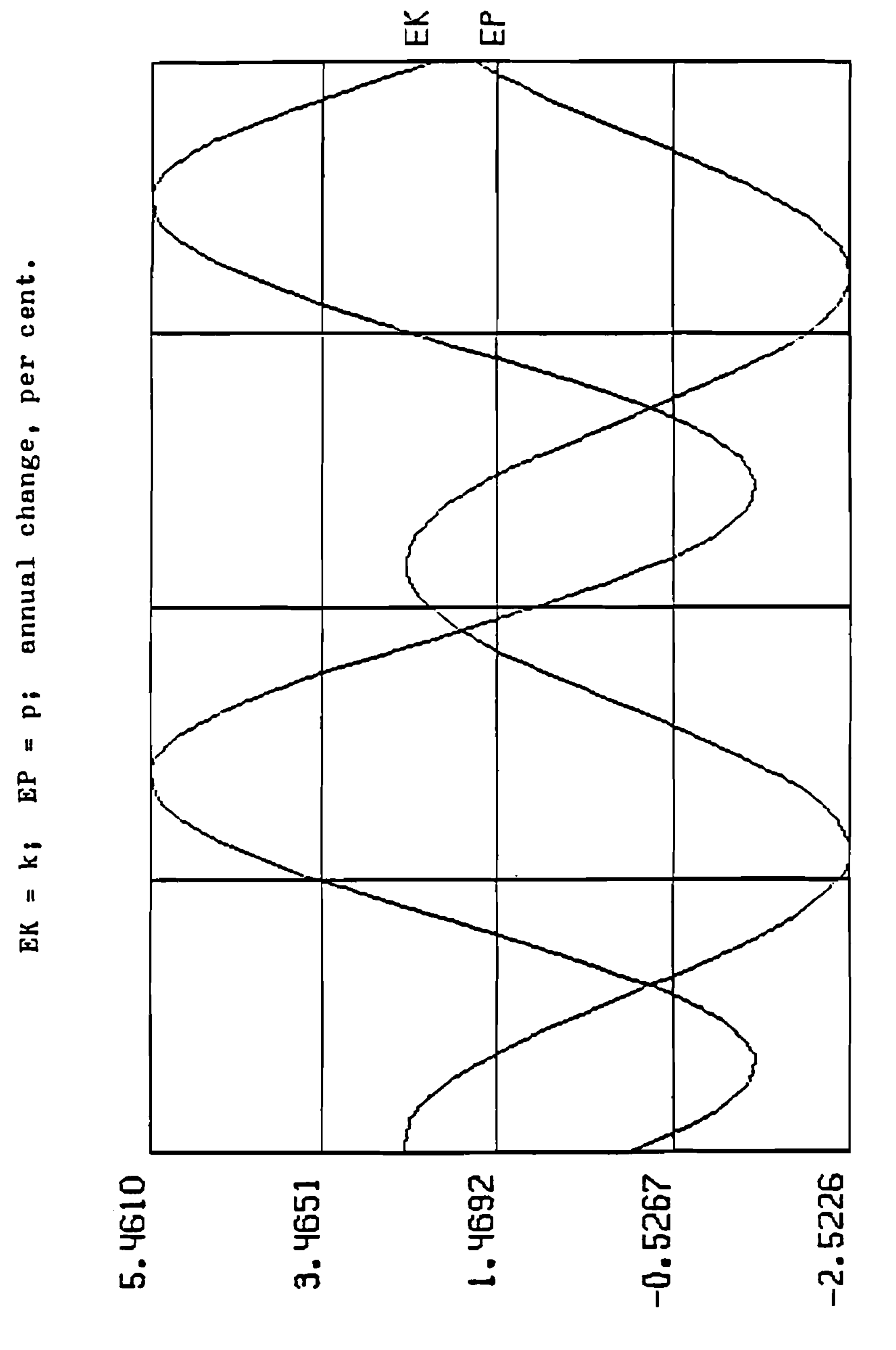

Figure 12 Theoretical model simulation (k and p).

The chart clearly shows that, as expected, k starts falling 7 years after P enters its depression phase (i.e. when p is starting to recover). The lag is nearly as long as the major economic cycle. Thus one should not expect a long-term upturn in investment before it is certain that the average rate of profit has definitely entered its upturn phase.

Though the peak of k is substantially higher than that of y, the period when k is larger than y takes exactly half the wavelength. If b were lower (or higher) than 1.0, this period would have been relatively shorter (or longer) and at excessively low values of b and small amplitudes would disappear completely. This is an important period, since it means an increasing output–capital ratio, and, other things being equal, a rising rate of profit. Taking into account the quarter-wave lag between y,k and their respective growth rates, the recovery and upturn in the model of the output–capital ratio occurs exactly at the time when y is higher than its trend and most of it happens while k is high but falling. The upper turning point of the output–capital ratio is reached when y enters its depression phase and before k starts recovering. The leading force of y which we have observed statistically, is thus fully reflected in the model.

The results of fitting the equations are presented in Table 1. OLS was applied either to:

$$y_{t+1} = (1-a)\, y_t + (ab)\, k_t + u_{1,t}\,, \tag{9}$$

where u_t is the stochastic component; or to a two-step algorithm, including:

$$y_t = bk_t + u_{1,t} \tag{10}$$

$$y_{t+1} = -a\ (u_{1,t}) + u_{2,t} \tag{11}$$

In most cases the estimated coefficients were close to each other for the same equation in spite of the different methods used.

Coefficient b was found to be in the range of 0.6–0.7, or much lower than the $\bar{y}/\bar{k}$ of 1.5. Large negative values of k in 1933–1944 coinciding with large positive values of y have introduced a downward bias. When a dummy variable was added for these years, the value of b increased to 0.9. When the equation was estimated for shorter (20–24 year) periods, b was found to be in the range of 1.0–1.5 (excluding the late 1930s and early 1940s).

The reaction coefficient a, which is too small (0.03–0.05) in most estimations, increased to a more realistic 0.12 in the dummy variant.

In the investment equation both positive and negative values of coefficient d were obtained. This was not unexpected. However, all variants with positive values had to be rejected as they failed to produce fluctuations in complete systems. The negative value for d in the third variant presented in the table is 0.62, which looks too low, especially in conjunction with the large constant 1.96, which is higher than the average $\bar{k} = 1.6$. When fitted for shorter periods the regression invariably produced negative d.

In the profit equation ($\dot{z}$) coefficient f was found to be positive and in the range 1.0–1.1. This result applies also to *all* shorter periods without exception. The reaction speed e, which was equal to or higher than 1.0 for 1894–1924, fell to 0.3 in most of the later periods, and also in the entire historical period. Thus, while profit was expected to increase slightly faster than product throughout the 90-year span, it was doing so even more intensively before the Great Depression. Perhaps the growth of trade unions and collective agreements brought about the short lag which appeared later on.

Function	Coefficients and t-statistics						
		b					
$\dot{y}$	a	b_1	b_2	const.	R^2	F	DW
	0.048	0.62	-	-	0.97	685	2.3
	(2.1)	(6.4)					
	0.04	0.74	-	-	0.91	419	1.2
	(2.3)	(1.4)					
	0.033	0.273	-6.76	-	0.95	492	2.5
	(30.9)	(2.67)	(2.8)				
	0.12	0.88	-	0.61 dum	0.95	476	2.4
	(18.5)	(2.1)		(2.0)			
		d					
$\dot{k}$	c	d_1	d_2	const.			
	0.035	1.54	-	-	0.89	347	1.7
	(2.5)	(1.8)					
	0.035	1.85	-	-	0.79	155	0.8
	(17.3)	(3.1)					
	0.25	-0.62	-0.62	1.96	0.85	158	1.2
	(14.2)	(4.6)	(4.6)	(3.9)			
	0.034	-0.15	-8.74	-	0.95	473	2.1
	(35.2)	(8.8)	(8.5)				
		f					
$\dot{z}$	e	f_1	f_2	const.			
	0.3	1.09	-	-	0.18*	17.5*	1.0*
	(4.2)	(18.3)					
	0.6	1.95	1.95	-1.38	0.77	89.9	1.1
	(5.6)	(7.8)	(7.8)				
	0.124	1.05	15.9		0.96	677	1.6
	(17.6)	(18.4)	(14.6)				

Table 1 Estimated coefficients
*Equation estimated in 2 steps. R^2, F and DW apply to 2nd step. dum indicates dummy variable = 1.0 for 1933-44, 0.0 otherwise.

It was also found that the variables strongly depend not only on factors, but also on their first derivatives:

$$\dot{y} = -a\,(y - b_1 k - b_2 k) \tag{12}$$

When both coefficients at the factor and its derivative have the same sign (as in the case of the investment and profit equations) the basic underlying functional relationship is strengthened and the adjustment lag reduced. When the coefficients have different signs (the case of the productivity equation) the movement of $\dot{y}$ is corrected in the opposite direction and the adjustment lag becomes longer.

Various combinations of fitted equations were tried. The following model is given as an illustration:

$$y = -0.048\,(y - 0.62k) \tag{13}$$

$$k = -0.25\,(k + 0.61p - 1.96) \tag{14}$$

$$z = -0.12\,(z - 1.05y - 15.9\dot{y}) \tag{15}$$

$$p = z - k \tag{16}$$

When solved theoretically as a differential system, it yields the characteristic equation:

$$x^3 + 1.322x^2 + 0.5117 \times 0.0411 = 0 \tag{17}$$

and roots:

$$x_1 = -0.1057; \quad x_{2,3} = -0.273 + 0.117i.$$

This is equivalent to damped fluctuations with a period of 53.7 years.

However, when simulated as a difference approximation the model produces periodic waves of 60 years' duration. Given actual initial conditions for 1894 ($y = 1.96$, $k = 2.63$, $z = 3.16$ and $p = 0.57$) the model produced turning points which were roughly coincident with some of those observed in the historical period (see Table 2).

Variable	k		y		z		p	
Type of Point	act.	sim	act.	sim.	act.	sim.	act.	sim.
upper	-	-	-	-	-	-	1902	1897
lower	1903	1903	1929	1926	1911	1919	1929	1928
upper	1928	1933	1951	1950	1951	1949	1962	1957
lower	1963	1963	-	-	-	-	-	-

Table 2 Dates of turning points: actual and simulated

The simulation was "pure", i.e. it contained only one out of three components of the actual trajectory – the endogenous mechanism. The two other components – exogenous and stochastic shocks - were absent. No wonder that the simulated course was in many ways different from the historical one.

One possible criticism of the model could be that it does not reflect long-term fluctuations in supply of and demand for product, capital and labor. As Marx shrewdly indicated, once capital is created, it introduces potential overproduction. As capital is accumulated, on the one hand, it creates increasing production capacity which after a while becomes excessive, and, on the other hand, decelerating demand for labor. Excess capacity and unemployment have a backward effect on productivity, capital intensity and the rate of profit. Thus an additional loop of long-term fluctuations emerges, closely tied to the first.

It is possible to take account of this loop by introducing additional variables and modifying the initial equations. The model would grow in size, and its theoretical analysis would become more cumbersome. At this point it is sufficient to include the influence of the supply-demand loop as an exogenous force.

This leads to:

$$\dot{y} = -a(y - bk) + g\overline{u} \tag{18}$$

$$\dot{k} = -c(k - dp - k) + h\overline{m} \tag{19}$$

$$\dot{z} = -e(z - fy) + i\overline{u} \tag{20}$$

where:

$\bar{u}$ = rate of unemployment (exogenous);

$\bar{m}$ = index of capacity utilization (exogenous);

g, h, i = coefficients.

Excessive unemployment in the depression phase is expected to affect both labor productivity and profit created per unit of labor. Labor productivity may be maintained and increased though capital intensity is falling. High unemployment will also negatively affect wages and help increase profit created per unit of labor. Thus both g and i are expected to be positive.

The capacity utilization index is known to positively affect capital investment. Investment booms are triggered when the index approaches unity, and are delayed when the index is low, even though profit rates may be increasing. However, the investment in the model is per unit of labor. Thus the influence of m may show up only with a lag.

The introduction of exogenous variables will affect the structural coefficients and modify the basic oscillatory properties of the model, but more importantly adds a substantially new component to the movement of variables making it more complex and closer to reality.

REFERENCES

Bianchi, G., G. Bruckmann, and T. Vasko (eds.) (1983) Long Waves, Depression and Innovation: Implications for National and Regional Economic Policy. Siena/ Florence.

van Duijn, J.J. (1983) The Long Wave in Economic Life. London.

Forrester, J. (1981) Innovation and Economic Change. *Futures*, No.4.

Freeman, C., J. Clark, and L. Soete (1982) Unemployment and Technical Innovation, London.

Historical Statistics of the United States (1975) Washington.

Howrey, P. (1968) A Spectrum Analysis of the Long-Swing Hypothesis, *International Economic Review*, vol. 9, no. 2.

Kendrick, J. (1961) Productivity Trends in the United States. Princeton.

Kuczysnki, T. (1980) Have there been Differences between the Growth Rates in Different Periods of the Development of the Capitalist Economy since 1850? *Historisch-Sozialwissenschaftliche Forschungen*, Bd.6.

Kuznets, S. (1961) Capital in the American Economy. Princeton.

Marx, K., and F. Engels (1960-63) Works, 2nd Edition, vol.23-26, 46. Moscow. (In Russian).

Mensch, G. (1979) Stalemate in Technology. Cambridge, Mass.

Rostow, W.W. (1980) Why the Poor Get Richer and the Rich Slow Down. New York.

TOWARD A COMPREHENSIVE THEORY OF LONG WAVES

Carlota Perez-Perez

1. THE NEED FOR AN "ENDOGENOUS" THEORY

I believe we all agree here that an appropriate theory of long waves should provide an explanation *endogenous* to the system. The real problem, however, lies in determining precisely *which* system it should be endogenous to. Clearly, the *economic* subsystem can, for many purposes, be treated as self-contained, because of its tremendous amount of internal feedback and self-determination. But... when it comes to explaining *long waves*, given the considerable transformations they imply in all spheres of society, it seems to me we need to step out and take a *global* look at the evolution of the *total system*, with its technological, social and institutional components *interacting* with the economic subsystem.

2. LONG WAVES AS SUCCESSIVE MODES OF EVOLUTION OF THE TOTAL TECHNO-ECONOMIC SOCIO-INSTITUTIONAL SYSTEM

Taking this total view, I would like to suggest that depression in a long- wave is a *structural* crisis. It is not just a halt in *economic* growth but rather the syndrome of a *serious mismatch between the techno-economic subsystem and the socio-institutional framework*. We are in fact witnessing the reversal of the positive interaction between these two spheres.

I hold that what we are actually *measuring*, when we detect long-wave behavior in *economic* variables, is the increasing degree of "*match*", in the upswing, and of "*mismatch*", in the downswing, between these two spheres of the system. In other words, depression is a "shouting" need for full-scale reaccommodation of social behavior and institutions, in order to suit the requirements of a major shift which has *already* taken place, to a considerable extent, in the techno-economic sphere. The upswing, then, can *only* be unleashed by appropriate social and institutional transformations that will re-establish structural coherence.

But, why should this occur?

Mainly because the two sets of subsystems, though in permanent interaction, have very different rates of change.

While economic activity, spurred by profit and growth motives, can result in very rapid shifts at the micro level, the additive effect of successive and increasingly massive shifts will only be *visible* in the aggregate when change has reached critical proportions.

Institutions, on the other hand, not only come late as regards visibility and awareness of these changes, but also suffer from a high degree of "natural" inertia, strengthened by past successes and upheld by vested interests.

I suggest that the type of fundamental shift, which underlies these periods of "match" and "mismatch", are *successive techno-economic paradigms*, diffusing throughout the productive sphere about every 48 to 68 years. They can be seen as overall technical and managerial revolutions transforming the "how" and the "what" of profitable production, in general, and establishing a new "best practice frontier". The life cycle of each of these paradigms follows a logistic curve and so does its rate of diffusion across firms, branches and countries.

The upswing in the economy is the steep part of the paradigm curve for *both* productivity gains *and* generalization. It is stimulated by a whole set of social and institutional arrangements, national and international, influencing the operation and evolution of factor and other markets, and designed to suit the requirements of that particular techno-economic paradigm.

As limits to growth are reached along that path, a complex set of interactions between the technological and economic spheres gradually bring about the crystallization of a new paradigm, which again revolutionizes the productive system. Yet the social and institutional mechanisms, adapted to the now "old" and declining paradigm, cannot cope with the new pattern of investment and the unexpected behavior of most markets, as the new paradigm diffuses. These mechanisms, therefore, become increasingly powerless and counter-productive.

That is why depression is a process of *"creative destruction"* not only in the economic sphere but *also* in the social and institutional.

3. A TECHNO-ECONOMIC PARADIGM AS A SYSTEM OF BEST-PRACTICE GUIDELINES FOR MOST PROFITABLE BEHAVIOR

To avoid misunderstandings, let me make clear that I am not referring just to "clusters" of technological innovations, but to a *system* of interrelated product and process, technical, organizational and managerial innovations, embodying a quantum jump in potential productivity for all, or most, of the economy and opening up an unusually wide range of *truly new* investment and profit opportunities.

Again, when I say *"paradigm"* change, I mean a radical transformation in the prevailing engineering and managerial *"common sense"* for best productive and most profitable practice.

But, how would this come about?

The organizing principle of each paradigm can be found in the dynamics of the relative cost structure of *all* possible inputs to production. In it, a particular input (or set of inputs), which can be called the "key factor" of each paradigm, fulfills, for a relatively long period, the following conditions:

(a) Clearly perceived low – and descending! – relative cost,

(b) Apparently unlimited supply (for all practical purposes),

(c) Obvious potential for all-pervasiveness, and

(d) A generally recognized capacity, based on a set of related innovations, to reduce the cost and change the quality of capital equipment, labor and products.

I say this conjunction of characteristics holds today for microelectronics, leading the way towards the fifth upswing. It held until recently for oil, which underlay the fourth Kondratiev upturn, together with organic chemicals and other energy-intensive materials. Before that, for the third Kondratiev, the role of "key factor" was played by low-cost steel for the second, by low-cost coal and steam-powered transportation, and, for the Industrial Revolution or first Kondratiev upswing, one might perhaps suggest that the role of "key factor" fell upon low cost machine-tending and cotton-growing labor.

Yet, the new "key factor" does not appear as an isolated input, but rather at the core of a system of technical and managerial innovations, some related to the production of the key factor itself and others to its utilization. These innovations take place through an intensive feedback process, spurred by the decreasing capacity of the previous key factor to further diminish costs or increase productivity and profits.

Thus, the corresponding techno-economic paradigm emerges gradually, in the midst of a world dominated by the old, until it clearly appears as the "ideal type" of productive organization to take maximum advantage of the particular "key factor", which is becoming more and more visible in the relative cost structure. The new paradigm represents a quantum jump in total factor productivity and opens an unprecedented range of new investment opportunities. It is for these reasons that it brings about a radical shift in engineering and managerial "common sense" and that it tends to diffuse as rapidly as conditions allow, replacing the investment pattern of the old paradigm.

The full constellation – once crystallized – goes far beyond technical change and brings with it a restructuring of the whole productive system. Among other things, it involves:

(a) A new "best practice" form of organization at the firm and at the plant level.

(b) A new skill profile, affecting both quantity and quality of labor, with its corresponding pattern of income distribution.

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

(d) New trends in both basic and incremental innovations geared to substituting relatively high-cost elements by more intensive use of the key factor.

(e) A new pattern in the location of investment, as the change in the relative cost structure transforms comparative cost advantages.

(f) A particular wave of infrastructural investment destined to provide the appropriate externalities.

(g) A tendency for the largest firms to concentrate – by growth or diversification – in those branches where the key factor is produced or most intensively used, which results in having distinctly different branches acting as the engines of growth for each Kondratiev upswing.

To give a brief example, the fourth Kondratiev techno-economic paradigm, now exhausted, was based on low-cost oil and energy-intensive materials and was led by giant oil, chemicals, automobile and other mass durable goods producers. Its "ideal type" of productive organization at the plant level was the continuous-flow assembly line, to turn out massive quantitites of identical units (much of it for *consumers*, which was in itself an innovation, considering that these markets had traditionally been covered by smaller and less productive units, except, of course, in the textile-led first Kondratiev). The "ideal type" of firm was the "corporation", with a *separate* and very complex managerial and administrative hierarchy, including in-house R&D and operating in oligopolistic markets. It benefited from economies of agglomeration and required an ever-expanding highway network, together with oil and energy distribution systems for energy-intensive production, transportation and lifestyles. It demanded increasing amounts of middle-range specialization in both blue- and white-collar skills.

Today, with cheap microelectronics widely available (higher with the consequent low cost of information handling), it is no longer "common sense" to continue along the – now expensive! – path of energy and materials intensity.

The "ideal" productive organization brings together management and production into one single *integrated system* (a process we might call "systemation"), for turning out a *flexible* output of preferably information-intensive, rapidly changing, products *and services*. Growth would presumably be led by the electronics and information sectors, requiring massive externalities from an all-encompassing telecommunications infrastructure, which would bring down to negligible the cost of access for producers and consumers alike. The skill profile tends to change from mainly middle-range to increasingly high- and low-range qualifications, and from narrow specialization to broader and multipurpose basic skills for information handling. *Diversity* and *flexibility* at all levels substitute identity and massification as "common sense" best practice.

4. RELATIONSHIP BETWEEN LONG-WAVE BEHAVIOR IN GROWTH AND TECHNO-ECONOMIC PARADIGM SHIFTS

I do hope these merely illustrative examples, sketching some of the main features of two successive techno-economic paradigms, will help in bringing to light the amount of innovation that would be required in government and social behavior to adapt to such shifts in productive practice requirements.

At the micro level, when you introduce numerical control or computer technology in a firm previously working with electromechanical technology, it is not possible to reap all the productivity increase potential without transforming the whole organization both at the plant and the office levels, including extensive retraining and redefinition of the forms of interaction. In a similar manner, when the full constellation of a new techno-economic paradigm tends to take over the bulk of production within a society, it will not yield its full growth potential until the socio-institutional framework is transformed to adapt to its requirements.

In the previous upswing, a change as profound as massive state intervention in the economy, along Keynesian principles, was necessary to unleash the full deployment of the oil based paradigm.

Historically, though not always and not only, these changes have affected the specific forms of operation and regulation of the various markets (product, labor, capital, money) on the national and international levels; the organization of the banking and credit systems; the relative proportions and character of public and private responsibility in production, distribution and redistribution of income, as well as the corresponding social arrangements; the forms of organization of workers and major interest groups, together with the legal framework within which they operate; the social provision of education and training in its quality, volume and the type of institutions in charge of it; the conditions under which inventions are generated, protected and traded; the international division of production as well as the means for regulation of trade; and last, but certainly not least, the arrangements for maintaining the international relative power balance.

Clearly, such changes cannot, and indeed have not occurred without social and international conflict, and they are actually the result of a tremendous amount of experimentation. The proposed solutions vary quite widely and, in fact, as far as being able to achieve high rates of growth, they can be as different as fascism and Keynesian democracy, as was seen in the last Kondratiev trough. The challenge, of course is to strive for appropriate arrangements to achieve both economic growth and maximum social welfare. Yet the outcome will ultimately depend on the relative strength, lucidity and capacity to innovate of the social forces at play.

Let us now briefly look at the four phases of the long wave in the light of techno-economic paradigm changes:

RECOVERY is the period when favorable social and institutional conditions have been put in place to foster the generalization of the previously crystallized techno-economic paradigm. Innovations multiply within the range of applications of the paradigm, reaching more and more products, more and more branches and even influencing the form of organization of non-productive activities. Investment, profit rates and productivity growth are high.

PROSPERITY is a period of exceptionally high growth rates resulting from the combination of the final optimization and maximum potential yield of the established and, by then, thoroughly generalized paradigm, and the first successful applications of the *future* paradigm. The latter generally occur as relatively risky trial and error efforts to avoid diminishing returns on more "traditional" investment. Other efforts to counter the reduction of profit margins of those reaching the top of the logistic curve may include mergers, acquisitions and whatever forms of speculation are found to be attractive in that particular period.

RECESSION is the decline of the now "old" paradigm, aggravated by the cross-currents and counter-trends created in most markets by the consequences of the new pattern of investment. This new pattern is created both by the appearance of many new innovative firms and by the efforts at diversification toward the new areas on the part of existing firms. At this time, the first signs of difficulty for further development of the "new" paradigm are encountered.

DEPRESSION is the exhaustion of the "old" paradigm but with inertia in its corresponding social and institutional mechanisms. The latter have become insurmountable barriers for the fructification of the growth potential of the new techno-economic paradigm and must be transformed.

5. IMPLICATIONS FOR THEORY, MODELING AND POLICY

Coming to the implications, let me first of all point out that the hypothesis I have presented has the virtue of being able to incorporate the various theories that have been presented here:

(1) It is consistent with the MIT model of self-ordering and excess capacity of the capital goods sector. The *excess* would relate to the capacity to produce the inputs and equipment corresponding to the established paradigm, where demand slackens as diminishing returns on investment are reached. Whereas, a good part of investment in the capital goods sector, which continues from late prosperity into recession, might in fact be oriented toward the *new* types of inputs and equipment, whose demand cannot grow at the appropriate rate because of institutional and social constraints.

(2) It is also consistent with the Mensch approach of "bi-valued technical progress", because we are witnessing the coexistence of technologies belonging to one paradigm, which are reaching their maximum potential through labor-saving improvements, while those belonging to the new are being introduced at the basic innovation level. So that if one were to incorporate a third dimension, relating to old-or-new techno-economic paradigms, to Mensch's basic-or-improvement and process-or-product dimensions, his model would still hold.

(3) It is also consistent with van Duijn's infrastructural long waves by pointing to loss of value of previous externalities and the need to invest in creating the new appropriate networks.

(4) Finally, it is very consistent with the SPRU (Freeman, Soete) approach, who also assign a central role to innovation, shifting employment patterns and structural change in industry. Their idea of "technological systems" is also taken up but within the wider concept of techno-economic paradigms. There certainly is full agreement as to the importance of the appropriate social and policy innovations, which Freeman emphasizes and most authors mention more or less centrally in their conclusions.

In general then, the implications of what we are proposing are:

For theory and modeling:

The need to take the interdisciplinary approach, but short of that, the need to introduce the qualitative dimension as a key element in modeling, for classifying investment, innovation and employment patterns. This, on the hypothesis that we are dealing with quantum jumps and bimodal distributions. That is, we are faced with discontinuity within the aggregate and with two divergent sets of techno-economic relationships impinging upon one another.

For policy research:

The main task would be to identify the specific characteristics, requirements and potential of the new techno-economic paradigm (which is already in place to a sufficient degree for recognition), in order to determine the criteria for appropriate response in terms of social and institutional innovations.

If the model we have briefly sketched is an acceptable approximation to the workings of the system, that would certainly be the path to follow in order to unleash the fifth Kondratiev upswing. Hopefully, *if it worked*, counter long-cyclical policies could be devised based on "early warning" mechanisms for the detection of paradigm shifts.

ELASTIC MECHANISMS OF INTERCOUNTRY ATTRACTION OF LOGISTIC INDUSTRIAL GROWTH

Roberto Vacca

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.

Durable goods penetrate the markets of industrial countries increasing their quantities following logistic curves. These S-shaped curves are identical to those representing the increase in time of animal, vegetable or bacterial populations. This had been proved in a large number of cases by Cesare Marchetti.

For example, the logistic curve of car registration in the United States has the equation:

$$L = F/(1-F) = 2.1833^{-54} \;. e^{(x/15.98)} \tag{1}$$

where F is the current fraction of the saturation level, L is the current level and x is the current year (date).

Schmidt and Marchetti (1982) have observed that the penetration rate of cars on the market of an industrial country is faster the later that country starts getting motorized. We do not know how to compute *a priori* the saturation level of a country's car population on the basis of other socio-economic factors. So saturation is defined empirically as the asymptotic value towards which the logistic growth curve is aimed.

The time taken to go from 10% to 90% saturation, along the logistic curve, is termed T, the penetration time constant. For the United Sates 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% of saturation for a given country, the time constant T decreases regularly as a function of x according to the equation

$$T = 2.103 \quad .e^{(2000-x)}0.04146 \tag{2}$$

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 reached an appreciable level of car registrations. In this very simple model the current level $L\ (=F/1-F)$ in the USA plays the role of the constant determining the elastic attraction force. The time constant T plays 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-squares differences indicates that the time constant T is expressed by the relationship:

$$T = 5.8686 \ \cdot \ L^{-2/3} \tag{3}$$

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

All this rather naive exercise – which results, however, in a 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 or railway networks have been built in this century or that, as noted before, the level of cars per capita at saturation tends to decrease monotonically. 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, mass diffusion of culture, migration of populations.

CAPITAL AND CREDIT

At present the chronic and increasing indebtedness of Third World countries points to moratoriums and a stop to further credit as the only feasible way out. Many countries need 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 capital to finance development as well as the practical exploitation of these resources. Similar arrangements may be reached with other types of natural resources, provided modern tools are adequately used for their prospecting and assessment.

MASS DIFFUSION OF CULTURE

The population of a country cannot engage meaningfully in the production and 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). Rising above this threshold appears very probably to be the largest single cause of automatic demographic control. However, it 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 inadequate 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 rise above higher cultural thresholds. This process should also produce the spinoff of defining mass education procedures capable of leading Third World population to rise above 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, modest effects on balances of payment and no cultural effects. Planned mass migration in either direction between North and South could transfer: technology, ideas, lifestyles and favor mass diffusion of culture.

CONCLUSIONS

It is quite difficult to measure cultural levels or 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

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.

THE MACROECONOMIC POTENTIAL

Günter Haag

1. INTRODUCTION

In the literature several kinds of economic cycles have been identified: Kondratieff cycles, Kuznets cycles, Juglar cycles, business cycles. Clearly, in reality only a superposition of these different cycles can be observed.

One problem arises from the fact that the economic output seems to depend in a nonlinear way on variations of certain input variables. This makes it difficult to separate the effects of various cycles. Another basic problem in research on cyclical economic movements is the lack of historical data. Because of the restricted set of data available it is almost impossible to predict the period of the Long Waves and the phase of the cycle with some accuracy. Therefore, in the present state of the art, it seems interesting to gain additional theoretical insights through the construction of simple models.

Of course, it is easy to obtain cyclical structures by writing down a set of differential equations or difference equations. However, several nontrivial questions arise. What are the initial conditions? What is a reasonable set of parameters, and which values for these parameters must be chosen? How many differential – or difference equations do we have to combine? Are the parameters of the model time-dependent and why?

The observed and measured macroeconomic set of data is the result of a certain aggregation of microeconomic variables. On the microeconomic scale the decision process of actors (firms, entrepreneurs...) is related to the concepts of utilities and utility maximizing principles. Since we cannot expect to describe the individual decisions on a fully deterministic level, a probabilistic treatment seems to be adequate. As a consequence the resulting theory should be a stochastic one. This means, we expect that the theory yields as a main result the evolution of a probability distribution over the possible configurations arising in the decision process. From such a moving distribution it will then be possible to derive deterministic equations of motion for the mean values. A systematic theory for the quantitative description of sociological and ecopolitical processes is given in the book of Wolfgang Weidlich and Günter Haag (1983).

The individual actors of society contribute through their cultural and economic activities to the generation of a general "field" of civilization with cultural, political, religious, social and economic components. This collective field determines the sociopolitical atmosphere and the cultural and economic standard of the society and may be considered as an *order parameter* of the system characterizing the *phase* in which the society exists.

Vice versa, the collective field strongly influences the individuals in the society by orientating their activities and by influencing their utilities. One of the features of this sort of cyclic coupling of causes and effects is that self-accelerating as well as self-saturating processes result. In the "normal case" the feedback between individuals and the collective field leads to a sustained quasi-stable or evolutionary phase, i.e. a "self-consistent" collective structure of society. In this case there exists a certain predictability of further development because the space of mutually influencing relevant macrovariables is known and these macrovariables obey a quasi-closed subdynamics.

If, however, the control parameters governing the dynamic behavior of the system attain certain *critical values* due to internal or external interactions, the macrovariables may move into a criticial domain out of which highly divergent alternative paths are possible. In this situation business fluctuations of the Schumpeter kind and also small unpredictable microfluctuations may decide into which of the diverging paths the behavior of the society – and also the economic subsystem – will bifurcate.

The transition from one phase to another (Phase transition) shows that self-consistent structures are ambiguous in the sense that there may exist several stable or unstable collective states even under the same external conditions.

But, as Carlota Perez mentioned "...when it comes to explaining *long waves*, given the considerable transformations they imply in all spheres of society, it seems to me we need to step out and take a *global* look at the evolution of the *total system*, with its technological, social and institutional components *interacting* with the economic subsystem."

It is the task of this paper to derive a potential function from the observed values of macroeconomic data. This potential function can be seen as a candidate for these general social and economic fields mentioned above. The parameters of the macroeconomic potential will be determined by a superior principle. As far as policy research, we are saying that the main task is identifying the specific key factors (variables) yielding structural variations in the economic output or long waves. This can be done in a self-consistent way via a link between the time series of the potential parameters obtained in the first step and an appropriate set of input variables.

The significance of certain input variables as well as their weights describing their influence on the potential parameters are found using an optimizing procedure.

The first step, section 2, 3, consists in describing *where* we are and what we expect, the second step, section 4, aims at finding out the variables relevant to explain our historical – and future way. In section 5 our considerations are applied to data of the FRG and the USA.

2. DEFINITION OF THE MACROECONOMIC POTENTIAL

This section summarizes the concept of a macroeconomic potential and delineates in some detail its formal definition and determination. Using this macroeconomic potential we try to answer several questions.

- Can we explain structural economic changes by introducing an economic potential?

- How can we separate business cycles and structural economic effects?
- Is our economy in a monostable or in a bistable situation?
- What is the equilibrium path of our economy?
- Are we near or in an absolute minimum of this potential or in a relative minimum?
- Are we near a phase transition point of the economy between higher and lower levels of the macroeconomic output variables?
- Are we in a region where business cycles or output fluctuations are enhanced?
- What do we expect in the future?

For this aim let us first glance at the net production of Germany, Figure 1, (a) and (b).

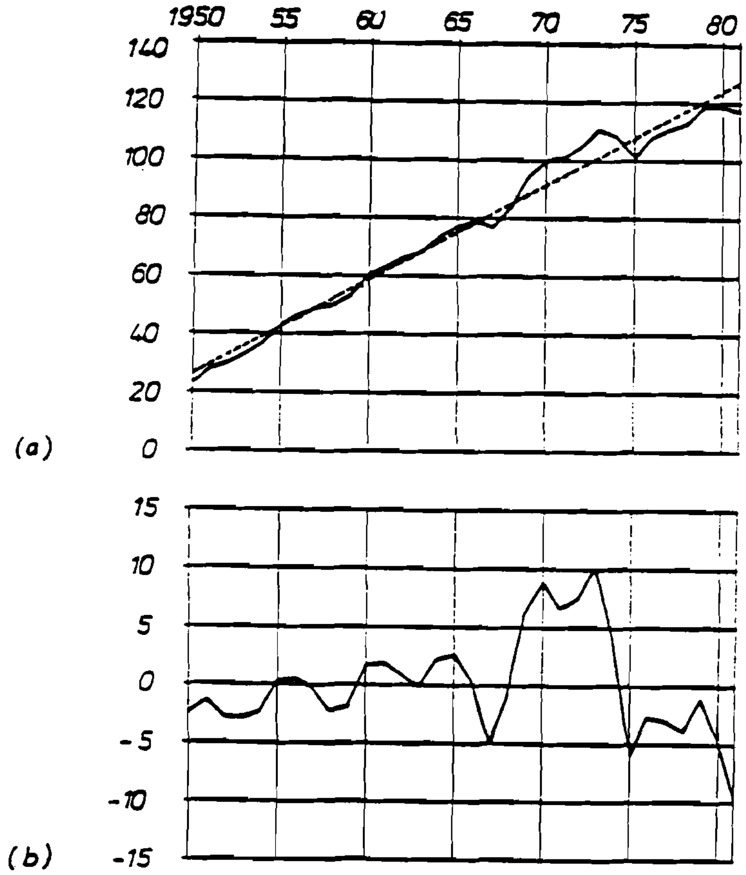

Figure 1 (a) and (b) Index of net-production of FRG, Basis 1970 = 100.

In Figure 1(b), we have subtracted the linear trend and observe well definable business cycles. On the other hand for certain times the simple cyclical structure of the business cycles is dramatically perturbed and we assume that this kind of perturbation comes from structural economic effects, i.e., crisis in the economic development influenced by changes of the general social- and economic field.

Regarding Figure 1, one is tempted to interpret these structural effects as *phase transitions*. Namely, it looks as if during 1950 and 1965 the trend in the FRG was *stable* and became *unstable* afterwards leading to an ambiguity of equilibria. This possible ambiguity in the relation between causing input variables and resulting output variables should be included in the definition of their relationship from the very beginning. A relation which can assign to one set of input variables more than one set of output variables, however, is typically a *nonlinear* one.

We exemplify such a nonlinear relation between macroeconomic input – and output variables by defining a *macroeconomic potential* according to the following *principles of construction:*

1. The potential $V(y_1,\dots,y_r,c_1,\dots,c_n)$ is assumed to depend nonlinearly on one or several *representative* output variables $y_1,\dots,y_r$. Its coefficients $c_1,\dots,c_m$ are assumed to be single-valued functions of given input variables $\Omega_1,\dots,\Omega_A$.
2. The potential is a function of time, since the input variables evolve with time.
3. The potential is meant to describe the long-term structural change of the economy but not its short-term oscillations. Hence, its definition must imply a filtering procedure which excludes or renders irrelevant the short-term motion of input and output variables.
4. The potential is to be seen as a macroeconomic measure of the *structural balance* or *imbalance* of the economy at a given instance of time during its long term evolution. By definition, those values $y_{1e},\dots,y_{re}$ of the output variables which are taken at the *minimum* (or the *minima*) of $V(y_1,\dots,y_r,c_1,\dots,c_n)$ are values of (instantaneous) *structural equilibrium* of the economy. Correspondingly, the difference

$$\Delta V = V(y_1,\dots,y_r,c_1,\dots,c_n) - V(y_{1e},\dots,y_{re},c_1,\dots,c_n) \tag{2.1}$$

is a measure for the degree of *economic disequilibrium* at a given time generated by the deviations $(y_1-y_{1e}),\dots,(y_r-y_{re})$ of the output variables from their equilibrium values.

5 Since the economy tends to *adjust* itself, a relaxation towards or oscillations around the long-term path of the equilibrium values $(y_{1e},\dots,y_{re})$ is to be expected. Per definition, the macroeconomic potential is associated with the *macroeconomic forces* $F_a(y_1,\dots,y_r)$ driving the economy back into its structural equilibrium

$$\frac{dy_a(t)}{dt} = F_a(y_1,\dots,y_r) = \frac{\delta V(y_1,\dots,y_r,c_1,\dots,c_n)}{\delta y_a} \qquad a=1,\dots,r \tag{2.2}$$

(The full dynamics of short-term motion must, however, be described in terms of microeconomic concepts beyond the macroeconomic potential.) The long-term path $(y_{1e}(t),\dots,y_{re}(t))$ of the structural equilibrium (or equilibria) is not *a priori* known. But the very fact that the empirical values of $(y_1(t),\dots,y_r(t))$ perform short-term fluctuations or oscillations around these equilibrium values leads to the determination of the latter by filtering out this short-term motion.

6. Since the potential should include a possible ambiguity of equilibria in periods of structural change, its mathematical form should allow for more than one minimum.
7. The simplest specification of the macroeconomic potential adopted henceforth consists in choosing *one* representative output variable only and a potential form allowing for one or two minima. Later the coefficients (potential parameters) are assumed to depend on certain input variables $\Omega_1(t),\dots,\Omega_A(t)$.

Proceeding as required in the definition we use the simplest model for the macroeconomic potential which is rich enough to explain the historical facts

$$V(y) = \frac{y^4}{4} + \frac{py^2}{2} + qy \quad . \tag{2.3}$$

For given potential parameters p and q the equilibrium values y_e, at which the potential has its extremum (its extrema) are defined by

$$\frac{\delta V(y)}{\delta y}\Big|_{ye} = y_e^3 + py_e + q = 0 \tag{2.4}$$

This cubic equation can have one or three real solutions in dependence on the sign of the discriminant

$$D = (q/2)^2 + (p/3)^3 \quad . \tag{2.5}$$

For $D > O$, (2.4) has one real solution corresponding to one minimum of the potential, while for $D < O$, (2.4) has three real solutions corresponding to a potential with two minima and one maximum in between. The maximum belongs to an unstable equilibrium point.

While in case (a) only one equilibrium state (minimum of V) is present, a transition from a one minimum to a two minima form of V can occur in case (b). This transition describes a change of the economy from a more stable to a less stable structure, since the availability of two minima instead of one means an ambiguity and uncertainty with respect to finding a macroeconomically consistent state of structural equilibrium. The "phase transition" from a monostable to a bistable potential occurs at a *critical point* $p=p_c$ and $q=q_c$ defined by $D=O$ or more explicitly

$$(q_c/2)^2 = (-p_c/3)^3 \quad , \quad p_c < 0 \quad . \tag{2.6}$$

If we compare (2.3) with the Bi-equilibrium model proposed by Gerhard Mensch (1981) we find

$$p \Longleftrightarrow -R \quad ; \qquad q \Longleftrightarrow -E \quad . \tag{2.7}$$

Therefore we may expect a high correlation of these quantities. On the other hand, this approach here generalizes the ansatz of Mensch, since p and q can be

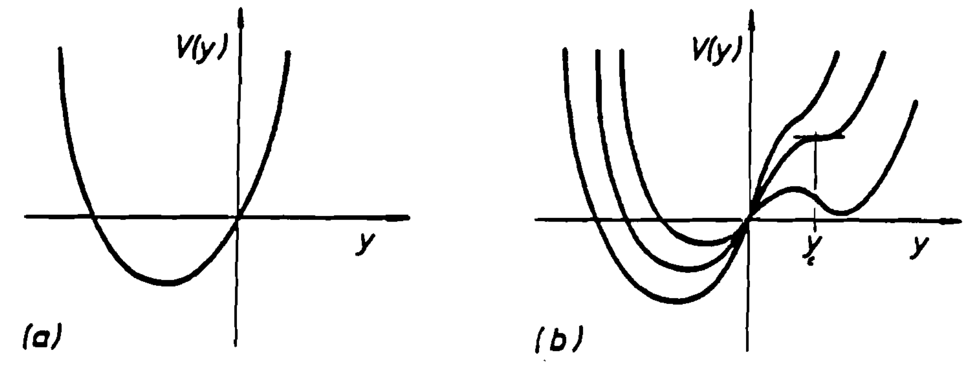

Figure 2 (a) and (b) The shape of the macroeconomic potential for different signs and magnitudes of the potential parameters p and q. (a) $p > 0$, $q > 0$. (b) $p < 0$, $q > 0$.

functions of a set of input variables as we shall see below. Also the economy is treated as a *dynamic system* here. Hence, the Bi-equilibrium model is incorporated completely. The time series of the potential parameters p_t, q_t are obtained by a superior principle from the empirical data. How this works, we shall see in the next section.

3. DETERMINATION OF THE POTENTIAL PARAMETERS FROM EMPIRICAL DATA

The fully explicit specification of the macroeconomic potential necessitates the determination of its parameters p, q. We proceed along the line of the potential construction principles mentioned above, especially points 3 and 5. The assumption is that the structural dynamics of the empirical output variable y will perform short-term fluctuations or oscillations in a macroeconomic potential created by a general social- and economic field.

Step 1

A representative output variable is chosen, for which empirical values y_t for the years $t=1,\dots,T$ are available. The linear trend (or nonlinear trend) is subtracted and the variable is scaled to have standard deviation 1.

Step 2

The time series of the potential parameters $p_t, q_t (t=1,2,\dots,T)$ can now be determined by the requirement that the macroeconomic potential describes the dynamics of the output variable y in a fixed time interval $M=2\tilde{M}+1$ as precisely as possible. Since a discrete set of empirical values of $y_t (t=1,2,\dots,T)$ is used, the equation of motion (2.2), (2.3) yields a difference equation instead of a differential equation.

To exclude or render irrelevant the short-term motion, the filter length M should be of the order of the duration time of the business cycles.

More explicitly p_t and q_t are found by the requirement, that the functional $G_t(p_t,q_t)$

$$G_t(p_t,q_t) = \sum_{t=t-\tilde{M}}^{t+\tilde{M}} [(y_{t+1} - y_t) + (y_t^3 + p_t y_t + q_t)]^2 \tag{3.1}$$

be minimized. This procedure leads to the two linear equations in p_t and q_t

$$\frac{\delta G_t(p_t,q_t)}{\delta q_t} = 0 \tag{3.2}$$

$$\frac{\delta G_t(p_t,q_t)}{\delta q_t} = 0$$

from which the result

$$p_t = \frac{v_t - \bar{y} w_t}{\dot{y}^2 - \bar{y}^2} \; . \tag{3.3}$$

$$q_t = -p_t \bar{y} + w_t \tag{3.4}$$

with the abbreviations

$$v_t = -(\bar{y}_t^4 + \frac{1}{M} \sum_{t=t-\tilde{M}}^{t+\tilde{M}} (y_{t+1} y_t - \bar{y}_t^2)) \tag{3.5}$$

$$w_t = -(\bar{y}_t^3 + \frac{1}{M} \sum_{t=t-\tilde{M}}^{t+\tilde{M}} (y_{t+1} - \bar{y}_t)) \tag{3.6}$$

and

$$\overline{y_t^n} = \frac{1}{M} \sum_{t=t-\tilde{M}}^{t+\tilde{M}} y_t^n \; ; \quad t = 1,2,\ldots,T \; . \tag{3.7}$$

is easily derived. If the economy always is in a quasi-equilibrium state, the two terms

$$\frac{1}{M} \sum_{t=t-\tilde{M}}^{t+\tilde{M}} y_{t+1} y_t - \bar{y}_t^2 \approx 0 \quad ; \quad \frac{1}{M} \sum_{t=t-\tilde{M}}^{t+\tilde{M}} y_{t+1} - \bar{y}_t \approx 0 \tag{3.8}$$

cancel. These terms therefore yield the difference between a quasi-static approach and the dynamic approach.

Step 3

Using the parameters p_t, q_t for $t = 1,2,\ldots,T$ the time-dependent macroeconomic potential can be set up according to (2.3)

$$v_t(t) = \frac{y^4}{4} + \frac{p_t\, y^2}{2} + q_t\, y \; . \tag{3.9}$$

which yields the macroeconomic force (2.2)

$$F_t(y) = y^3 + p_t y + q_t \tag{3.10}$$

The structural equilibrium values of the economy y_{et} are now determined by the condition that according to the definition of the potential the macroeconomic force vanishes

$$F_t(y_{et}) = 0 \quad \rightarrow \quad (y_{et}) \tag{3.11}$$

It depends on the criterion $D > 0$ or $D < 0$ whether one or two minima are found at time t.

Correspondingly, the degree of economic disequilibrium at time t

$$\Delta v_t = v_t(y_t) - v_t(y_{et}) \tag{3.12}$$

generated by the deviation $(y_t - y_{et})$ of the output variable from their equilibrium value can be computed.

Step 4

The underlying dynamic process (2.2) can also be used for predictive purposes. A dynamic forecasting of the output variable y caused by structural effects yields

$$y_{t+1}\,|_{structural} = y_t + F_t\,(y_t) \tag{3.13}$$

However, we must always bear in mind that short-term fluctuations and business cycles are eliminated. Therefore, a total prediction of the macroeconomic output variable y has to take into account the short-term cycle effects (Schumpeter cycles), too.

$$y_{t+1}\,|_{total} = y_{t+1}\,|_{structural} + y_{t+1}\,|_{business\ cycles} \tag{3.14}$$

I think it is worthwhile to emphasize the joint work of Mensch, Weidlich and myself on the subject of business cycles in the book: Weidlich, Haag (1983).

4. THE DEPENDENCE OF THE POTENTIAL PARAMETERS ON CERTAIN INPUT VARIABLES

In this section we make a first step towards a theoretical derivation and explanation of the coefficients p_t and q_t. It may be promising to analyze the correlation between the potential parameters p_t, q_t and possible relevant input variables Ω_α, $\alpha = 1,2,\ldots,A$ creating the dynamic structure. Then the following standard method can be applied: let $p^e(t), q^e(t), t = 1,2,\ldots,T$ be the empirically determined potential parameters according to (3.3), (3.4) and let $\Omega_\alpha(t), \alpha = 1,2,\ldots,A$ be properly standardized empirical macroeconomic input variables net of linear (or nonlinear) trend with time, in the time interval $t=1,2,\ldots,T$ under consideration. A tentative theoretical linear relation between the potential parameters and the input variables can then be assumed:

$$p^{th}(t) = \sum_{\alpha=1}^{A} a_\alpha \Omega_\alpha(t) \tag{4.1}$$

$$q^{th}(t) = \sum_{\alpha-1}^{A} b_\alpha \Omega_\alpha(t) \quad , \quad t = 1,2,\ldots,T$$

Between the empirical potential parameters $p^e(t), q^e(t)$ and its theoretical expression (4.1) there will exist a random deviation

$$\eta_p(t) = (p^e(t) - p^{th}(t)) \quad , \quad \eta_q(t) = (q^e(t) = q^{th}(t)) \ . \tag{4.2}$$

The $\eta_p(t), n_q(t)$ have to be minimized by an optimal choice of the coefficients a_α, b_α in (4.1). The principle of the least sum of squares then yields

$$\frac{\delta G_p\,(a_{1,\ldots,}\,a_A)}{\delta a_\alpha} = 0 \tag{4.3}$$

$$\frac{\delta G_q\,(b_{1,\ldots,}\,b_A)}{\delta b_\alpha} = 0 \qquad \alpha = 1,2,\ldots,A \ .$$

with

$$G_p(a_1,\ldots,a_A) = \sum_{t=1}^{T} [p^e(t) - \sum_{\alpha=1}^{A} a_\alpha \Omega_\alpha(t)]^2 \tag{4.4}$$

$$G_q(b_1,\ldots,b_A) = \sum_{t=1}^{T} [q^e(t) - \sum_{\alpha=1}^{A} b_\alpha \Omega_\alpha(t)]^2 \ .$$

The evaluation of (4.3) leads to the set of linear equations for the a_α, b_α

$$\sum_{\alpha=1}^{A} c_{\beta\alpha} a_\alpha = D_\beta^p \tag{4.5}$$

$$\sum_{\alpha=1}^{A} c_{\beta\alpha} b_\alpha = D_\beta^q \ , \qquad \beta = 1,2,\ldots,A$$

where

$$c_{\beta\alpha} = c_{\alpha\beta} = \sum_{t=1}^{T} \Omega_\alpha(t)\,\Omega_\beta(t) \tag{4.6}$$

and

$$D_\beta^p = \sum_{t=1}^{T} p^e(t)\,\Omega_\beta(t) \ , \tag{4.7}$$

$$D_\beta^q = \sum_{t=1}^{T} q^e(t)\,\Omega_\beta(t) \ , \qquad \beta = 1,2,\ldots,A$$

The correlation coefficients $r_p(p^{th}, p^e)$ and $r_q(q^{th}, q^e)$ can be used as a measure for the agreement between $p^{th}(t)$ and $p^e(t)$ as well as between $q^{th}(t)$ and $q^e(t)$. Also the signficance of certain input variables can be tested proceeding in this way.

Concrete choices of the input variables can now be made in order to test their significance and influence on the macroeconomic potential. Candidates for relevant input variables $\Omega_\alpha(t)$ are – total investment, investment structure, number of working hours, energy consumed, birth- and death rates, technological innovations... (see also Casetti 1981, Delbeke 1981, Dendrinos 1981, Forrester 1977, Freeman *et al.* 1982, Kleinknecht 1981, Mandel 1980, Mensch 1979, Nijkamp 1982, Wilson 1981).

5. THE MACROECONOMIC POTENTIAL OF THE FRG AND THE USA

In this final section we demonstrate some aspects of the numerical evaluation of the model. For the empirical analysis we consider the economy of the Federal Republic of Germany (FRG) in the years 1950 to 1981 (Figures 3-6) and the economy of the United States of America (USA) in the years 1948 to 1979 (Figures 7-10). We chose as representative output variable the net production of the FRG and the USA standardized and net of trend. Since the duration time of business cycles is about 4 to 5 years a filter length of $M = 5$ years seems to be adequate to exclude or render irrelevant the short-term fluctuations. Let me present only a few results without going into deeper interpretation. This will be done in detail in our book Mensch, Haag and Weidlich, The Schumpeter Clock, forthcoming with Ballinger, Cambridge, Mass.

Figure 3 shows the macroeconomic potential of the FRG. The solid lines represents the observed time path of the net production. During 1950 to 1965 the economy moves in a monostable smooth potential (post war time, Wirtschaftswunder), while afterwards the structural situation becomes much more complex and bistability occurs (1969 to 1975 Flatterkonjunktur). Phase transitions can be identified from Figure 6 in the years 1967-68. (high -> low), 1970-71 (low -> high) and 1974-75 (high -> low). Comparing the observed path of the production with the macroeconomic driving force (Figure 5) the structural phase transitions can be explained. Nevertheless, it is worthwhile to emphasize that phase transitions (in the bistable region) can be triggered by business-cycles. Business cycles must not be neglected if we want to understand our position today.

In Figure 6 the potential parameters p, q for the FRG are shown. Towards a better understanding of the dynamics of p, q an analysis according to Section 4 seems to be adequate. This will be done in our book mentioned above.

Compared with the FRG, a totally different behavior is met with the macroeconomic potential of the USA in Figure 7. Since, according to Figure 8 the potential parameters p,q of the USA move for a long period of time in a critical region, business fluctuations are much more enhanced compared with the FRG.

The structural force of the USA shows enhanced oscillations between 1948 to 1960 with a period of 2 years. These short-time oscillations are afterwards (1960 to 1972) damped out and cycles of about 4 to 5 years occur.

Figures 7, 10 also demonstrate that there was a structural economic problem in the USA in the years 1958 to 1964 which cannot be observed in the FRG at that time. In contrast to the FRG, the structural potential of the USA shows bistability in the years 1948 to 1965.

Phase transitions in the bistable region of the potential are again triggered by the business cycles.

In Figure 10 the potential parameters p, q for the USA are depicted. The structural variations of p, q should also be analyzed according to Section 4. Since it is reasonable to assume that the same socioeconomic interactions are responsible for the macroeconomic potential the same set of input variables should be relevant. This provides a further test of consistency of the model.

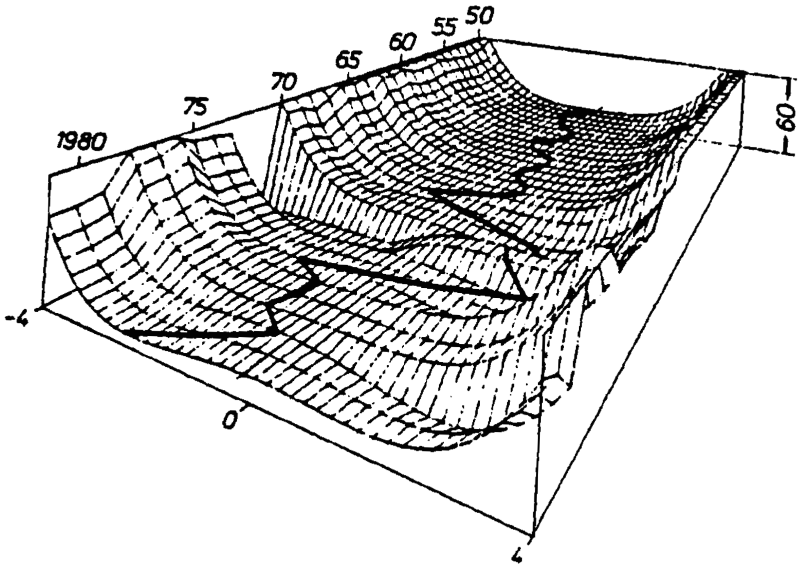

Figure 3 The macroeconomic potential of the FRG.

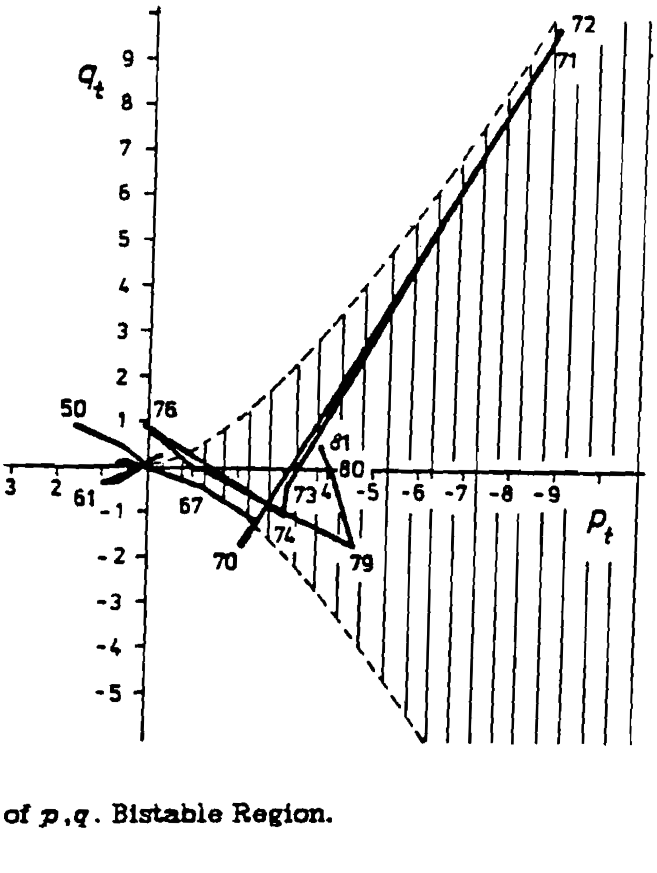

Figure 4 Parameter space of p,q. Bistable Region.

Figure 5 Macroeconomic force of the FRG.

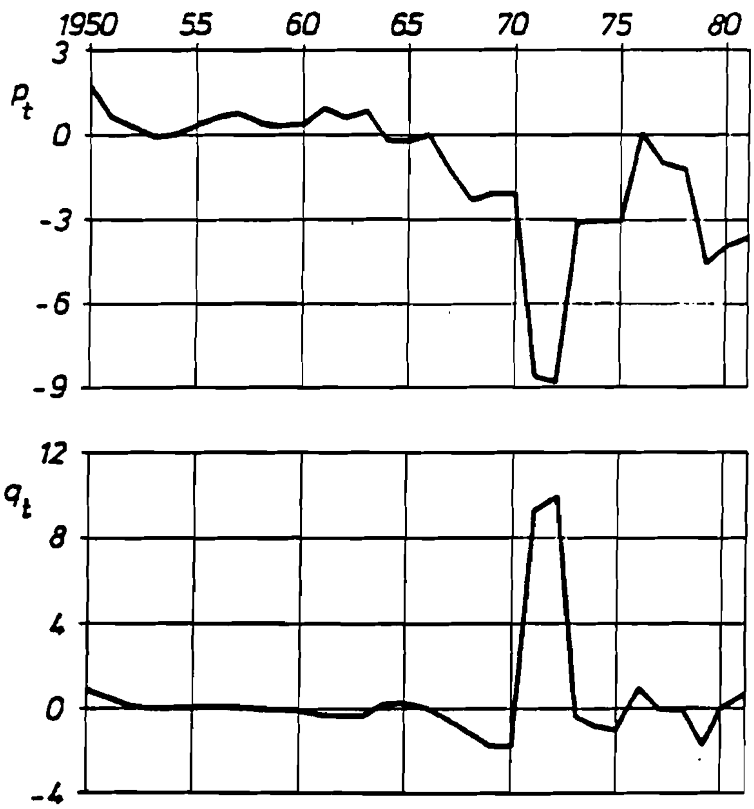

Figure 6 Potential parameters p_t and q_t of the FRG.

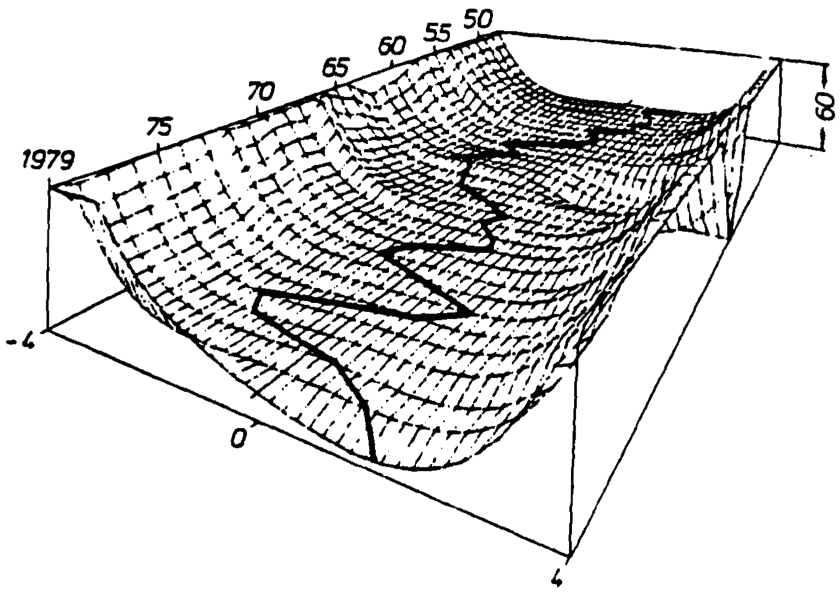

Figure 7 The macroeconomic potential of the USA.

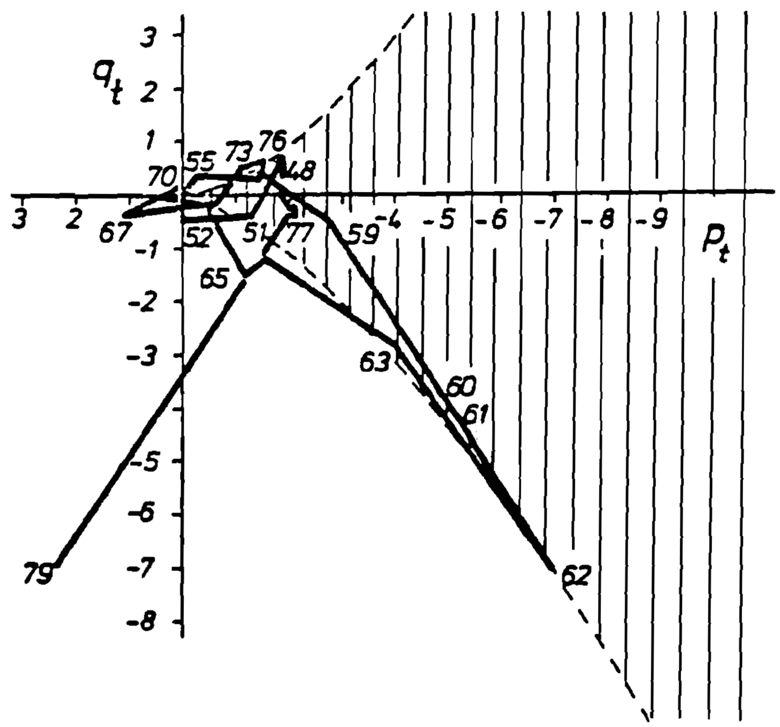

Figure 8 Parameter space of p, q. Bistable Region.

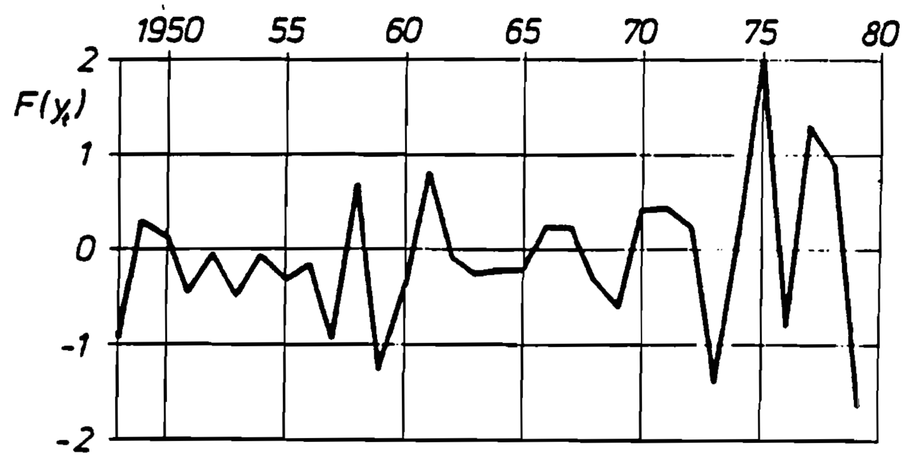

Figure 9 Macroeconomic force of the USA.

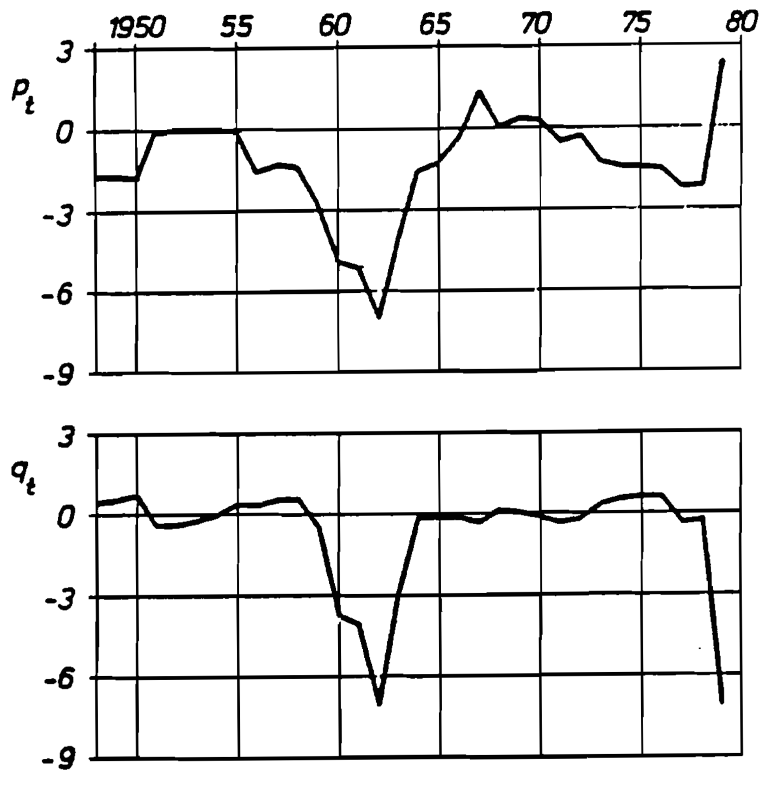

Figure 10 Potential parameters p_t and q_t of the USA.

REFERENCES

Casetti, E. (1981) Technological Progress, Exploitation and Spatial Economic Growth: A Catastrophe Model, *Dynamic Spatial Models* (D.A. Griffith and R. Mackinnon, eds.), Sijthoff and Noordhoff, Alphen aan de Rijn.

Delbeke, J. (1981) Recent Long-Wave Theories: A Critical Survey *Futures* Vol. 13.

Dendrinos, D.A. (ed.) (1981) *Dynamic Non-Linear Theory and General Urban/Regional Systems* School of Architecture and Urban Design, Lawrence, Kansas.

Forrester, J.W. (1977) Growth Cycles *De Economist* Vol. 125.

Freeman, C., J. Clark and L. Soete (1982) *Unemployment and Technical Innovation* Frances Pinter, London.

Kleinknecht, A. (1981) Observations on the Schumpeter Swarming of Innovations *Futures*.

Mandel, E. (1980) *Long Waves of Capitalist Development* Cambridge Univ. Press, Cambridge.

Mensch, G. (1979) *Stalemate in Technology* Ballinger, Cambridge.

Mensch, G., G. Haag and W. Weidlich (1984) (forthcoming) *The Schumpeter Clock* Ballinger, Cambridge.

Nijkamp, P. (1982) Long Waves or Catastrophes in Regional Development *Socio-Economic Planning Sciences* Vol.16.

Perez, C. (1983) Towards a Comprehensive Theory of Long Waves, Paper presented at the IIASA/IRPET Meeting on "Long Waves", Siena-Florence.

Weidlich, W., and G. Haag (1983) *Quantitative Sociology* Springer Series in Synergetics, Vol. 14.

Wilson, A.G. (1981) *Catastrophe Theory and Bifurcation* Croom Helm, London.

LONG WAVES IN A LARGER CONTEXT

Johann Millendorfer

The Study Group for International Analysis, 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 results of the investigations build a framework for the understanding of various issues and for conditioned forecasts.

In the question of structural change we arrived at the issue of long waves in the societal development. To this issue STUDIA has three approaches:

- Oscillations from growth reducing (self-inhibiting) factors;
- A socio-psychological feedback system;
- Main-Plane-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.

INTRODUCTION

In Schumpeter's approach to the problems of long waves, innovations play an important role. He stated that the beginning upswing is characterized by new technologies. Mensch observed clusters of innovations, which support Schumpeter's hypothesis. The call for new technologies becomes now very common as the only possibility for a new upswing and the preconditions for innovations are a question widely discussed.

In our approach we understand economic development as a collective learning process: inventions and their applications in innovations are results of this learning process. In this context this paper is concerned with the questions: What are the economic circumstances for the necessity of new technologies? Where are the limits for the old technologies? Where are the roots of the creativities for new technologies? Investigating these questions we find also new insights into mechanisms leading to long-term oscillations.

In the first chapter a scope of this learning process on the base of marginal productivities is described. Starting from empirical observations which show that on the one side the marginal productivity of labor is deciding for the competitiveness in industrial countries and that on the other side the marginal productivity of labor is closely connected with innovations, it can be shown that innovations govern the worldwide distribution of labor. For this reason industrialized countries are forced to innovations. Until now innovations have been understood in a rather narrow technical sense. In the second and the following two sections it is shown that noneconomic factors influence negatively the economic efficiency and achievement of the industrialized countries and that this leads under certain circumstances to oscillations and a downswing. To minimize this downswing it is necessary to extend the concept of innovation beyond the pure economic and technical field. Here we need new paradigms.

STRUCTURAL CHANGE, MARGINAL PRODUCTIVITY AND CHANGING INTERNATIONAL DISTRIBUTION OF LABOR

In a study for UNIDO 'Future Structural Changes in Austrian Industry' (STUDIA Research Report to UNIDO 1979) STUDIA found that since the mid-seventies competitiveness in industrialized countries is determined no longer by capital intensity alone but rather by a high qualification of labor. The qualification of labor was measured as marginal productivity of labor derived from sectoral production functions (Millendorfer 1977).

Three categories of marginal productivities were quantified: total marginal productivity of labor, the marginal productivity of labor without higher education and the marginal productivity of labor with higher education. The relations between the three categories of qualification of labor differ from branch to branch; the functions of the three categories are different. The total marginal productivity of labor is deciding for the development of the economic branches. Forecast of STUDIA on this base for all branches were fully verified later.

In the research report it was shown that the qualification of labor is the higher the earlier the stage is which the respective learning technology has in the product cycle. An early stage in the product cycle is based on innovations. So we can say that since the mid-seventies innovations are the deciding precondition for competitiveness in industrialized countries based on a high qualification of labor and/or on a high marginal productivity of labor.

Developing countries have better comparative advantages in the late stage of the product cycle with relative low marginal productivity of labor. Our empirical investigations show that the international distribution of labor changed in this direction with an increasing gap of qualification of labor between industrialized and developing countries. Details about the impact of qualification of labor in the process of economic development can be seen observing the two components:

The marginal productivity of labor without higher education, it means the qualification of the manual labor of the skilled workers at the machine, which has been very important for the economic development until the mid-seventies is now less important than the other component described below. It is only in few branches (e.g. furniture) essential for competitiveness.

In most branches the marginal productivity of higher education is not only important for competitiveness but contributes, in addition, essentially to the economic development of a whole region (Millendorfer 1983a). We interpret these empirical observations so, that the external components of the societal

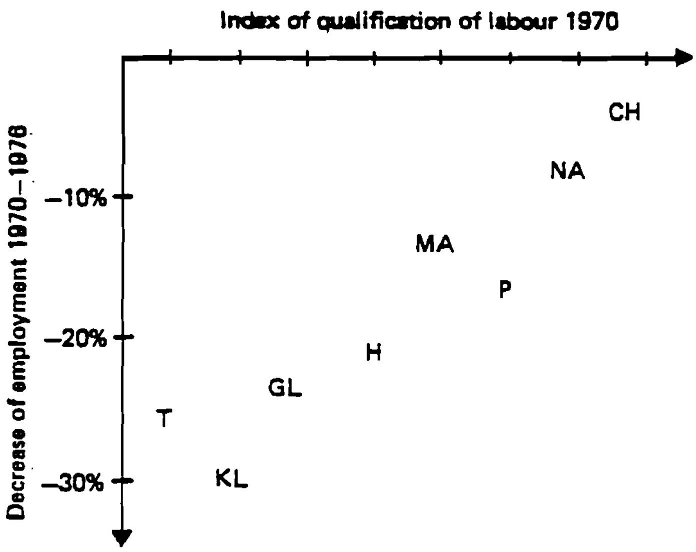

Figure 1 Fulfilled Prognosis – Abscissa: forecasts on the basis of marginal productivity (qualification of labor); Ordinate: actual development of employment. *Source:* "Future Structural Changes in Austrian Industry," STUDIA-Report to UNIDO, Vienna 1979. *Branches:* CH – Chemical, GL – Stone, glass; H – Wood; KL – Clothing; MA – Machinery; NA – Food, Luxury food; P – Paper; T – Textile.

informations processing of a firm plays an important role in the learning processes in the economic environment of the firm. In the current situation of dramatic structural changes these learning processes are of a vital significance. They teach to find and apply new societal paradigms from which new technologies can be derived; the term technology understood in the widest sense of the word implying not only technical but also societal inventions, e.g. a new efficient style of management (Millendorder 1983b) or the optimal adaptation of new technologies to the societal demand. Even more as the inventions and technical development of new technologies the adaptation of new – and some of the old – technologies to the societal demand according to quite new paradigms is the most challenging task in this time.

Summarizing we can say that due to the changes in the international distribution of labor the industrialized countries experienced a reduction of their growth rates becase of losses of market shares in the routine technologies. Therefore they are forced to innovations. In this situation it is an essential additional fact that even now the fruitfulness of the existing paradigms of the economic-technological development arrived to an end due to growing negative impacts and that these negative factors lead under certain conditions to a downswing which can be understood in the context of long waves This is shown in the following chapter.

OSCILLATIONS FROM GROWTH REDUCING FACTORS

A research order of the Institute of World Economics, Kiel about institutional determinants of economic growth (Millendorder 1980) led in the first step to an empirical investigation of the relationship between growth rates $dy/dt/y$ and GDP per capita y.

We have observed in various cross sections negative correlations between these two variables.

Describing mathematically this relationship (compare Millendorfer 1982) we get the following equation:

$$\frac{dy/dt}{y} = a - by \tag{1}$$

or

$$\frac{dy}{dt} = y\,(a - by) \tag{2}$$

Equation (2) is a Bernoullian differential equation with the solution

$$y = \frac{e^{at}}{c + (a/b)(e^{at} - 1)} \tag{3}$$

This is the logistic curve with the ceiling $y_{\infty} = (a/b)^{-1}$. The term by in the expression $(a - by)$ in equation (2) can be interpreted as a factor linearly growing with y and with a negative impact to growth. We call it a growth reducing factor z.

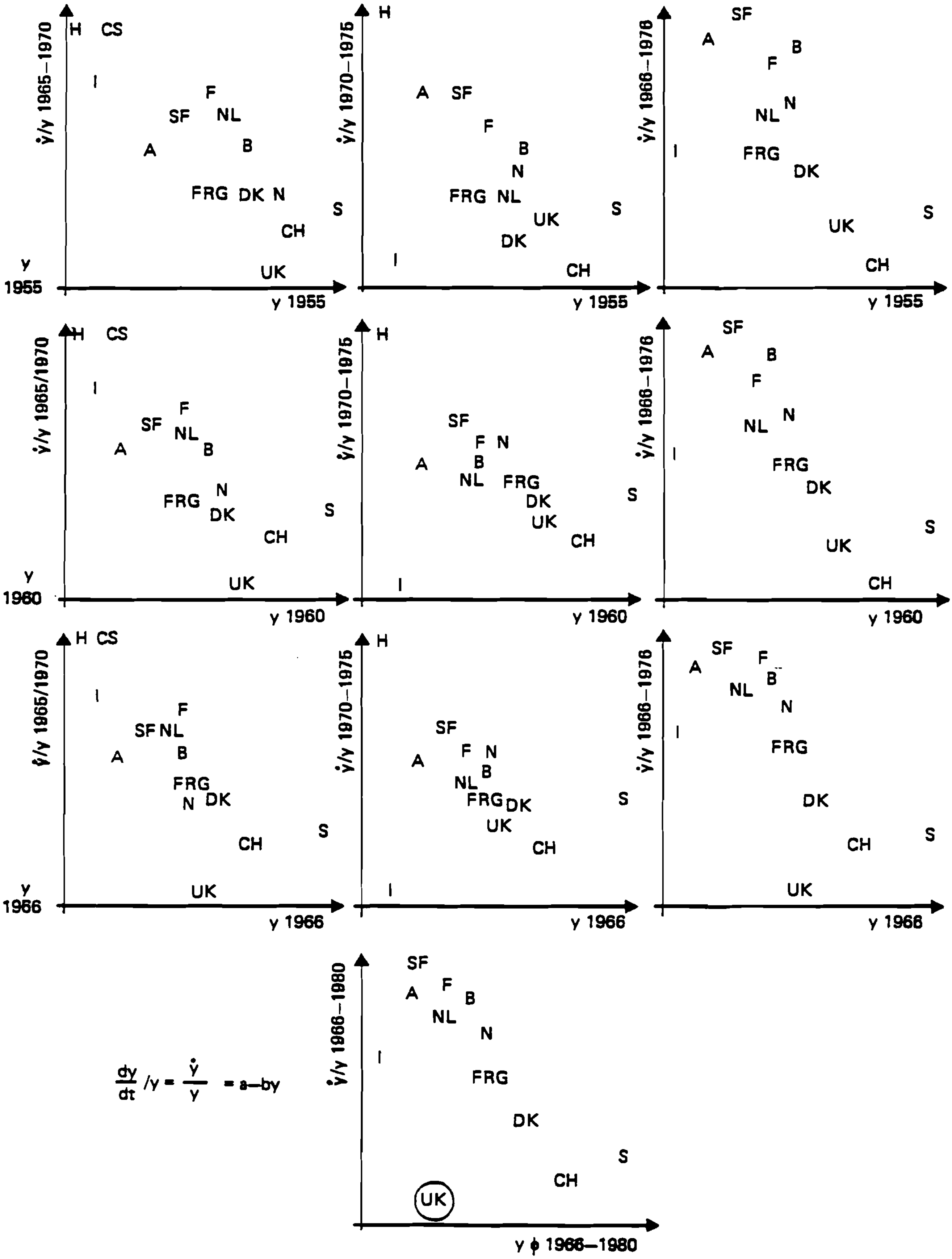

Figure 2 Per capita income y and growth rates $\dot{y}\ /\ y$

Now we can ask if there exist more than one growth reducing factor. In our empirical inquiries we have found various variables $z_1, z_2, z_3,...$negatively correlated with the growth rates. If we combine these factors in a function $g(z_1, z_2, z_3,...)$ we get a better explanation of the decrease of the growth rates.

Equation (2) now can be rewritten as:

$$\frac{dy}{dt} = y\,[a - g\,(z_1\, z_2\, z_3\, \cdots)] \tag{4}$$

We call the function $g(z_1 z_2 z_3 \cdots)$ as growth reducing function. It is important to analyze the form of this function, because on one side the analytical form of this function decides about the dynamic behavior of the societal system. On the other side the form of dependency of growth reducing factors from GDP per capita (y) is deciding for future economic development.

If the growth reducing function is linear, e.g. if

$$g(z_1, z_2, z_3...) = k_1 z_1 + k_2 z_2 + k_3 z_3 = \sum k_i z_i \tag{5}$$

and the growth reducing factors z_1, z_2, z_3... depend linearly on y

$$z_1 = c_1 y,\ \ z_2 = c_2 y,\ \ z_3 = c_3 y \cdots \quad z_i = c_i y \tag{6}$$

then we still have the Bernoullian equation:

$$\frac{dy}{dt} = y\,[a - (k_1 c_1 + k_2 c_2 + k_3 c_3 + ...)\,y\,] = y\,[a - \sum k_i\, c_i\, y\,] \tag{7}$$

and as a solution the above mentioned logistic curve.

If the growth of the growth reducing factors depends on the time integral y

$$\frac{dz_i \,/\, dt}{z_i} = b + c_i \int_{-\infty}^{t} y\,(s) k_i\,(t - s) \quad (k_i \cdots \text{kernel}) \tag{8}$$

then we have a case of Volterra's differential equation which has as a solution cyclic oscillations or waves.

Equation (2) is well founded on empirical data for OECD countries. Very high significance is obtained if the z_i are variables describing: undue expansion and bureaucratization of the public sector, too big units ruled in an excessively centralistic way, too much levelling, sinking moral standards, disturbance of the equilibrium between the relation to things, to human beings and to sense.

The other question whether the growth reducing factors depend on the GDP/cap.(y) according to equation (6) or equation (8) is not very clearly answered by the empirical observations. Some of the variables are more or less positively correlated with the GDP/cap according to equation (6). Other variables follow in their growth rather equation (8). Both relationships are not very significant. In the first case the solution of the Bernoullian differential equation would be a logistic curve, in the second case the solution would be cyclic oscillations. According to the empirical observations of the dependency of the growth reducing factors z_i on y and $\int y dt$ a mix of the two cases seems to be most probable.

In any case the political conclusions are similar. In the first Bernoullian case the ceiling of the logistic curve indicates an end of the fruitfulness of the old paradigms of the former period; a new upswing is only possible on the base of new paradigms. In the second case the downswing of the oscillation is caused by the same reasons; only the anticipation of the new paradigms of the coming upswing can reduce the downswing. In addition in this case the impact of the growth reducing factors must be diminished by investments for this purpose. This new form of investment leads also to returns if the costs for diminishing the growth reducing factors are smaller than the gain due to improved efficiency.

Summarizing we can say that we have empirical evidence that growth reducing factors contribute to the decline of economic growth. Investigating details of the process we arrived at differential equations. The form of the solutions is determined by the form in which the growth reducing factors depend on the level of economic performance or on the time integral of wealth. In the latter case we have oscillations.

Somebody asked me in this Conference if I am for or against long waves. I would say I am certainly against long waves but our empirical observations and their theoretical interpretations show that we cannot escape from the problems caused by negative factors which lead to a ceiling or to a downswing five or six decades after the last downswing of the first crisis of the world economy. For applied systems analysis the question of long waves is not so much a theoretical issue but rather a challenge to the practical economic problems we have to cope with.

MAIN-PLANE-ANALYSIS

In a quite new field where there is no mature theory, we have to be careful in deriving a hypothesis from empirical data. The best way to cope with this difficulty is a redundancy in an abundance of empirical observations. Here a difficult questions arises: How to handle the mass of data. We developed a new formal method of multivariate analysis, the Main-Plane-Analysis, which facilititates the theory building on a large empirical data base.[1] The results of M-P-Analysis plotted graphically show clearer the relationships between hard and soft variables. Long arrows represent variables which are explained with a high correlation by the eigenvectors of the plane. If two long vectors are parellel then they are correlated. Three long non parallel vectors are in a multiregressional relationship. Short vectors have bigger residuals to be explained by variables usually not in the plane. Knowing this formal relationship it is possible to derive from the

[1] M-P-Analysis can be described from two approaches, factor analysis and Cholesky-factorization. Factor analysis and M-P-Analysis are looking for $(n-k)$ dimensional spaces in the n-space. M-P-Analysis limits the dimension $(n-k)$ to 2 or 3 and is looking for different 2 or 3-dimensional spaces. Each space or main-plane explains a subgroup of the whole sample of variables. This subgroup and the interrelations of samples in it can be understood as issues, it means as subproblem. 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 (Millendorfer 1983a).

main-plane heuristic hypothesis with a high probability not to be falsified in detailed investigations. On this basis interesting mechanisms between soft and hard variables were found.

There are different main-planes which are related to certain issues: One main plane is related to the issue policy and social psychology, another to the issue of economy and institutional structures, etc. The investigation of the relationship between the main planes 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. 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 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 plane during 20 years.

The following figures show possibilities for empirical estimation 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 for 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 activities. An interesting possibility is to analyze in this way oscillations of the form of government activities in long waves. The turning vector of divorces leads to another issue described in the following chapter.

SOCIOPSYCHOLOGICAL MECHANISMS

A Sociopsychological Feedback System

A macropsychological investigation of the situation of the family in Europe (STUDIA 1977) 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 on 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. The following Figure 8 gives insights in details of of sociopsychological feedback system.

The feedback system in the centre of Figure 8 works in the sequence: (high) quality of family → (high) achievement motivation → (high) systems performance → dominance of the system over the human area → decreasing quality of family → decreasing achievement motivation... The feedback system has a delay of 25-30 years. This delay could be understood as something like an anthropological constant caused by interrelationships between generations. The delay leads to cyclical oscillations with a length of 50-60 years.

Figures 8(a), 8(b), and 8(c) show the empirically observed relationships in the feedback system: 8(a) the positive relationship between per capita income and achievement motivation three decades before and 8(b) respectively 8(c) the negative relationship between quality of family and achievement motivation three

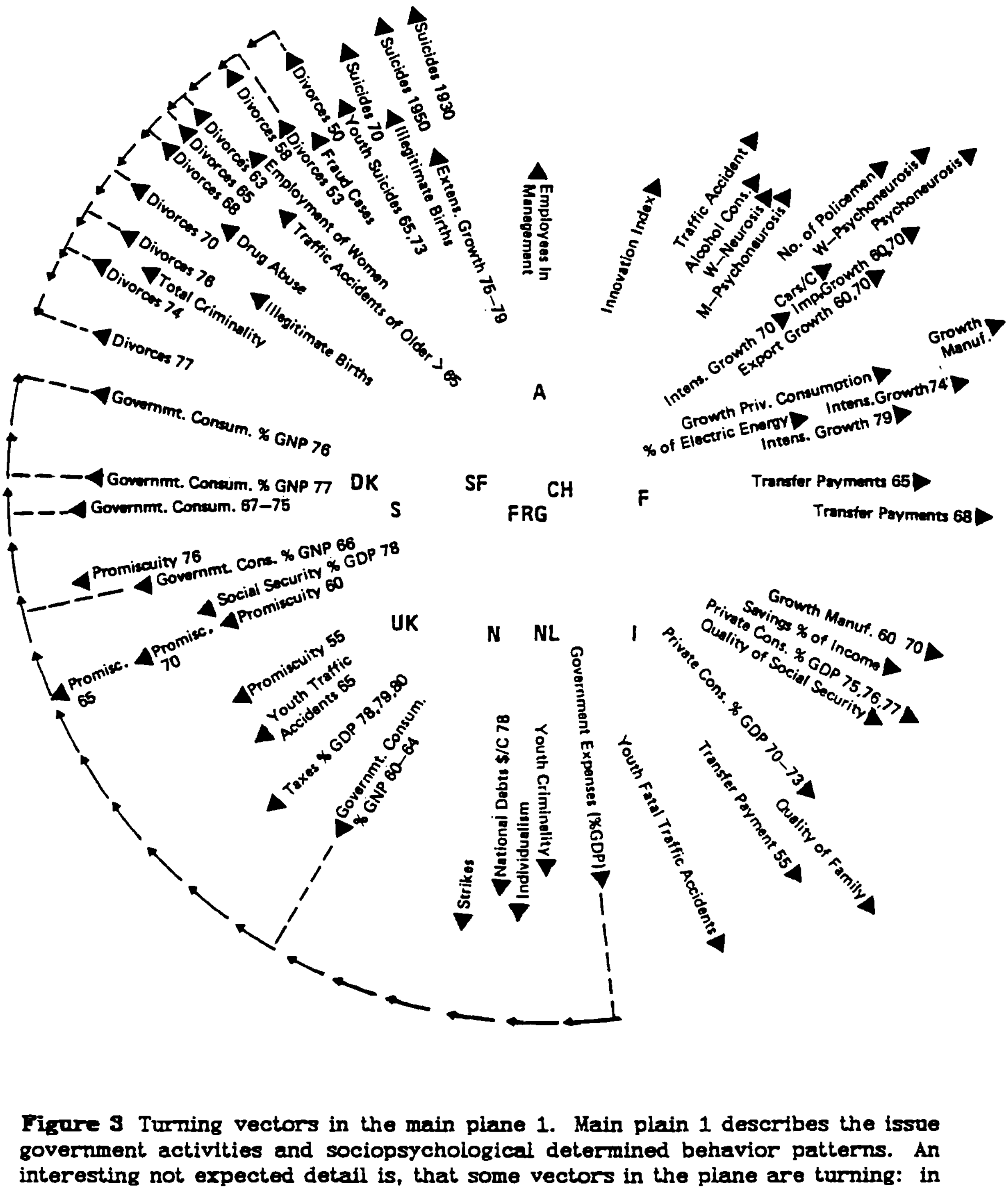

Figure 3 Turning vectors in the main plane 1. Main plain 1 describes the issue government activities and sociopsychological determined behavior patterns. An interesting not expected detail is, that some vectors in the plane are turning: in the 50's government activities and an indicator for the quality of family were nearly parallel and the vector of divorce had the opposite direction. In the following decades the vectors of government activities and divorces turnes in an opposite direction so that now government activities and divorces are nearly parallel.

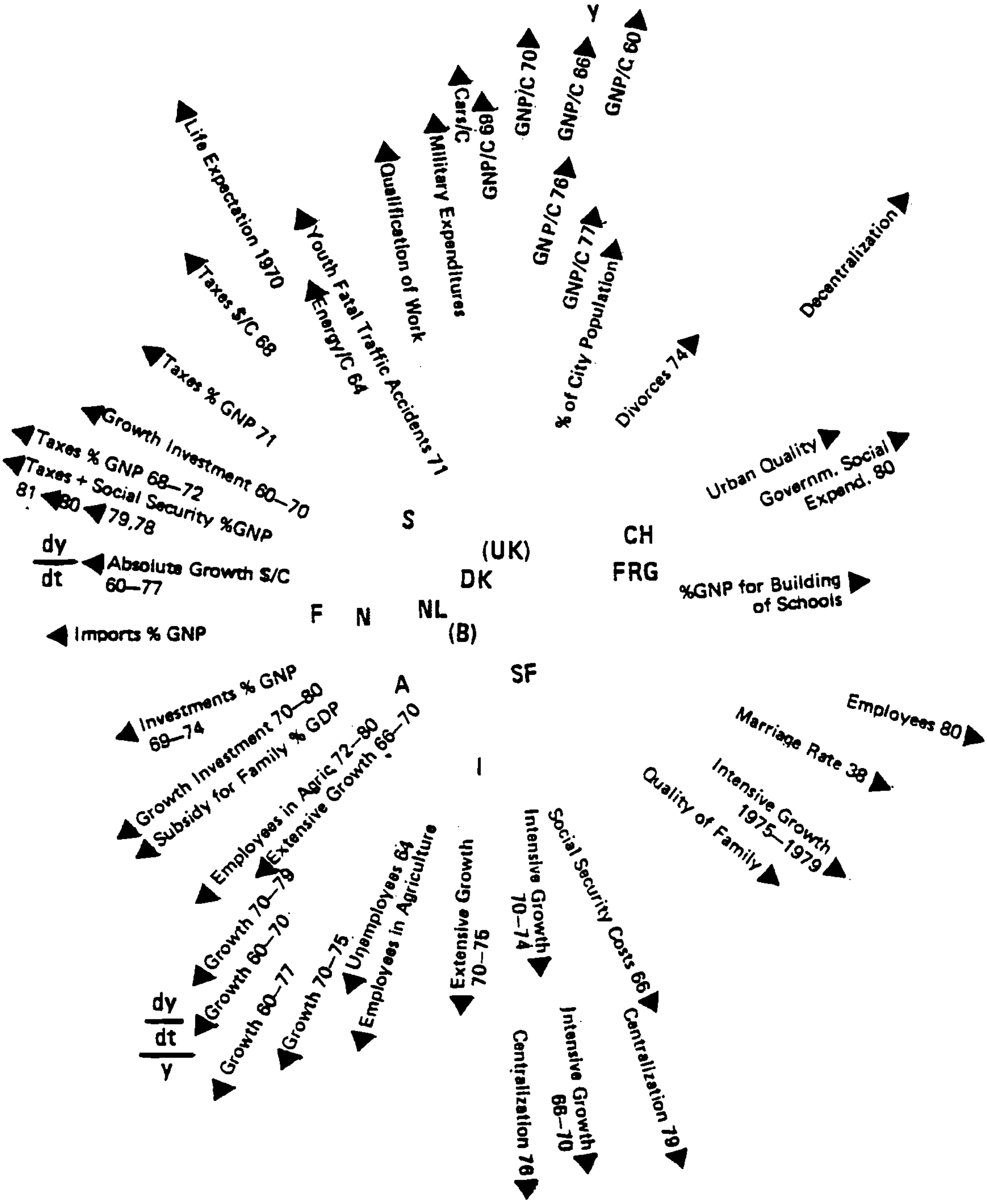

Figure 4 Main Plane with the issue economy, economic growth, bank dynamics, big units, etc. The various variables are interdependent. The kind of linear dependency is expressed in the direction of the arrows. The degree of dependency is shown by the length of the arrows. The main plane contains also y (GDP per capita) and integrals and derivations of y. Transforming the arrows into equations we obtain differential equations.

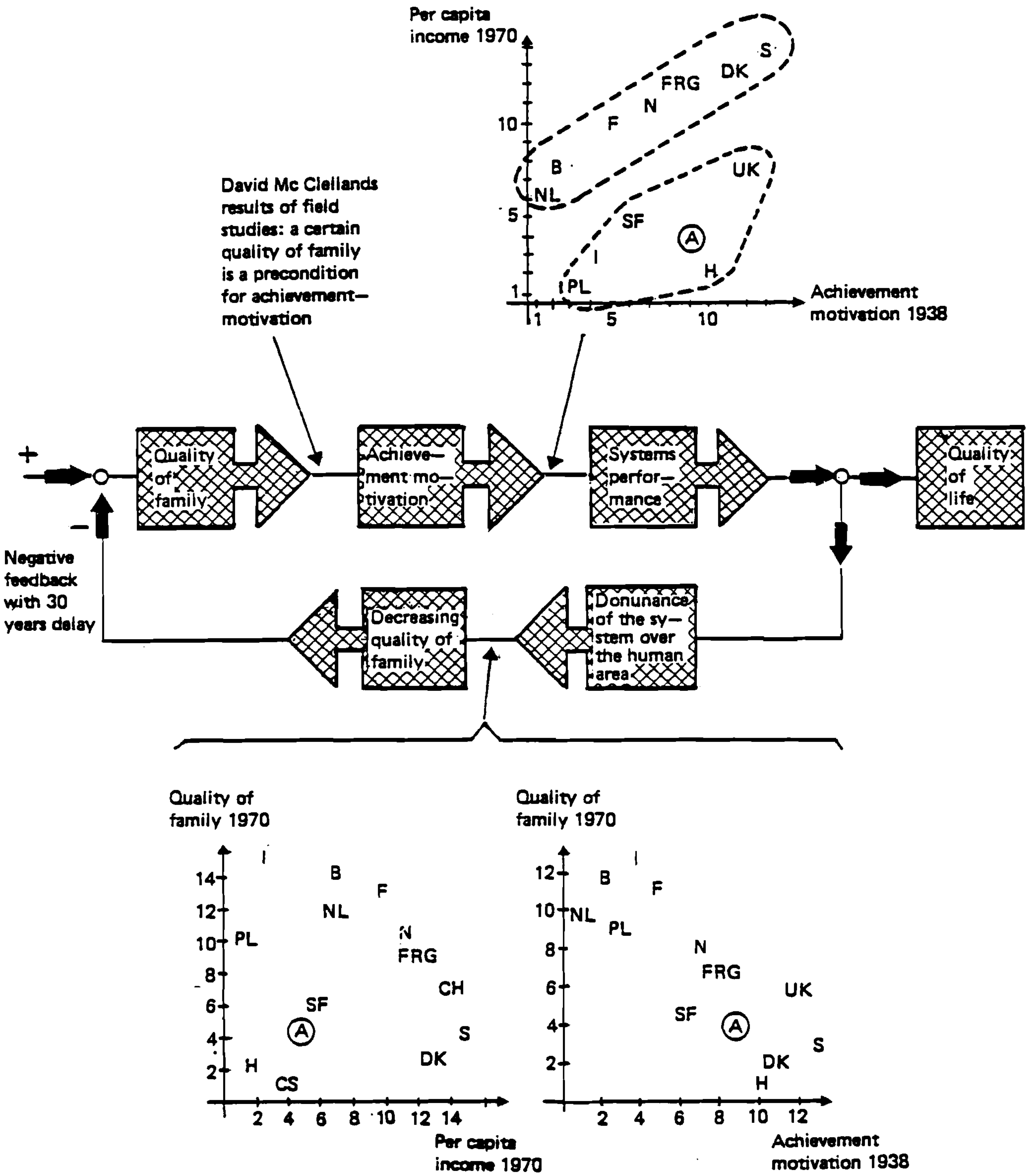

Figure 5 Figures 5a, 5b, and 5c show the empirically observed relationship in the feedback system: 5a the positive relationship between per capita income and achievement motivation three decades before; 5b and 5c respectively the negative relationship between quality of family and achievement motivation three decades before respectively per capita income at the same time (two efficiency zones).

decades before respectively per capita income at the same time (two efficiency zones).

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

Another empirical support for the existence of such oscillations come from Marchetti. He observed cycles of suicides with a length of 54 years (Marchetti 1983). Suicides are correlated with divorces as Dürkheim discovered with investigations on the base of individual data. With country comparing investigations we found also a positive correlation between suicides, divorces and the indicator for the quality of family. If one of the variables oscillates the other variables should also do so. So Marchetti's observation fits very well in our framework of oscillations.

In this framework the concept of desublimation is also integrated: The quality of family is negatively correlated with promiscuity and positively with sublimation, it means – according to Freud's thesis[2] – with high creativity. Therefore we have to expect from our sociopsychological feedback system not only oscillation of achievement motivation but also oscillations of creativity.

This interrelated framework of long waves in the living area caused by a sociopsychological feedback system and the turning vectors in the main plane I opens a new approach to understand economic long waves in a larger context. One important link between the two long waves comes from the relationship between creativity and innovations.

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

At the present state of the art we cannot reject the hypothesis that oscillations of creativity and achievement motivation contribute to the innovational waves with the same length of the cycles namely around 60 years.

Maybe the future empirical investigations falsify one or the other part of the outlined sociopsychological feedback system; we are sure that the basis of our framework will hold especially the hypothesis that the length of the long waves is determined by something like anthropological constant – based on interrelationships between generations.

INNOVATION, CREATIVITY AND SUBLIMATION

In the Conference 'Toward Explaining Economic Growth' in Kiel 1980 Lord Vaizey asked an interesting question to this issue: Is Freud's thesis that sublimation is a precondition for cultural creativity also true for all kinds of creativities including creativity for technical and economical innovation? (Millendorfer 1983b). To answer this question it is necessary to have a measure for sublimation, or for the lack of sublimation ('desublimation'). In the understanding of Freud sublimation means that sexual tribes are under moral control. The opposite is

[2] See next section.

desublimation due to promiscuity as it grew strongly since the early seventies.

STUDIA developed an indicator for desublimation (Millendorfer 1979). This enables us to answer the question of Lord Vaizey. A comparison of the indicator of desublimation with growth rates shows a negative correlation. Even more important is the relationship with the two components of growth namely extensive and intensive growth. While extensive growth rates show no correlation intensive growth rates correlate negatively with desublimation (Figure 6).

Intensive growth rates are caused by a more efficient use of the factor input due to technological progress. It means mainly due to innovations based on creativity. So we can interpret our observations as an empirical support for a positive answer to the question of Lord Vaizey.

All this may sound very strange, but it is typical for the paradigms of the ending period that human factors were neglected in economic considerations. The problem is also in our situation: We must understand economy looking beyond economy in a comprehensive holistic approach. In our holistic approach detailed interdisciplinary studies are interrelated and build together a framework for understanding of long-term societal mechanisms. In this sense it is interesting to see that the point 2 is a part of point desublimation is one component of the growth reducing factors 'sinking moral standards' and contributes as such to the oscillations. On the other side it is connected with the mechanism described in the previous section.

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 which are usually investigated and the soft variables describing socio-psychological and institutional circumstances; e.g. Schumpeter's description of long waves with the innovational upsurges cannot explain, why these occur 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 inventions have 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.).

CONCLUSIONS

If the outlined mechanism of long waves including hard and soft variables is close enough to reality then we can say that the length of the cycle is determined by something like an anthropological constant. It means that we have no

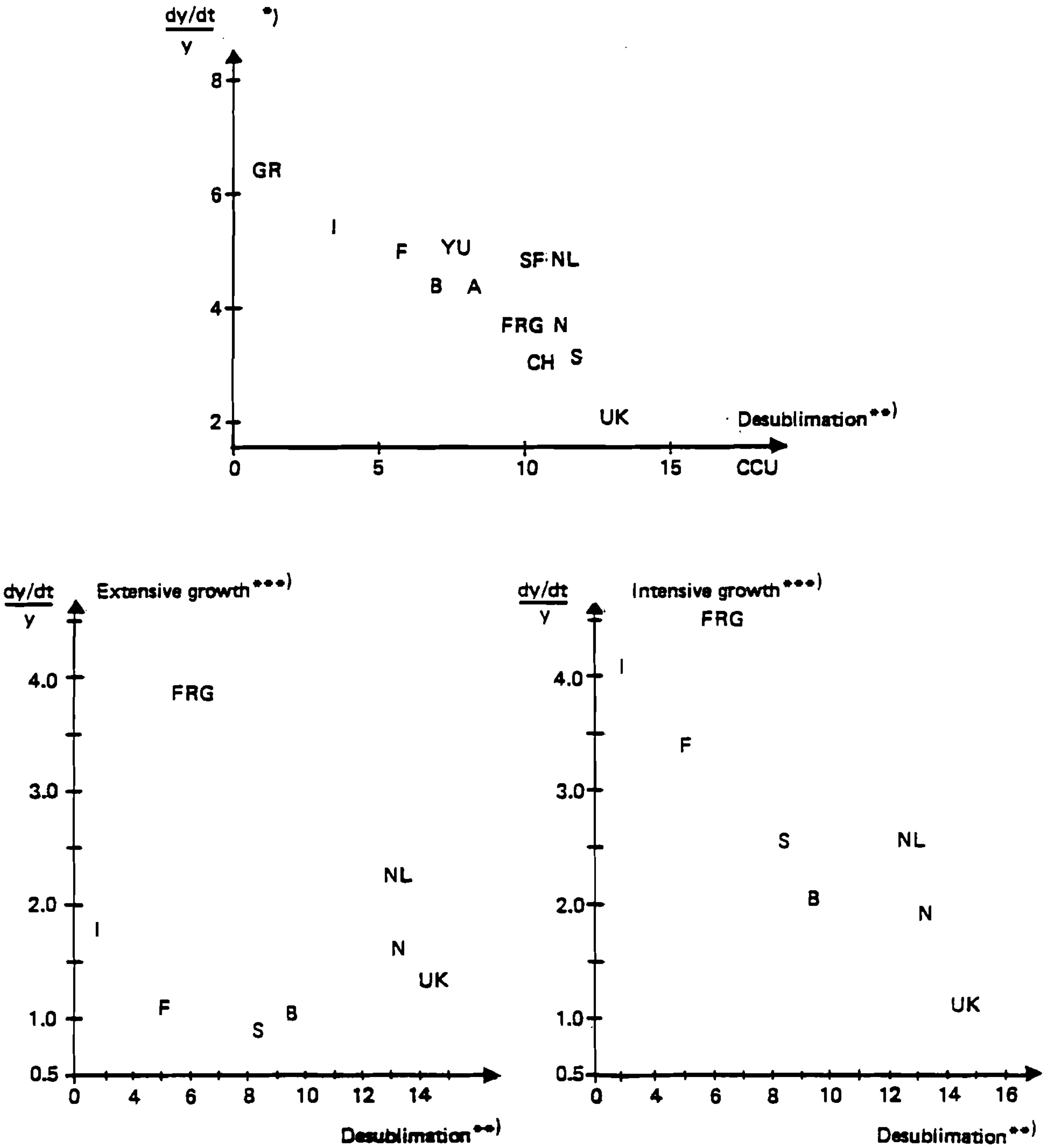

Figure 6 Freud's Hypothesis: Desubliminination — A Growth Reducing Factor. Desublimation as a growth reducing factor. Note that there is no relationship between extensive growth and desublimation and a negative correlation between intensive growth and desublimation. This can be interpreted with the help of Freud's hypothesis that sublimation is the precondition of creativity and our interpretation that creativity causes a new technological progress and efficiency.

*)Kravis/Heston/Summers: Real GDP per capita for more than 100 countries; *Economic Journal 88* (1978)

**)Age corrected death rate of cancer cervix uteri. WHO *World Health Statistics Annual.*

***)O.Aukrust: *Factors of Economic Development–A Review of Recent Research.* Productivity Measurement Rev. 11/65.

State of the long wave	'hard'	'soft'				
	Economic and technological variables	Concept of Government	Institutional Rigidity	Quality of Family	Achievement Motivation	Sublimation
upswing	Innovation new sectors increasing investment increasing employment	ethic	low		increas.	high
				high		
	Competition rationalization concentration capital goods overemployment	prag– matic ('rules of the game')	increas.		high	decreas.
top				decreas.		
	Increasing export overaccumulation capital intensity labour–saving–investment	welfare state	high		decreas.	low
				low		
	flight into money– and capital markets					
downswing	underinvestment		unstabl.		low	increas.
	unemployment	crisis	break down	increas.		

Table 1 Hard and Soft Variables in the Long Wave

instrumental variables, no political tool to change the length of the cycle. But what we can do is to minimize the amount of the downswing by anticipating the coming upswing. In other words: There is no chance to continue the old paradigms of the ending period but if we understand the new paradigms we can minimize the problems of the change from one period to the next period. In the following contures the principles of the coming upswing are outlined. They are based on analysis (Millendorfer *et al.* *1978)* and discussed in many conferences (Millendorfer

1983c).

THE HUMANE-ECONOMICAL PRINCIPLE

The disturbance of the equilibrium mentioned above is characterized by an overemphasis on things, compared with the importance of man. If we consider the boundary condition of a necessarily rising importance of man and certain phenomena that could already be observed in the beginning of the seventies, the necessity of a new understanding of economic principles becomes clear. The law of maximization of output with a minimum of input stays unchanged. The significance of the output has to be considered anew though. In times of a bottleneck in material goods output meant an increase of material products. Today the question concerning output has to be asked once more in those countries which are not suffering from the shortage of material goods any more. This will lead to a concept of higher quality of life guaranteed by the equilibrium of the relationships between things, man and sense. It requires a new attitude, that critically investigates value and importance of a given product according to its application in the sphere of life. The value of a product then is as high as it helps the consumer to create a sphere of life more valuable. According to the theory of the marginal utility the price of the product is defined to be the added improvement of quality of the sphere of life divided by the added increase of input of material goods and services:

$$P = \frac{dVe}{dIe}$$

P = prices

V_e =quality of sphere of life

I_e =input of economic sector into the sphere of life

This principle, though it looks so theoretical, has already been adapted to practical applications. Changes in urban planning are a vivid example. Ten years ago towns were understood to be systems whose functioning could be optimized by separating the spheres of life. Consequently emphasis was put on solving the problems of traffic, which enjoyed highest priority. Contrary to all technocratic planning, spheres of human dimensions have succeeded in the last years to grow more and more, e.g. the pedestrian zones. They not only have become centers of a new urban life, but also even centers of economic success.

To generalize the problem we should stress the urgent need of "pedestrian zones" in all fields. Pedestrian zones in management are organizatory structures that present only a dynamic framework for the essential: the human activities in groups that can be overlooked. Pedestrian zones in science will replace the usual monstrous conference by work-intense conferences that do not lose survey, as happened in our conference. Pedestrian zones in the medical field replace the treatment of so-called 'cases' in enormous factories of health by a concept of the patient as a human being. Many more examples can be given.

Another consequence rising from the humane-economical principle, which already has been quite fruitful, can be seen in various sectors: There is a definite trend, though, towards a consumers creativity. This new trend has become most obvious by the expansion of the 'do-it-yourself-sector'. Firms which are in charge of preparing this sector revive even in todays economic recession: they are producers of all kinds of hobby implements and semi-prepared products. Information services for hobby craftsmen are only starting to develop.

Revalorization of the sphere of life compared with the field of production and the exact inversion of the positions that were held by the so far dominating structural sphere and the sphere of life are the essential points in the humane-economic principle. It will not do any harm to the world of structure or the field of production, if this new trend is recognized and taken into consideration. The example of the hobby craftsmen mentioned above shows how activities that would cause added costs in the production process are shifted from the field of production to the sphere of life where they are carried out most willingly. This diminishes the costs and often customers are willing to pay even more, if they are given the opportunity to be creative.

THE PRIORITY OF IMMATERIAL FACTORS OVER MATERIAL FACTORS

The inquiries of STUDIA mentioned above have made obvious that from about the mid-seventies onwards competitive strength is not so much gained by the intensity of capital but by qualification of labor. The qualification of labor before and after the actual act of production, e.g. the social information processing, has prior significance. STUDIA has just completed a study of regional comparisons for Austria, which shows, that the external communication of establishments plays the major role. The task of the external communication of establishments is to adapt the technical production to the economic environment. The economic environment is constituted by the intermediary sphere that encloses the mutual relations between producers, as well as by the field of final demands, which implies the relationship to the consumers. The adaption to the economic and social environment is a collective learning process leading to social inventions.

The application of microelectronics is a vivid example to demonstrate the importance of social inventions. Text-processing machines can be brought into action in various ways: They may be installed in a central office for typists or in a secretary's office of each referee. In between these alternatives there may exist a third solution, namely to install a central bureau for tasks that appear occasionally. Each of these solutions naturally has different human and social consequences. The first example will lead to an alienation between referees and typists, the second one gives the typists a chance to use the time saved by the aid of the machines for creative secretary's work according to their personal disposition in narrow contact with the boss.

From this it follows that the hardware and the technical software which is strongly connected with the hardware are not sufficient in themselves, but that it is furthermore important to consider the social software brought about by the social modifications and inventions which inevitably take place, when new technologies are introduced. Changes are inevitable, the way these changes are taking place is not pre-determined, as shown in the example above. Normative decisions, which are independent of the technology, are necessary and only they will bestow technology with a kind of social significance, which then can be understood as being a positive or negative contribution to social development.

A very different way where the principle of priority of immaterial factors applies can be seen in the development of long-lived goods. The past epoch has developed a 'throw-away-technology', which led to an extensive use of raw materials and energy. Considering the limitation of the planet, this 'throw-away-technology' cannot be continued, but can be modified by production of long-lived goods. Longevity of goods is attainable by solid workmanship and qualified labor, by repairing-possibilities that are built-in by the designer, like in the 'modul-design', by a pleasing design, that outlasts the short-lived fashions, and by anticipation of a possible technical progress by help of modern principles of design, which would allow to invest further modernizations and modifications by exchanging parts of the system. The new principles of construction require the immaterial factors: creativity, initiative, qualification of labor, and reduce, by help of these immaterial factors, the exploitation of the material factors: energy and raw materials. Energy that was wasted so far by producing 'throw-away-goods' could be saved and could serve us as one of the greatest reserves of energy in industrialized countries.

FINELY STRUCTURED FORMATIONS RATHER THAN GIGANTOMANIA

One of the growth restraining factors mentioned above: units of exaggerated size, press hard on the industrialized countries, as can be seen with the so called 'ill giants', many great enterprises which are more and more running into trouble. This causes an increasing decentralization of the enterprises and the stressing of the importance of small and independent establishments, which are forced by the market forces to work with higher efficiency. Not the rejection of big firms on the whole is necessary, but a rejection of the overemphasis of big units by means of an ideological 'economy of scale'. A new outline concerning the division of work between big and small units becomes apparent, which defines the big units to be the infrastructure for small, independent units of high efficiency. The task of big units will be to coordinate the production of the small units; they will have to specialize in this function. Interesting new trials that tend in this direction are followed up, for example, by the Venture Capital firms.

The size of firms has been overemphasized not only for reasons of organization; technical reasons were of importance, too. One paradigm of the old, vanishing technologies represented the one-way direction of the stream of materials, starting from the extraction of mineral raw materials up to the deposition of refuse implying all the growing problems that were caused by garbage. This paradigm can be changed by introducing recycling methods, though not as a single, but as a series of recycling as can be learned from nature. It is not enough to let recycling come up incidentally, they have to be considered right from the beginning of design. The kind of refuse we have to cope with nowadays is a sheer by-product; in future times one will have to consider it already during the period of design in a way that will guarantee the best use of it. This requires a cooperation that covers many sectors, since refuse will hardly be used by the branch that produced it.

The design of products with the understanding of their place in the extensive recycling-process surely is a fascinating task. Nature by its innumerable overlapping cycles that do not leave any refuse, has solved this task perfectly. Nature should be the model for a new technology.

CONTEXT AND TOTALITY

If we apply the principle just discussed to the problems of the organization, it will require a maximum of autonomy and freedom of decision making for small units which can be overlooked. This requires a way of thinking connecting highly specialized knowledge with the ability of understanding of how his own special branch fits into the wider context. It coincides with the old principle of 'universita', e.g. an extensive comprehension not limited to one single discipline. The objection near at hand, which makes a point of the fact that Alexander von Humboldt's time has passed, is cynical, since not very much has been invested so far to create the facilities that would lead to comprehensive understanding.

History of science has always been developing through phases, both analytical and synthetic. In ancient Greece specialists of parabola, hyperbola, ellipse and circle have each devoted a lifetime to their specialized field. The invention of conic sections comprised all these fields in a new way of understanding. Further developments like the curves of derivatives in analytical geometry have made it possible to master intellectually all partial fields after a couple of months of high-school study. Systems analysis is about to develop such 'conic sections' for all possible fields and is starting to be quite successful, connecting thereby all sorts of different disciplines. Practical needs of economy call for despecialization. The higher a managerial position, the more comprehensive his horizon! The most extensive know-how of a firm is shaped by the understanding of its ability to solve problems, not to be a producer of bits and parts. According to a firm's self-understanding of its ability to solve certain problems, certain tasks follow that will make the production of certain appliances and parts necessary. Firms that want to be successful have applied this concept for some time and they have achieved a great flexibility in the way they solve problems. This ensures a possibility to survive even in an economic environment radically changing.

The problem a firm is solving is always a part of a more extensive sociological problem and is finally part of the more extensive problems of man, which can be indicated by the question: Where do we come from, where do we go to?! In a paper prepared for the Helsinki Conference about human factors in management it was shown that morals – to talk in an engineer's term – are somewhat similar to a factor of production of a higher derivation. They take over the inner control in a decentralized style of ruling, where social control is fainting. Since morals are not to be proved by economical measures alone, the necessity of arrangement with morals leads the manager onto fields that have been taboo so far. This alone is a proof of the dramatic change of paradigms for times to come. New strategies outlined in this paper and new learning-processes will characterize the future development. The twofold task of learning-processes will be to define the new strategies in every detail and to develop completely new technologies according to these new strategies. The understanding of new technologies is not limited by the sheer technical developments in the physical sense. They have to be understood in the sense of social inventions as well. The creative force of social inventions will concentrate first and foremost on the organization of learning processes, processes of the kind we just experienced during this Conference.

REFERENCES

STUDIA-Research Report to UNIDO, (1979) 'Future Structural Changes in Austrian Industry', Vienna.

Millendorfer, J. (1977) 'Sectoral Production Functions', 5th IIASA Symposium on Global Modeling.

Millendorfer, J. (1983a) 'Kranke Riesen-Gesunde Zwerge', STUDIA Forschungsbericht an die Österreichische Nationalbank, Wien.

Millendorfer, J. (1983b) 'Qualification of Labor, Innovation and Management-Style', paper presented at the conference Human Factors in Innovation Management, Helsinki, Finland, October. Sponsored by IIASA.

Millendorfer, J. (1980) Comments to Lord Vaizey 'Economic Growth as an Endogenous Process – Human Resources and Motivation' in: 'Towards an Explanation of Economic Growth', Institut für Weltwirtschaft, Kiel.

Millendorfer, J. (1982) 'Growth Reducing Factors in Complex Systems' in: Cybernetics and Systems Research, R. Trappl (ed.), North-Holland Publishing Company.

STUDIA Forschungsbericht, (1977) 'Makropsychologische Untersuchungen der Familie in Europa', Vienna, cited in: Raoul Naroll: The Moral Order – An Introduction to the Human Situation, Sage Publications: Beverly Hills, 1983, pp.233-236.

Marchetti, C. (1983) 'Dying in Time – On Economic Cycles Homicides, Suicides and their Modes', Laxenburg, September.

Millendorder, J. (1979) 'Mechanisms of Sociopsychological Development', Proceedings of the third European Meeting on Cybernetics and Systems Research, Hemisphere Publishing Corporation, Washington, D.C.

Millendorfer, J., et al., (1978) 'Konturen einer Wende – Strategien für die Zukunft', Styria Verlag Graz.

Millendorfer, J. (1983c) 'Learning-Processes and Learning-Strategies', paper presented at the Task Force Meeting on Strategy and Long Term Planning in Innovation Management, sponsored by IIASA, Budapest, December.

ON THE STATISTICAL IDENTIFICATION OF LONG WAVES

Herman Wold

At this IIASA meeting Dr. Gerhard Mensch gives an exposition of "The Schumpeter Clock", which is fundamental work of his own and joint work with his team of collaborators. Dr. Mensch invited me to the conference he organized at Berlin, March 3-4, 1980, to present my PLS (Partial Least Squares) method for the estimation of Path Models with Latent Variables (PMLVs). Since then we have been collaborating on the adaptation of PLS estimation to the Schumpeter Clock. My IIASA Collaborative Paper "Systems Analysis by Partial Least Squares" gives an overview of the PLS approach to PMLV (Wold 1983). The present paper reports briefly on the status of the PLS approach to the Schumpeter Clock.

The Schumpeter Clock belongs to the problem area of the "long waves" known as Kondratiev waves. As illustrated in Figure 1 the Kondratiev waves are cyclic variations over time of production, employment, prices, investment, and other economic variables. In the present paper the consecutive long waves are denoted by W_1, W_2, ... and the in-between periods by B_1, B_2, ...

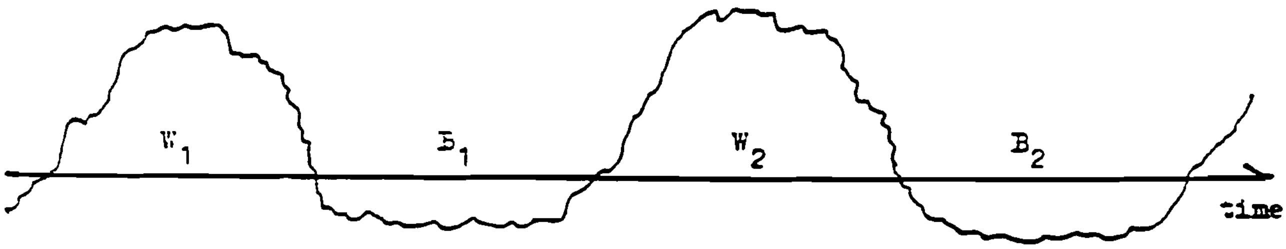

Figure 1 Long Cycles in the Variation Over Time of Economic Variables: Kondratiev Waves. Conceptual Sketch

Dr. Mensch's Schumpeter Clock is a theory in two parts or phases: the first part models a wave in the two dimensions of industrial employment and investment; the second part models an in-between period.

The first part is a bi-equilibrium model: A fundamental innovation brings an expansive stage in industrial production with increasing capital investment and increasing employment; as demand expands the production is rationalized, which brings increased capital investment, brings a gradual change from increasing production, employment and investment to a capital-intensive stage with increasing production and investment, but decreasing employment. The first part of the Schumpeter Clock thus is a model for one single long wave in the two dimensions of industrial investment and employment; let me call it a Mensch wave. The Mensch wave thus has two "equilibrium" or "stable" stages, first an expansive stage, and then after a vacillating phase a capital-intensive stage.

The Mensch wave model is a full-fledged nonlinear model in terms of the three variables labor, capital and production, a model that includes theoretical specification of the model and empirical estimation of the parameters; see G. Mensch, K. Kaasch, A. Kleinknecht and R. Schnopp, 1980. The key feature of the model is structural change. The shift from expansive to capital-intensive stage in a Mensch wave constitutes a change in the economic structure, an instability with important implications that break away from classical and neoclassical economic theory. The shift of the two "equilibrium" stages is discontinuous in the same sense as in René Thom's catastrophe theory.

The circles in Figure 2 illustrate the bi-equilibrium first part of the Schumpeter Clock model. There are three variables directly observed over time t, namely Labor L_t, Capital C_t, and Production output P_t; an oblique linear transformation of L_t and C_t gives Extensive investment E_t and Intensive investment J_t; denoted X_t the modeled production is obtained by solving the equation

$$X_t^3 - J_t X_t - E_t = 0;$$

the difference or distance between observed and modeled production is $P_t - X_t$; the two parameters of the oblique transformation from L and C to E and J are determined so as to minimize the distance $P_t - X_t$ in the sense of Least Squares. The equation has either one real root or three real roots; there are two cases of one real root, the case of three real roots is intermediate, and the two one-real-root cases define the two equilibria of the model. Computation in the first part of the Schumpeter Clock model thus proceeds in three stages: from L and C to E and J; from E and J to X; and third, the least squares minimization of the distance $P_t - X_t$.

To quote from Dr. Mensch's paper at this meeting, the model in Figure 2 has been applied to real-world data for an entire industry, be it the total industry of the nine OECD countries, or the industry of a separate country.

Splitting up the industrial data into data for separate industrial branches, the bi-equilibrium model can be applied to each separate branch. The splitting into branches will however make the model very unstable. Hence it is desirable to use a holistic approach, making a joint analysis of the separate branches.

As illustrated by the squares and circles in Figure 2, PLS modeling allows such a holistic approach. With total industry split into five branches, the squares illustrate the branch values of L_t, C_t, and P_t, whereas the circles the industrial totals of L_t, C_t, and P_t.

The ensuing nonlinear generalization of the basic PLS algorithm has been the aim of the joint work by Dr. Mensch and myself since 1981. Our design of the nonlinear PLS algorithm is iterative, and each iterative step proceeds in two sequences of substeps, the first from L and C to P, the second back from P to L and C. Thus far we have tested the nonlinear PLS algorithm on simulated data with

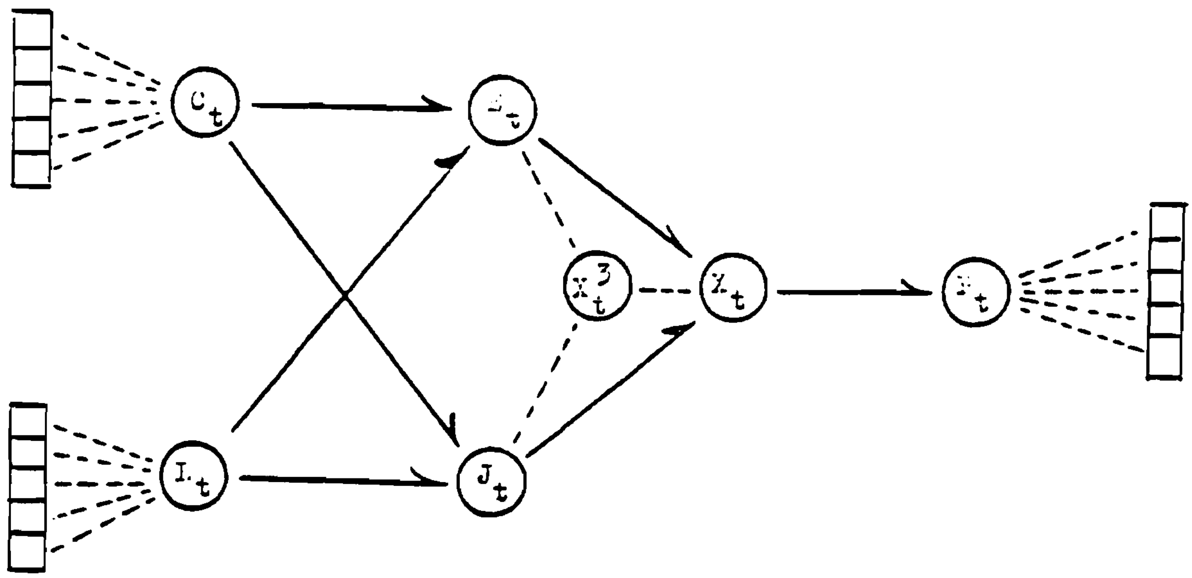

Figure 2: Graphic Illustration of Gerhard Mensch's Bi-Equilibrium Model. Only Circles: Original Version with Directly Observed Variables. Circles and Squares: PLS Version with Variables Directly Observed (Squares) and Directly Observed (Circles)

varying degrees of "inter-branch noise". Next on our agenda is to apply the PLS algorithm to real-world branch data.

The modeling with variables directly and indirectly observed, variables manifest and latent, can be expounded by the old proverb: "He doesn't see the forest for mere trees". In terms of a PLS model the forest is a latent variable, and the trees are the manifest indicators of the latent variable. There are models for the forest, and other models for the trees. PLS models both the forest and the trees. More precisely, the PLS algorithm models the endogenous manifest variables, and PLS at the same time estimates the case values (the values for each t) of the latent variables.

MODEL EVALUATION

There are two main types of model evaluation: (i) hypothesis testing, and (ii) standard errors for the estimated unknowns.

PLS modeling is subject to hypothesis testing by Stone-Geisser's test for predictive relevance (1974); see H. Wold (1982). Speaking generally, the SG (Stone-Geisser) test criterion Q^2 is an R^2 evaluated without loss of degrees of freedom.

John Tukey's jackknife standard errors (1958, 1977) are obtained as a by-product of SG testing; cf. H. Wold (1983).

In contrast to ML (Maximum Likelihood) model evaluation, the SG test and Tukey's jackknife are distribution-free, and require no assumption about independent observations.

In consequence, the SG test, the jackknife, and PLS modeling have the same wide scope relative to ML modeling.

Classical standard errors are liable to underestimation because of the assumption of independent observations. To quote from a recent study the classical standard errors are subject to substantial underestimation, often by 50%, 100%, or more; see R. Bergström and H. Wold (1983).

ML methods provide asymptotic statistical inference, asymptotic for large samples. In contrast, the SG test and the jackknife are applicable also to finite samples; see H. Wold (1980, 1983).

This last point is of crucial importance in models that involve structural change. Thus in the Schumpeter Clock, again with reference to Figure 1, the consecutive parts of the model for phases W_1, B_1, W_2, etc., can be tested separately.

EXTENSIONS OF THE BASIC PLS ALGORITHM

The basic PLS algorithm is linear; an example is given by Figure 2 if we omit X_t and X_t^3, and assume that P_t is linear in L_t and C_t. The model in Figure 2 is a nonlinear generalization, where the latent variables E_t, J_t, and X_t constitute a hierarchical level above L_t and C_t.

Reference is made to three other generalizations of the basic PLS algorithm which greatly extend its scope in theory and practice:

(1) The basic PLS algorithm is designed for scalar data, and can be adapted to categorical data and contingency tables; see J.-L. Bertholet and H. Wold (1981, 1983).

(2) The basic PLS algorithm is designed for one-way observation of the variables, observing be it over time or a cross-section. As shown by J.-B. Lohmöller by ingenious use of Kronecker products (1981, 1983) the PLS approach extends to two-way observation of the variables, be it observations over time and a cross-section, or over two cross-sections.

(3) The basic PLS algorithm is designed for models where the latent variables form a causal chain system. The PLS approach extends to models where the latent variables form an Interdependent (ID) system; in such a case the estimation combines the PLS algorithm with my Fix-Point (FP) method for estimation of ID systems with directly observed variables; see B.S. Hui (1978, 1982). For the FP method, see H. Wold (ed. 1981).

In his recent important monograph Dr. M. Lösch (1983) has (i) shown that my FP method for estimation of ID systems can be interpreted as a method for estimation of linear RE (Rational Expectation) models with one period lead in the future expectations, and (ii) extended the F method to RE models that involve several leads in the future expectations.

In these RE models all variables are directly observed. Dr. Lösch invites us to estimate RE models with latent variables, using a combination of the PLS algorithm with his generalized FP algorithms.

SOME OBSERVATIONS ON THE LIMITS OF INDUSTRIAL POLICY
Contribution to the Discussion

Possibilities for Influencing Long-Wave Behavior

Gerhard Rosegger

Discussions of governments' potential role in mitigating the causes of long swings in industrial activity ought to be mindful of the gap between academic exercises in *policy design* and the realities of *policy implementation*. To ignore the veritable chasm between what a government *should do* in the best of all worlds and what it *can do effectively* in a world suffused with second- and third-best choices means to overrate the possibilities of "industrial policy", whatever that much-abused term may imply in the way of actions by the state.

As several discussants have already pointed out, we have recently learned a lot about the limitations (failures?) of Keynesian and Monetarist recipes in alleviating the industrial economies' current malaise. How can we be sure that other recipes will be any more successful?

Let me mention a number of reasons for my skepticism:

(1) The "political cycle" in modern democracies almost *ipso facto* forces upon elected officials a planning horizon that is too short for any serious attack on structural problems.

(2) Even if far-sighted legislators were to design such an attack, its long-term execution would have to rely on a bureaucracy, a powerful and articulate interest group whose motivations and resulting actions may in the end have little to do with the pursuit of clearly-pronounced legislative goals (Peirce, 1981).

(3) Decisions about industrial policy involve, explicitly or implictly, the centralized picking of "winners" and "losers" among sectors. Past experience suggests that this also means a *centralization of mistakes*. There is no evidence to suggest that legislators, or their agents, are any less fallible than "private" decision makers, except that the errors of the latter remain diffused and are therefore less likely to do long-lasting harm.

(4) In the case of the United States, at least, the existence of lobbies and pressure groups is bound to divert industrial policy in non-optimal directions. As Professor Raymond Vernon has so aptly pointed out, "the American political process almost guarantees that the decisions will be made *not* on economic grounds" (*Business Week*, June 30, 1980; emphasis mine).

(5) Economic systems have shown themselves extremely resilient (and inert) vis-à-vis active, interventionist government policies that try to "lean against the wind". On that count alone, the record of industrial policy in stimulating sectoral growth, alleviating structural unemployment, and reviving stagnating regions has been less than enviable.

Of course all policy recommendations involve normative issues, and therefore value judgments. It would seem to me, however that such judgments should be informed by our experience with the limits of government policy.

Under the circumstances, it may be more fruitful to ask what current policies, rules, and institutions stand in the way of a more vigorous global recovery. Protectionism, about whose detrimental effects there appears to exist almost unanimous agreement, provides but a starting point for such questioning.

REFERENCES

"Industries to push – or to prune" *Business Week*, June 30, 1980, pp.120-122.

Peirce, W.S., 1980 *Bureaucratic Failure and Public Expenditure*, Academic Press, New York, esp. Ch.20.

ITALIAN MULTIREGIONAL DEVELOPMENT: LONG WAVES AND REGIONAL TAKE-OFFS

Preliminary Findings

Giuliano Bianchi, Stefano Casini-Benvenuti, and Giovanni Maltinti

1. PREMISE

Some provisional results of the present step of IRPET's research stream about multiregional differentiations of Italian development are presented in this paper. This research stream aims at identifying evidences, patterns, causes and effects (relevant to regional policy making of the rather diversified behavior Italian regions have so far displayed, particularly in terms of the different, both quantitative and qualitative, reactions to the impact of international and national processes and policies.

Previous steps have been:

(i) empirical investigations into regional paths of industrial growth since the beginning of this century (IRPET and SEI, 1978) and into comparative regional development (Casini-Benvenuti, 1980), both leading to ascertainment of the existence of a number of very distinct regional development models;

(ii) an attempt to formulate interregional interdependencies of Tuscany analytically, by means of a bi-regional, Tuscany-Rest of Italy input-output model (a module of the IRPET regional model system for impact analysis and policy evaluation: Martellato, 1982), which confirmed that the "two regions" react quite differently even to the same impact;

(iii) a critical rethinking about fundamentals (appropriate measures and spatial units, nature of driving factors, growth mechanism) for analyzing the "multiregionality" of Italian development (Becattini and Bianchi, 1982).

It must be stated however that provisional results hereafter presented will deal mainly with shaping research hypotheses given that the present step of this research stream is still at its very beginning.

The authors of the present paper, not being "tenured" long wavers but simply regional analysts, would wish not to miss the opportunity of the "Long Waves Meeting" for receiving – hopefully – some useful criticism and advice for the continuation of this work.

2. INTRODUCING THE HYPOTHESES

It is sufficient just to cast a glance at 1981 Census data (Table 1) to acknowledge interregional differentiation of Italian development. It is apparent that such differentiation follows a more complex pattern than the simple dualistic scheme of North-South (Southern regions being the seat of Italian historical backwardness).

Table 1: Levels of Industrial Development in Italy (1981)

Region	Total Empl.% Population	Ind.Empl. Total Empl.
Piemonte	9.2	53.0
Lombardia	20.7	53.6
Veneto	17.4	49.6
Liguria	10.1	32.0
Emilia Romagna	17.6	45.7
Toscana	16.2	46.4
Umbria	14.5	47.7
Marche	17.4	49.8
Lazio	7.7	27.7
Abruzzo	10.4	40.0
Campania	6.3	33.0
Puglia	6.9	34.1
Basilicata	6.9	35.0
Calabria	3.5	21.7
Sicilia	4.4	25.0
Sargegna	6.5	30.6
ITALIA	12.7	43.0

Nevertheless the recognition of this complexity was, in Italy, a "strenuous" feat of research which took some fifteen years. Standard economics and economists were reluctant to accept the anomaly of the unexpected steady growth of the central-north-eastern regions (Figure 1) which took place after the Second World War, especially during the 50s and the 60s.

This was due to the fact that those regions were not only – at the starting point – far less endowed with productive and social fixed capitals than the regions belonging to the so-called "Industrial Triangle" (Liguria, Piedmont, Lombardy) but had also been even less favored – during the period – by public policies, which had mainly been directed to the "Triangle" (in terms of support to private industry) and to the South (in terms of direct public investments: heavy industry and infrastructures).

So, the anomaly to be explained was two-fold: the growth of central-north-eastern Regions despite the lack of standard prerequisites and the lack of growth in the Southern regions despite considerable investments.

Finally, however, this reality succeeded in being ratified by academic research, on the one hand, owing to the efforts of research workers who were less inhibited by standard theories, and on the other hand and much more so, due to the outstanding performance of the Center-North-East Italy economy which was also given the specific name: "Third Italy".

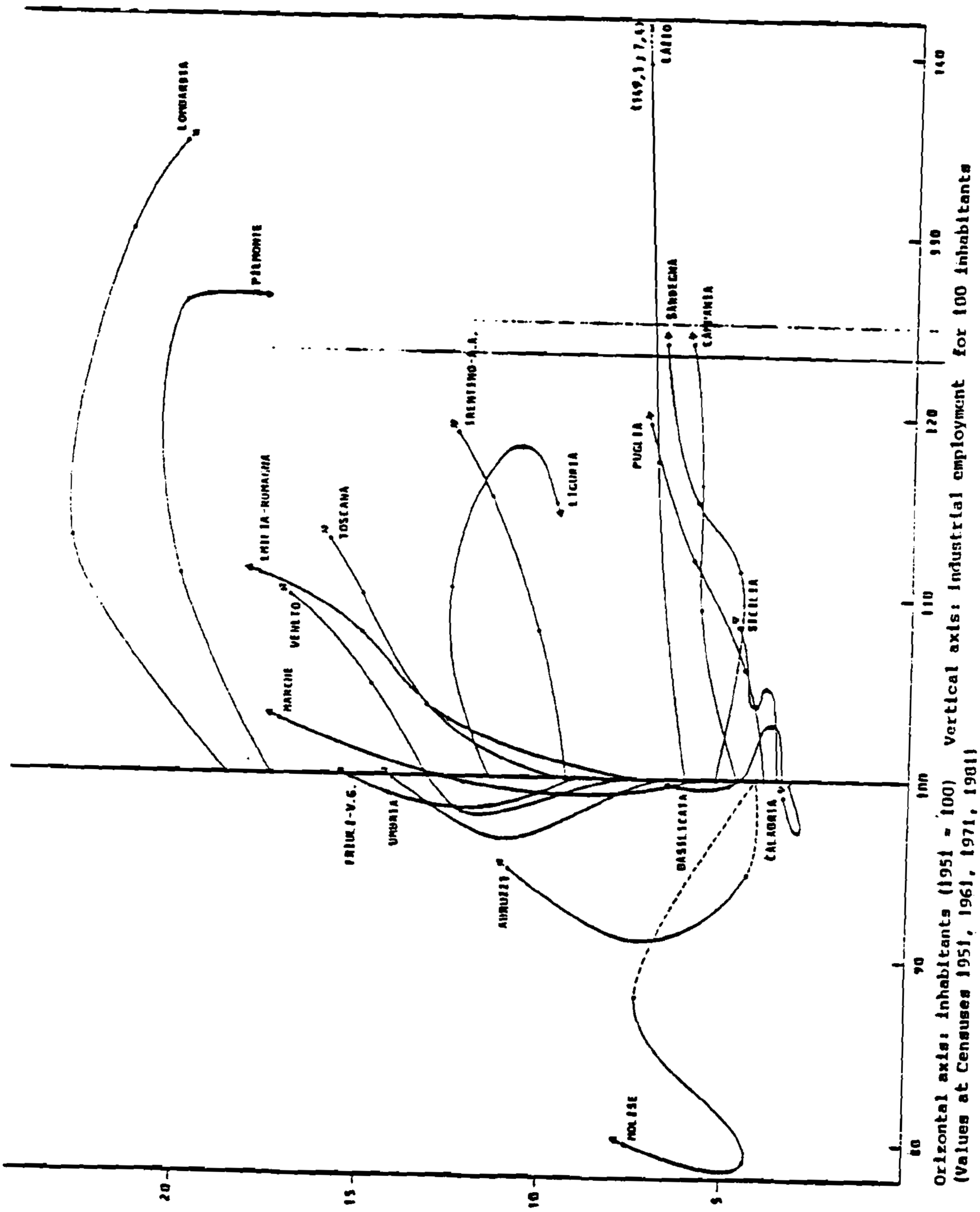

Figure 1 Regional Waves of Italian Development

Indeed, not even the "Three Italies" model represents and interprets Italian multiregionality exactly. Taking into consideration the 1951-77 period and the peculiarities of regional development, it has been proved (Casini-Benvenuti, 1980) that Italian regions can be classified into nine clusters (according to different development phases), through which regions move if the period is split into subperiods (1951-63; 1963-70; 1970-77). In addition it has been suggested (Becattini and Bianchi, 1982) that this classification might vary considerably if different spatial units and time-periods were assumed.

Anyway, it is true that whatever classification schemes are adopted the multiregional differentiation of Italian development does exist not only in terms of different forms, structures and levels of growth but also, and more significantly, in terms of very diversified regional behavior with regard to:

- structural change so far undergone (which enable the identification of declining, post-industrial, early mature, and backward regions, as will be seen later on);
- reactivity to short term cycle shocks.

Naturally, when searching for an explanation of regional behavior differentials it is necessary to look into economic structure disparities among the regions (mix and specialization of productions, industrialization levels, peculiar patterns of industry location and of production processes). But this recalls, macroscopically, the region "families" respectively belonging to each one of the "Three Italies" and hence the times of their industrial take-off, remembering that the regions of the "First Italy" (the "Triangle") developed before the Second World War; the regions of the "Third Italy" developed after the Second World War; the regions of the "Second Italy" (the South, more or less) have not yet developed.

Figure 2 displays "short waves" of Italian regional industrial growth, thus clearly distinguishing the "Triangle" from the "Third Italy" and the South.

On these grounds it seem worthwhile to look for an explanation for the different regional behavior looking at the differences in time of the regional take-offs. These are the reasons why, moving from analysis of the multiregionality of Italian development, we have met, bottom-up, the broader theme of Long Waves, normally felt as "far away" regional analysis.

3. THIRD WAVE UPSWING (1892-1929) AND MULTIREGIONAL DEVELOPMENT OF ITALY

By common consent, Italy's take-off (1894-1913) is located in time within the third Long Wave upswing (Rostow, 1978; van Duijn, 1983), which approximately corresponds to the upturn phase of the third Kondratiev. Driving forces of the take-off have been identified in heavy (iron and steel) industry growth and railroad investments.

If we assume a convenient time period (1881-1911) around the Italian growth peak and measure the country's development by means of new industrial employment create in that period and within each region, it is easy to assess that Italy's take-off is generated *by* and is made up *of* the take-off of the regions which constitutes the "Industrial Triangle" (Table 2).

Investigation into the causes of the development of these regions and of the missed opportunities of development of the others is the subject of a vast and rather sophisticated literature of economic history. Our task here is just to try and test whether the working hypothesis (to be examined more thoroughly with

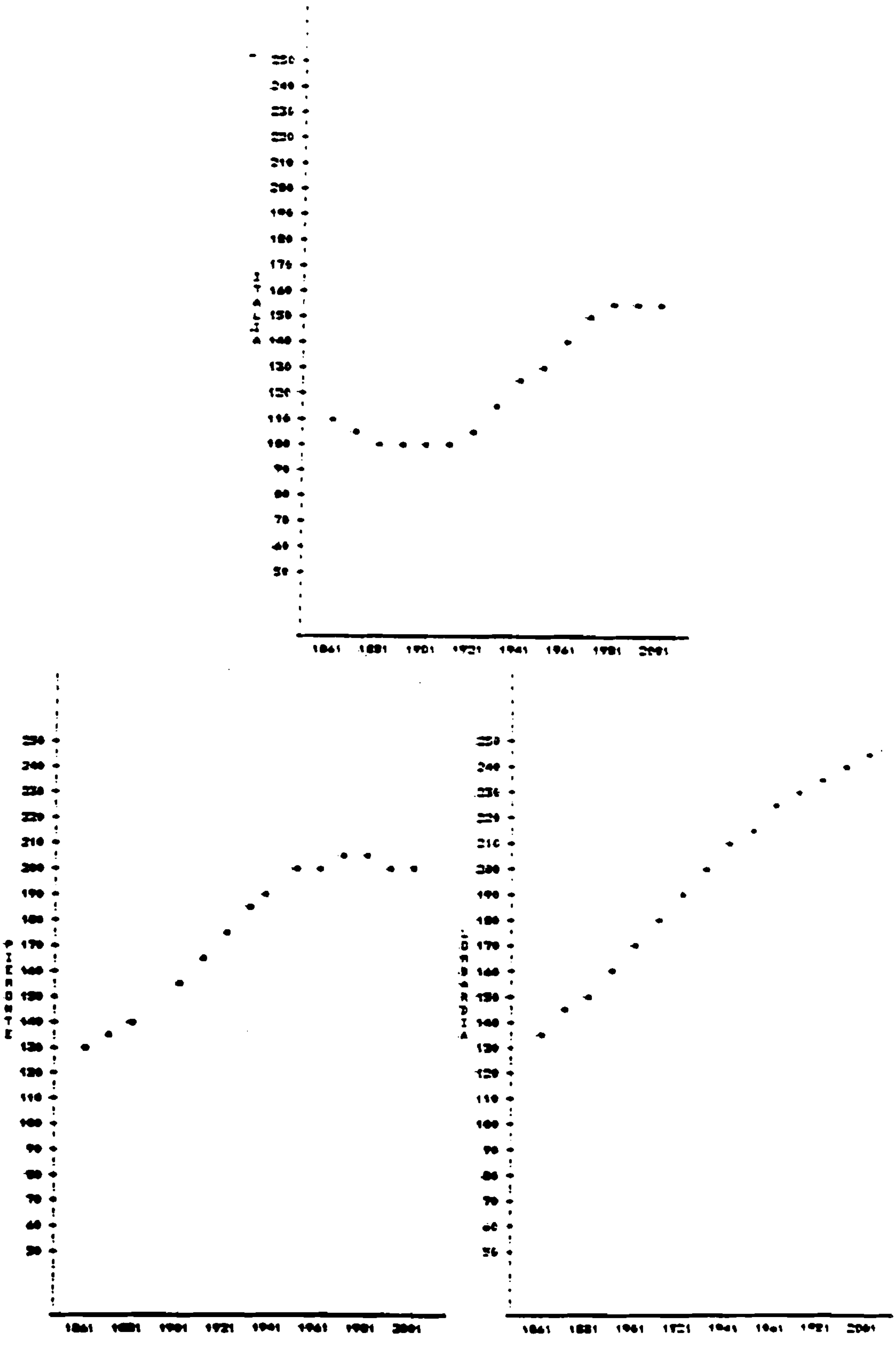

Figure 2 Industrialization Pattern of the Italian Regions

TABLE 2: New Employment 1881–1911

Industrial triangle	85.2
Other regions	14.8
Italy	100.0

further research) about meaningful relationships between Long Waves and regional take-off, on one side, and differentiated regional behavior, on the other, makes sense or not.

In order to explain why and how national economies brought about their initial "big spurt", theory and history of economic development make vast use of concepts such as: prerequisites (Rostow), endogenous social and cultural factors (Hirschmann), economic and noneconomic preconditions (Kuznets). Other authors (e.g., Gerschenkron, 1965), while warning about the risk – inherently implicit in every attempt to explain successive events through previous ones *(post hoc, propter hoc)* – of circular reasoning (e.g. to assume *ex-ante* as driving sectors, those sectors you know *ex-post* have developed), yet do not cease to use the concept of "prerequisites".

However, our task is not to explain the national take-off, which we assume as given. We have to assess why certain regions participate *in* and contribute *to* the national take-off, whereas other regions do not. Therefore it seems to be more appropriate for our purposes to adopt the notion of "original characters", i.e. main features of the various regional situations before the development process had started.

In other words, our idea (even if it is here rather roughly expressed) is that it is the interplay of socio-economic structural characters (which are, to some extent, measurable), regional (both formal and informal) institutions and local "social culture"[1] that selects Regions more apt and/or ready to grasp the opportunities of the international Long Wave and national take-off.

Though bearing in mind the crucial role played by "soft" characters (institutions and social culture), within the limits of this simple numerical exercise, we can only deal with measurable "original characters", as far as they are represented by indicators listed below (most of them are also more or less "proxies" of what has been termed as "prerequisites", "endogenous factors", etc.).

So, in this analysis the following variables have been chosen: illiteracy rate, child mortality rate, number of university teachers, number of newspapers and magazines, railways and roads, bank deposits, weight of light and heavy industry, the ratio between male and female workers in industry, and income distribution.

These variables, by means of factorial analysis, have been grouped into two main components (Table 3): the first one identifies a sort of "latent modernity", in

[1]The definition of "social culture" we adopt is the following: "Knowledge and faith welded together in a basic doctrine which is present in all the various activities of every individual, whatever his or her place in society. This culture is inhibitory, and is reflected in the structure of the economy and of society, that is the whole system of institutions in which are embodied, whether in legal or customary form, the principles informing the behavior of the population, and also in the moral and political philosophy, at varous levels of elaboration, but always fitting the respective social classes, which is used to justify and defend that structure." (A. Bertolino, *Cooperazione internazionale e sviluppo economico*, Firenze, La Nuova Italia, 1961).

the sense of potential reactivity of the regional system to exogenous shocks; the second one identifies a factor related to infrastructure equipment.

Table 3 Main Saturation Coefficients – 1881

	Factor 1	Factor 2
Light industry	-0.55	-0.55
Heavy industry	0.73	-
Male/Female	0.60	0.65
Illiteracy rate	-0.37	-
Railways	-	0.80
Roads	-	0.74
Deposits	0.76	-
Child mortality rate	-0.59	-0.43
University teachers	0.76	-
Newspapers	0.81	-
Interest and Rents	0.78	-
Profits	0.96	-
Independent work income	0.57	-
Variance explained	60.8	23.2

According to the values of the two factors in each region the following points can be made:

(1) There is great disparity between the central-northern regions and the southern ones in terms of "latent modernity" but not in terms of "infrastructure equipment";

(2) Within the first group of regions, however, the "Industrial Triangle" is not so privileged with regard to the two factors (Table 4).

So the regression analysis between the industrial growth (measured in terms of new employment per 1000 inhabitants in the period 1881-1911) and the above mentioned factors shows that only the factor 1 has a significant positive relationships with the dependent variable.

$$\begin{array}{lllllll} Y & = & 9.226 & + & 1.679F1 & + & .380F2 \\ & & (2.03) & & (5.04) & & (.76) \\ R^2 & = & 0.663 & & & & \end{array}$$

where the figures in brackets refer to "t Student" value.

Summarizing, the ability of the regions of taking the opportunity of a world upswing seems to be related more to social and cultural features than to strictly economic ones.

Hereby stems the suspicion that the unexplained residual of our indicators' variability might be attributed to policy influence. Policies cannot generate upswing even if they can delay its effects in terms of take-off. But policies can greatly affect spatial distribution of a given take-off: an example of this is that Tuscany "missed" the opportunity of the Italian take off, despite the fact that the Region "appeared to be a suitable site for a process of

Table 4 Regional Values of the Factors – 1881

	Factor 1	Factor 2
Piemonte	5.638	.342
Lombardia	8.159	-8.389
Veneto	-.521	1.849
Liguria	17.725	-5.690
Emilia Romagna	2.947	-2.566
Toscana	13.043	-1.045
Umbria	-3.067	18.385
Marche	2.659	-7.954
Lazio	32.930	3.129
Abruzzi Molise	-16.494	1.781
Campania	.162	-11.212
Puglia	-13.026	-3.294
Basilicata	-19.038	-3.333
Calabria	-20.642	-3.454
Sicilia	-7.827	-9.051
Sardegna	-2.647	23.836

industrialization as intensive ... as that which occurred subsequently in areas such as Piedmont, Lombardy and Liguria" (Becattini, 1979). And this was due, mainly if not only, to the anti-industrial attitude of the Tuscan ruling class.

During the next downswing (1929-1948) of the same Long Wave no new regional take off occurs, according to the "general rule" for national take-off, whereas the new developed regions (the "Triangle") reinforced their position, thus increasing interregional disparities (Table 5). This looks like a confirmation, at a regional scale, of the hypothesis which says "after a country has taken off, it will be less affected by the next downswing" (van Duijn, 1983).

4. MULTIREGIONAL DEVELOPMENT IN ITALY DURING THE FOURTH LONG WAVE UPSWING (1948-73)

The sophisticated debate about Italian economic growth within the fourth world Long Wave has been copious and comprises many different interpretations of the causes and characters of the rapid postwar growth. A common feature is that most of the authors emphasize the role, among the external factors, of an increasing demand of durable consumer items. However we are not going to enter into the debate; our aim is to observe that the reaction of Italian economy to this external push was, once again, spatially differentiated even if this time there was a wide process of industrialization almost everywhere.

So, during this world upswing, the take-off of the new regions became the driving force, together with the oldest industrialized regions, of Italian economic development. With the only exception of Liguria (in a declining phase) all the central-northern regions have created a large amount of further employment, but differently from the previous upswing, now the most dynamic regions are Veneto, Emilia-Romagna, Toscana, Umbria and Marche.

Table 5 Regional Levels of Industralization Level

	1921	1936
Piemonte	148.1	180.4
Lombardia	171.0	210.9
Veneto	106.3	107.4
Liguria	171.5	162.1
Emilia Romagna	101.5	97.8
Toscana	116.8	124.7
Umbria	75.1	85.8
Marche	83.7	82.7
Lazio	100.6	97.7
Abruzzi Molise	52.5	51.9
Campania	101.3	92.4
Puglia	84.6	94.8
Basilicata	60.1	53.9
Calabria	71.5	60.2
Sicilia	86.8	75.7
Sardegna	67.9	71.2

Table 6 New Employment – 1951-81

Region	Employees × 1.000 inhabitants
Piemonte	45.11
Lombardia	48.15
Veneto	62.47
Liguria	-21.31
Emilia Romgna	81.75
Toscana	56.65
Umbria	56.41
Marche	86.51
Lazio	38.61
Abruzzi e Molise	34.09
Campana	11.02
Puglia	25.71
Basilicata	38.42
Calabria	9.73
Sicilia	17.64
Sardegna	41.39

Given the external push of an increasing consumer demand the debate has concentrated on the internal factors that allow the single region take-off. The main factors identified in literature are, generally, related to the economic conditions (in the sense of pre-existence of an industrialization process connected with the agricultural crisis), but also social and cultural factors that define a sort of entrepreneur ability have enough room in these interpretations.

Therefore the variables we now consider are related to the phenomena already analyzed in the previous upswing with the addition of the social stratification aimed at detecting a sort of "latent entrepreneurship".

The factorial analysis enables the identification of two main factors (Table 7):

- The first one identifies a cluster of variables which are related to a previously reached industrialization level, and so this factor scores high positive value in the first take-off regions (the Industrial Triangle);
- The second one identifies social and infrastructural conditions for industrial development, the "latent capability"; according to Table 8 this factor is mainly present in the Central-North-Eastern regions.

Table 7 Main Saturation Coefficient

	Factor 1	Factor 2
Light industry	0.873	-
Heavy industry	0.669	-
Mechanics	0.911	-
Railways	-	-
Deposits	0.815	-
University teachers	-	-
Newspapers	0.681	-
Agr. bourgeoisie	-	0.813
Ind. bourgeoisie	0.516	-0.581
Illiteracy rate	-0.640	-
Roads	-	0.854
Child mortality rate	-	-
% of explained variance	66	21

The regression analysis shows that only this second factor has a significant relationship with the industrial growth measured, as in the previous period, in terms of new employment per 1000 inhabitants between 1951 and 1981.

$$\begin{aligned} Y &= 39.5 + \underset{(0.12)}{.428F1} + \underset{(3.84)}{2.406F2} \\ R^2 &= 0.663 \end{aligned}$$

The role factor 2 plays in explaining variability fits in very well with what we know about development models of the "Third Italy" regions.

The "latent entrepreneurship" within the rank and file of agricultural independent workers ("sharecroppers") and craftsmen (both accustomed to production and market decisions) was one of the most powerful forces of the peculiar industrialization process which took place in those areas. Differences among regions are not insignificant, but the common features are more relevant: industrialization driven by a multitude of small firms, operating in

Table 8 Regional Values of the Factors – 1951

	Factor 1	Factor 2
Piemonte	24.81	11.89
Lombardia	25.53	-.98
Veneto	2.68	5.51
Liguria	18.94	-9.36
Emilia Romagna	3.76	5.37
Toscana	9.02	2.65
Umbria	-3.49	11.06
Marche	-4.49	10.70
Lazio	13.12	-10.26
Abruzzi e Molise	-15.06	6.06
Campania	-2.54	-10.01
Puglia	-10.07	-9.49
Basilicata	-22.70	4.70
Calabria	-17.16	5.38
Sicilia	-7.49	-10.91
Sardegna	14.87	-1.57

light industry sectors markedly export oriented, with very specialized production cycles, and spatially arranged in specialized networks of industrial units, thus generating territorial systems (recently termed as "industrial districts"), which produce remarkable flows of economies, external to the single firm and even to the industrial sector, but internal to the "sectoral-social-territorial" network (IRPET, 1975; Bagnasco, 1977).

As our data series include the period after 1973 the ("oil crisis" normally assumed as the starting point of a new downswing), it is worthwhile to stress the excellent performance of these regions during the current downturn, as compared with the behavior of the other regions. Let us derive from this a few brief remarks.

Flexibility and external economies of small business systems are of course more appropriate than rigidity and scale economies of large plants for competition in increasingly unstable international markets. However, the small business model should no longer be interpreted as an accident in the history of development nor as a temporary production expedient to cope with "nervous" markets. As it has been proved the "model of decentralized, flexible production, based on general purpose machines and skilled workers" can also be correctly regarded as a possible historical alternative to mass production by means of large factories (Sabel and Zeitlin, 1981).

Finally, it should be pointed out that van Duijn's hypothesis seems to receive new support from the evidence that: regions which took-off within this Long Wave have been less affected by the last downswing than regions which took off before (or have not been affected at all).

5. THE MULTIREGIONAL DEVELOPMENT IN A SECULAR PERSPECTIVE: AN ATTEMPT AT GENERALIZATION

The different behavior patterns of the Italian regions during the up and downswing of the last 150 years may suggest that each region has its own development path.

Actually, the data seem to underline the existence of a common growth pattern in terms of industrialization for all of them even though each of them has its own peculiarity in terms of the stage or level reached. This evidence suggests that one should endeavor to make the research hypothesis more general.

For this purpose a function, which is appropriate for the regional and national data observed, has been worked out. This functional representation permits:

- the evaluation of secular movements of Italian development from a multiregional view point;
- some tentative interpretations based on function parameters and limits.

The actual evolution of the industrialization process in the regions appears to follow five different stages within the analyzed period:

- a decline in total industrial employment in the less structured activities occurred mostly in the female labor forces of the traditional sectors and was caused, generally, by the market opening up;
- the stagnation of industry before the actual take-off;
- the rapid growth starting from the take-off;
- a reduced employment increase during the industrial maturity;
- the decline in a "post-industrialized" economy.

The logistic function, often used for this kind of phenomena, does not allow us to include the first and the last stage of the industrialization process, so we have used a similar function which is able to introduce these five stages.

So we have adapted a function with these features:

$$\frac{E}{P} = \frac{t - a}{e^{b(t-a)^2}} + c \qquad (1)$$

where the three parameters c, b and a point out: respectively, the long-period level of industrialization, the rapidity of growth, the year in which, after the take-off, the growth rate began to decrease.

The function (1) fits in very well with the observed data of the Italian regions, with few exceptions, as the Theil index shows (Table 9).

The estimated functions point out the existence, within the same period, of regions at different stages of growth, and we can observe also how the different take-off period seems to influence the long-term level of industrialization.

By analyzing the values of the parameters and, as a consequence, the behavior of the regional curves we may identify four main clusters of regions (see Figure 2):

- the oldest industrialized regions (Liguria) now declining to a low industrialization level (152 industrial workers per 1000 inhabitants);

Table 9 Parameters of Estimated Function

	a	b	c	u-Theil
Piemonte	48.9	1.20	164.4	922
Lombardia	53.3	0.47	182.4	965
Veneto	92.5	0.58	140.4	948
Liguria	28.4	2.10	122.8	947
Emilia Romagna	97.7	1.30	139.3	940
Toscana	97.4	0.95	156.3	961
Umbria	94.6	0.72	117.1	946
Marche	99.8	1.50	126.3	926
Lazio	-	-	-	-
Abruzzo	99.2	3.20	95.4	907
Campania	90.6	31.60	110.6	934
Puglia	68.7	85.20	104.9	921
Basilicata	100.7	3.60	91.7	929
Calabria	-	-	-	-
Sicilia	196.0	0.50	144.1	928
Sardegna	75.9	3.00	79.1	937
ITALIA	84.2	2.20	126.7	968

- the oldest industrialized regions (Piemonte and Lombardia) in post-industrial maturity with a high long-term industrialization level which has already been attained;
- the "second-comers" regions in a phase of early maturity, with no growth of industrialization at a lower level than the previous ones (Veneto, Emilia Romagna, Toscana, Umbria, Marche);
- regions of miscarried development (Campania, Calabria, Sicilia), whose long term industrialization level will remain, in any case, very low.

6. OUTLINE OF THE HYPOTHESES

The two final decades of the present century seem to put a "ceiling" on regional growth, in terms of industrialization levels, according to the implicit rule "the earlier the take-off, the higher the level".

Should this statement be true (but we are somewhat doubtful), two consequences would follow (about which we are even more hesitant):

- entire regonal trajectories through take-off-development-maturity would be contained within the present Long Wave whose limit would act as a "wall" against possible further regional growth;
- thereafter, trajectory lengths, being given the ending point *(dies ad quem)*, would only depend on the starting point *(dies a quo:* take-off date).

This "ceiling and wall" hypothesis would match – too attractively! – the idea that the current Long Wave downswing will close the whole "hypercycle" consisting of the four Kondratievs. "Though this be madness, yet there is method in it": indeed, authoritative scientists have asserted "we are the witnesses of the transition from a growth economy to an equilibrium economy" so that "future historians will divide the economic history of man into three major periods: the pre-industrial period, the industrialization era and the post-industrial period".

Even though our aim is not to project the regional curves mechanically, we can however, observe that, at the national level (Figure 2), but also in many regions, the maximum level of industrialization has already been reached or near about to be reached, and so the effects of the industrialization era seems to be exhausted. Starting from this hypothesis we can assume that the opportunity of profit of the "new" Long Wave (if any) should be located where the environment appears more favorable for innovations.

For this purpose a new factorial analysis on the main regional characteristics in 1981 has been worked out, by inserting, with the old variables, new ones probably linked to this "potential reactivity" to innovations (private and public expenditure research and professional training courses).

The results of this factorial analysis (Table 10) confirm that a factor "propensity to innovations" appears to exist and that its spatial location would, again, discriminate between Central-Northern regions and the southern ones, even if within the first group the new relevance of Emilia Romagna sets the decline trend of Liguria (Table 11).

Table 10 Main Saturation Coefficients – 1981

	Factor 1	Factor 2	Factor 3
Metal and mechanical industry	.850	-	-
Light industry	-	-	.792
Letteracy level	-	-	.531
Roads	-	.645	-
Deposits	.712	.417	.453
University teachers	-	.677	-
Theatrical events	-	.677	-
Professional training courses	.704	-	.411
Child mortality rate	-	-	.759
Scientific research	.899	-	-
% of explained variance	62.3	19.4	15.0

7. FINAL REMARKS

First of all, the limits of our preliminary findings must be clearly pointed out. Some of these limits stem from analysis criteria. In our view the most crucial questions are:

- Which are, actually, *the* infranational systems? Elsewhere (Becattini and Bianchi, 1982) we questioned whether Italian administrative regions are true systems, arguing that "daily-urban-systems" hold more neat system requisites (boundaries, feed-back mechanism, observable behavior);

Table 11 Regional Values of Factor 1 ("Propensity to innovation"?)

	1981
Piemonte	18.9684
Lombardia	17.9027
Veneto	5.9980
Liguria	0.3527
Emilia Romagna	12.1679
Toscana	7.9904
Umbria	3.0074
Marche	1.4775
Lazio	7.7778
Abruzzi e Molise	-5.2575
Campania	-9.7325
Puglia	-10.9409
Basilicata	-15.3985
Calabria	-17.4705
Sicilia	-7.7796
Sardegna	-9.0634

- How does growth diffuse, interregionally, during the second bunch of regional take-offs in Italy? Does it really proceed from a "center" (which is seen, at the same time, as geographical industry location and the ideal place of capitalistic accumulation) towards its "periphery"? or is it not rather a much more complex movement of local entrepreneurship upsurges?
- To what extent did the nonmeasurable original characters (local institutions and social culture: *Ort- und Zeitgeist*) affect take-off dynamics and still influence regional behavior?

Some other limits stem from interregional interdependencies. Given a certain "amount of growth" historically available for a certain country how is it distributed among the regions? On one hand, the problem looks as risky as the chicken-and-egg question: the "amount of growth" historically available for a certain country is the amount the country is able to capture according to its original characters; but the country's endowment of original characters is the synthesis of the regional endowments...

On the other hand, the problem challenges researchers to distinguish sharply between the original characters of the country which derive from the regional ones and the original characters of the country as a whole (mobility of productive factors, labor first of all, through regional boundaries provides an example of this).

It is enough – we hope – to suggest that the authors of this paper are not so candid as to believe that regional development processes might be represented by means of a simple function. Nevertheless what we do really believe is that regional behavior and differences in time of regional take-off are meaningfully related and that a closer acquaintance with multiregionality of Italian development will demonstrate it.

Secondly, we would dare to say that some hypotheses have not been contrasted by preliminary findings so far achieved, so that it would seem worthwhile to go into them more deeply with further research.

(i) Spatial effects of Long Wave impacts are relevant to multiregional analysis, namely in order to explain the coexistence, within the same country, of regions at different phases of development; on the other hand, little attention has been devoted up to now to this aspect of multiregional analysis: not surprisingly, if – as Pollard complains – "the regional element has been neglected in the past" also in the field of history of industrialization, despite the fact that "industrial growth is essentially a local rather than a national affair".

(ii) The balance "public policies versus market forces" in affecting spatial distribution of Long Wave impact effects should be accurately assessed over different upswings; for instance, one may wonder why public policies in Italy seemed to be fairly effective in locating spatial effects of the take-off during the early years of industrialization (when public intervention was quite limited), whereas are market forces, beyond doubt, to drive the process during the post Second World War upswing, despite the massive State capital investments.

(iii) The less negative impact of downswing on a country which has taken off during the precedent upswing has been verified also at a regional scale.

On the contrary, even it if is quite appealing, the "ceiling and wall" hypothesis deserves to be carefully tested not only on the ground of empirical data (which suggested the hypothesis) but also, and first of all, taking into account

(a) the industrial-post-industrial transition ("ceiling and wall" seem to limit only levels of industrialization – nothing can be said about growth driven, e.g. by service sectors) and

(b) the interplay between international-interregional division of labor (potential increases of "mature" sector employment can be captured abroad: for instance by less developed countries).

Thirdly, and finally, we would attempt to draw some hints from previous discussion, mainly addressed to policy making. Of course, one must be aware of the dramatic disparity between the epoch and world dimensions of operating processes, when Long Waves are the subject, and the very limited regional powers. However we feel there is room for action.

It is true that national economic policies seem to shut themselves up in very narrow horizons as far as they are mainly concerned with the illusion of recovering lost conditions of steady growth by controlling inflation only by means of controlling labor costs and public expenditure.

But it is only a supplementary difficulty for the regional policy-makers: yet, we repeat, there is room for action. Even at regional scale if the challenge is to create and to enhance a climate favorable for innovation through "active public policy", "creative management", "political innovations" (Forrester, Freeman).

Guidelines for regional policies are virtually compulsory and are necessary so as to refrain from scattering human and monetary resources on a lot of irrelevant projects in order to concentrate them in critical mass available for truly relevant policies aimed at:

- improving existing endowments of natural resources and human capital;
- reducing external diseconomies, stemming from insufficient public services and from the scarcity of social fixed capital (infrastructure), which heavily affect economic performance of the regional system as a whole;
- creating appropriate tools for understanding the R&D demand implicit beneath the present state of productive sectors in order to provide efficient linkages with R&D supply (in other words: public and private sectors need less bureaucratic staff and more "intelligence units").

REFERENCES

Bagnasco, A. (1977) *Le tre Italie*, Bologna, Il Mulino.

Becattini, G. (1978) The Development of Light Industry in Tuscany. An Interpretation, *Economic Notes*, 2-3.

Becattini, G. and G. Bianchi (1982) Sulla multiregionalita dello sviluppo economico italiano, *Note Economiche*, 5-6.

Casini-Benvenuti, S. (1980) Analisi comparata dei processi di sviluppo regionale, *Nuovi contributi allo studio dello sviluppo economico della Toscana*, Firenze, IRPET.

Gerschenkron, A. (1965) Riflessioni sul concetto di pre-requisiti dell'industrializzazione moderna in *Il problema storico dell'arretratezza economica*, Torino, Einaudi.

IRPET (1975) *Lo sviluppo economico della Toscana* (a cura di G. Becattini), Firenze, Le Monnier.

IRPET and SEI (1977) *Le vie regionali allo sviluppo industriale*, Firenze, Le Monnier.

Martellato, D. (1982) *The Tuscany interregional input-output model (TIM)* CP-82-30, Laxenburg, IIASA.

Pollen, S. (1981) *Peaceful Conquest. The Industrialization of Europe 1760-1970*, Oxford University Press.

Rostow, W.W. (1978) *The World Economy – History and Prospect*, London, Macmillan.

Sabel, C. and J. Zeitlin (1982) Alternative storiche alla produzione di massa, *Stato e Mercato*, 5.

van Duijn, J. (1983) *The Long Waves in Economic Life*, G. Allen.

LONG-TERM ECONOMIC FLUCTUATIONS: A SPATIAL VIEW

Peter Nijkamp

INTRODUCTION

In recent years, the issue of qualitative and structural changes in dynamic systems has increasingly received attention in the social sciences. Differential topology, polyhedral dynamics, singularity theory, bifurcation theory and catastrophe theory are some of the mathematical representations of the increased interest in the qualitative aspects of evolutions of complex systems (cf. Casti 1979).

Especially if a system is driven by mutually conflicting forces (e.g., differences in short-run and long-run adjustments, opposite interest groups, etc.), the behavior of normally continuous and stable models may exhibit various perturbations (including shocks). Smooth transitions may evolve into sudden changes due to rigidity in adjustment processes, inertia in decision-making, or different time paths (e.g., slow and fast dynamics) of components of interdependent systems. Changes in the qualitative structure of complex systems can thus hardly be studied by means of conventional algebraic tools, so that there is a need for models dealing with *structural dynamics*.

Structural dynamics has to be distinguished from *constrained* dynamics (see Nijkamp and Schubert 1983). Constrained dynamics is a feature of a system in which the time dimension plays an intrinsically important role in the evolution of response or control variables without however affecting the structure of the system itself (in the sense of changes in the formal linkages between systems components, in structural parameters, or in the impact pattern of time itself). Structural dynamics, on the other hand, means that a dynamic system is not only showing a shift in response or control variables, but also in the parameters and relationships defining its structure. In such cases, not only the stability of equilibrium points in the system may be affected, but the system as a whole may exhibit a new topology of systems trajectories (cf. Dendrinos 1981, Haag 1983, Nijkamp 1982a, and Wilson 1981).

Systems characterized by structural dynamics may lead to unstable behavior, especially if the parameters of a (usually non-linear) dynamic system reach a critical limit, beyond which the system displays a different set of structural relationships.

The present paper will address the issue of long-term spatial fluctuations, with a special view of urban systems. Attention will be paid to various theories on spatial dynamics and long-term fluctuations, particularly those which are able to generate or to explain structural changes.

In this paper, *fluctuations* will be used as a general term to indicate any long-term trajectory of a dynamic system. Consequently, fluctuations may include discontinuous shocks, oscillatory behavior such as smooth periodic cycles and stable random variations, and even chaotic fluctuations. Fluctuations may be regarded as a more general evolutionary pattern than cycles (periodic and stable fluctuations) and waves (regular economic oscillations with regular time intervals).

Two classes of explanations may be distinguished that aim at providing more insight into spatial dynamics:

- Theories that explain structural changes in a spatial system (a city, a region) on the basis of *external* factors outside the spatial system itself.
- Theories that explain structural changes in a system on the basis of *internal* factors causing a shift in the systems structure.

Both classes will be dealt with in this paper, but first a concise overview of some major contributions to the field of spatial (notably urban) dynamics will be given.

SOME THEORIES ON SPATIAL DYNAMICS

Regional and urban systems appear to pass through complicated development processes caused by structural dynamics and urban-regional-national interrelationships. Such turbulent movements reflect in each stage the interactions of different dynamics with both multiplying and dampening effects, as well as thresholds of system responses. The identification of key variables and regularities in complex dynamic spatial systems is essential for planning and adaptive management.

Such a research issue is not only of theoretical relevance, but has also a profound practical meaning. For instance, in the past decades spatial discrepancies between regions in Europe have tended to increase rather than decrease; some areas (the Ruhr area, the greater Paris region, the Dutch Rimcity) have become better off compared to other areas (e.g., the Italian Mezzoogiorno, Ireland). Similar developments can be observed at an intranational level, where sometimes the discrepancies between cities and regions are growing, though interregional discrepancies may decline. The same remarks can be made regarding industrial evolution in the past decades: several industrial sectors (e.g., textile) are almost dying, whereas others (e.g., micro-electronics) are flourishing. Consequently, if we measure the evolution of variables (e.g., production growth, productivity rise, demand for labor) at a *national* level, we are only observing the top of the iceberg and do not get adequate insight into the underlying mechanisms which act as driving forces for the whole economy. Only by means of a more detailed analysis of regions, cities and sectors, we may arrive at more fruitful insight into the causes of stable growth in some areas, cyclical movements in other areas or even stable stagnation in others.

A concise overview of a selected set of spatial dynamic theories may illustrate the previous remarks. Eight contributions will be dealt with here, viz. Thomas (1972), Pred (1977), Jacobs (1977), Norton (1979), Van den Berg, et al. (1981), Allen (1981), Wilson (1981), and Nijkamp (1983). A more extensive review of theories on spatial dynamics can be found in Nijkamp et al. (1983).

Thomas has made a study of urban fluctuations, mainly in American cities. Taking for granted a Schumpeterian view, he concentrated mainly on the urban impacts of immigration before World War II. He was able to show the presence of wave-like fluctuations in these cities, caused by waves or urban immigration flows having an impact on the construction, building and housing sector. This close link between urban fluctuations and economic growth ceased after World War II due to more severe restrictions on urban immigrants to the USA.

Pred has made a profound study of the evolution of (mainly industrial) cities with particular emphasis on cumulative and circular feedback processes. Growth of industries and growth of population appear to interact with one another, while scale and agglomeration economies and regional export orientation (via economic base multipliers) favor spatial (especially urban) economic growth processes. These processes are in turn induced by technological innovations. Therefore, adoption and diffusion of innovation is of crucial importance for spatial dynamics. Pred has demonstrated that both Western Europe and the USA exhibit industrial evolution and spatial growth patterns, in which a multiple-nuclei structure (including spatial interactions) caused by innovation diffusion and improved communication infrastructure leads to integrated spatial-urban growth process.

Jacobs has explained urban fluctuations from shifts in the variety of functions (e.g., living, working, shopping, recreation) in a city. In her view an optimal urban diversity should exhibit a great deal of different functions, a variable age structure of buildings, a good accessibility of urban amenities, and a satisfactory spatial concentration of the urban inhabitants. An optimal diversity may lead to an efficient use of urban amenities, while lack of diversity may cause a downward spiral movement of cities. On the other hand, if a city has too many attractive functions, a self-destruction leading to congestion, environmental decay and endless land-use competition may take place, at last in a free market system.

Norton has examined urban life cycles in the USA. He claimed that stagnation or decline of older cities may be caused by a compact land use pattern, a strong social and ethnic segregation and an inadequate tax base (through which rich people are leaving the city). In his view, modern cities have a higher growth potential, as they are more spacious, less segregated and more tax-efficient. The weak base of older cities is even reinforced due to their industrial orientation which originated already in the last century, so that these cities could not compete with modern cities mainly based on the tertiary and quaternary sector. Thus lack of innovative forces has caused the decline of older urban areas in favor of modern cities.

Van den Berg et al. have also made an attempt at studying spatio-temporal development processes of urban agglomerations. In their view an urban agglomeration is made up of two subareas, viz. a core (center) and a ring (fringe). Then spatio-temporal processes can be observed and analyzed via the diverging evolution of both the core and the ring, as both subareas display different growth rates. This leads to a phase-wise growth process: urbanization, suburbanization, desurbanization and re-urbanization. Such fluctuations for urban agglomerations appear to emerge in many countries.

Allen at al. have studied spatio-temporal growth processes by means of models for human settlements and structures as dynamics of self-organizing systems. Special emphasis has been placed on non-linear dynamic models which were able to generate structural changes. In doing so, links to decision-making, behavioral spatial interaction patterns and multi-level structures have been taken into consideration. Such models served to provide analytical insight into the motives and impacts of transportation, migration, employment and growth in spatial economic self-structuring processes. By means of simulation experiments, the economic resurgence and fluctuation (including cyclical processes) could be imitated. These models were mainly based on attraction and repulsion effects for urban agglomerations (including bottleneck factors).

Wilson has made several contributions to an analysis of spatio-temporal growth processes, in which the notion of structural change plays a crucial role. He has also built a dynamic model encompassing employment, housing and retailing, mainly based on a Lowry-type of approach. Consequently, it is assumed that urban inhabitants orient their residential choice decisions toward the labor market, while retail facilities follow the demand for services. Due to non-linearities in these dynamic models (in a difference equation form), complex dynamic evolutions of the spatial system may emerge *(inter alia* oscillations and bifurcations).

Nijkamp has studied the evolution of a spatial system from the viewpoint of (dynamic) production theory. The production generated in a certain spatial system is assumed to be the result of a combination of productive capital investments, infrastructure investments (in a broad sense), and investments in innovation. On the basis of an optimal control model, the fluctuation in the system at hand can be reduced by choosing the appropriate controls in terms of savings rates for the respective categories of capital investments.

The conclusion from the previous concise overview is that a unifying theory for spatio-temporal dynamics is still lacking. Though it has often been indicated that technological innovation is a key factor for such dynamics, hardly any attempt has been made to treat innovation as an endogenous impulse in spatio-temporal growth processes. Some examples in a spatial context however can be found in Andersson (1981), Batten (1981), Dendrinos (1981), and Isard and Liossatos (1979). It is evident, that especially in the context of the 'long wave' debate an endogenous treatment of technology is of utmost importance.

The foregoing eight contributions to spatio-temporal dynamics may be summarized in a table indicating whether (1) innovation is regarded as a key factor for spatio-temporal growth, (2) the analysis is – at least in principle – able to generate fluctuations, (3) bottleneck factors in spatio-temporal growth processes are taken into account, and (4) a formal dynamic model has be used.

authors	(1) innovation	(2) fluctuations	(3) bottlenecks	(4) dynamic model
Pred	x	x		
Thomas	x	x	x	x
Jacobs		x	x	
Norton	x	x	x	
van den Berg et al.		x	x	
Allen et al		x	x	
Wilson		x	x	x
Nijkamp	x	x	x	x

Table 1 Typology of theories on spatiotemporal dynamics

THE LONG WAVE DEBATE

In the present section, a concise overview of the long wave debate will be given, in order to build a bridge between spatio-temporal growth theories and long wave theories.

The past decade has been marked by a diversity of structural economic changes (including spatial dynamics). Clearly, shocks and perturbations are no new phenomena in the history of the world, witness the long lasting debate in economics on cyclical growth patterns, and in particular long wave patterns (see, for instance, Adelman 1965, and Schumpeter 1939).

In the past decade, there has also been a revival of analytical contributions to the analysis of long-term economic fluctuations, so as to provide contemporary explanations for the emergence of profound changes in the Western economies. The present economic stagnation, the uncertainty regarding the supply of natural resources, the gap between the Western and the Third world, and the unsatisfactory control of our economies have induced a new interest in theories and methods concentrating on long-run dynamics.

The issue of long-term fluctuations (including perturbations, balanced growth, unstable equilibrium trajectories, spatio-temporal discrepancies, etc.) has led to a renewed interest in Kondratieff's theory on long waves (see also Clark, et al. 1981, Delbeke 1981, van Duijn 1979, Freeman, et al. 1982, Mandel 1980, and Rostow 1978). Kondratieff's theory takes for granted that the long-run fluctuations of a free market system can be characterized by regular cycles of approximately 50 years, marked by five stages: take-off, rapid growth, maturation, saturation and decline.

Despite the abundance of literature on long waves, there is not very much empirical evidence regarding the existence of long waves in the history of Western economies. Only a few attempts have been made to satisfactorily demonstrate the existence of regular long-term cycles. In addition, 'proofs' for the existence of long waves have usually been based on price data, so that biased conclusions are most likely to emerge. Consequently, apart from Schumpeter (1939), in the past most economists have regarded long waves as exceptional cases of economic dynamics (cf. Mass 1980).

In recent years however, new attempts have been made to find a more rigorous empirical basis for the long wave hypothesis (see, for instance, Clark, et al. 1981, Kleinknecht 1981, and Mensch 1979). It is clear that the identification of long waves requires a very extensive data base, which is not available in many countries (see Bieshaar and Kleinknecht 1983).

An additional problem is caused by the question whether or not a long wave pattern is the result of *endogenous* forces within an economic system. Endogeneity of long waves requires a theory, which is able to explain the state of the economy at each phase of a long wave (such as prosperity, recession, depression or recovery) from economic and technological conditions from previous stages. In this regard, it is a fundamental issue whether the level of a lower turning point and its subsequent upswing can be explained from technological progress, innovation and economic conditions during the preceding downswing of the economy. It is evident, that in this respect endogeneity of technology is a basic issue (see Heertje 1981).

Another evident problem in long wave research is the identification of the timespan of the cycles. In the economic literature, several cyclical patterns have been distinguished, such as Kondratieff cycles (40 to 50 years), Kuznets cycles (15 to 25 years), Juglar cycles (5 to 15 years) and business cycles (up to 5 years). The real-world pattern of economic evolution is evidently based on a super-imposition of all these cycles, so that it is extremely difficult to identify one specific class of cycles (though temporal cross-spectral analysis may be a helpful instrument in this respect).

Given the economic stagnation in many countries it is no surprise that a

Schumpeterian approach to long wave analyses has gained much popularity, though it has to be added that Schumpeter's writings on innovation, market structure and industrial concentration are not always clear (see also Dasgupta 1982, Futia 1980, Loury 1980, Rosenberg 1976, and Von Weizsäcker 1980). In addition to Schumpeter's approach, various alternative explanations have been given to the long wave phenomenon, some of which may be speculative due to lack of satisfactory data. Only a concise overview of various alternative modes of thinking will be given here.

- *monetary theories:* based on an inverse relationship between exploitation of new gold fields and price level (Dupriez 1947).
- *resource theories:* based on long-term international fluctuations caused by variations in the supply of food stuff and raw materials (cf. Rostow 1978).
- *inertia theories:* based on rigid adjustment patterns of agricultural production to industrial inputs, so that industrial expansion leads to excess demand and thus high profits in the agricultural sector; the resulting new investments in the agricultural sector may lead to overproduction and lower prices for agricultural products, so that then the industrial sector may expand due to low prices for inputs from the agriculture sector, and so forth (cf. Delbeke 1981).
- *competition theories:* based on a free-enterprise system, which leads to an acceleration and deceleration of capital accumulation and hence to varying profit rates; a downswing of the economy (with declining profit rates) may be coped with by means of more efficient technologies, capital saving innovations or wage declines (cf. Mandel 1980).
- *capital theories:* based on cyclical movements of capital costs, investments and economic growth, caused *inter alia* by indivisibilities, threshold effects and long gestation periods of productive capital; examples of such over- and underinvestments situations can be found in vintage and puttyclay models (cf. Clark 1980, Graham and Senge 1980, and Heertje 1981).
- *acceleration theories:* based on multiplier and acceleration mechanisms caused by discontinuous capital stock adjustments precluding smooth adjustments, so that a fine tuning does not take place (cf. Forrester 1977).
- *innovation theories:* based on lack of adjustment (or lack of diffusion) of innovations to structural economic changes (cf. Clark, et al. 1981, Kleinknecht 1981, and Mensch 1979); this issue will be further taken up in the next section.

STRUCTURAL CHANGES IN SPACE AND TIME

The above mentioned theories on long waves have one feature in common, viz. the emphasis on structural changes in the economy. They offer however, different explanations for long-term economic fluctuations. In almost all theories one important element is missing, viz. attention for the element of *space* both as a driving and a constraining factor for economic dynamics. It has already been demonstrated in section two that various theories on spatial dynamics have been designed, although only a few of them take into consideration the explanations developed in the long wave debate. It may therefore be meaningful to indicate the extent to which spatial dimensions are present in the above mentioned seven theories on long waves. The following spatial levels may be distinguished: global, national and regional/urban. By classifying these theories according to the spatial scale assumed in each of them, the following typology can be obtained (see Table 2).

spatial dimension			
theories	global	national	regional/urban
monetary	x		
resource	x		
inertia	x	x	
competition		x	x
capital		x	x
acceleration		x	x
innovation		x	x

Table 2 Spatial Typology of Long Wave Theories

As mentioned above, space may be a driving force of economic development, as it may shape the conditions under which an accelerated growth may emerge (for instance, the forward and backward accessibility of the port of Rotterdam). On the other hand, space may also act as a constraining factor hampering the take-off of economic growth (for instance, the unfavorable physical conditions and poor accessibility of the region of Calabria in Southern Italy).

In general, one may argue that structural changes in a spatial economic system are related to two phenomena:

- *unsatisfactory threshold values*, which preclude an area from reaching a take-off stage for economic development (e.g., bad climatological conditions);
- *constraining bottleneck factors*, which hamper a further economic development of an area due to limits to growth (e.g., congestion).

Both threshold values and bottleneck factors are closely linked to innovation and to public policy, so that in the context of this article on economic fluctuations in space and time it is necessary to pay more specific attention to both innovation and public policy.

INNOVATIONS AND SPATIAL ECONOMIC DYNAMICS

In the recent literature, innovation is regarded as a key factor for economic dynamics. Innovation will be conceived of as a phase-wide process of research, development, application and exploitation of a new technology or organization (cf. Haustein, et al. 1981). This distinction into phases is useful, as usually invention, adoption and use of a new finding do not take place simultaneously, *inter alia* due to market structures, patent systems, monopoly situations, lack of information or lack of diffusion (see Brown 1981, Davies 1979, and Rosegger 1980). Usually a distinction is made between *basic* innovations (new products, new industries) and *process* innovations (new processes in existing industries). Especially basic innovations are assumed to take place periodically and cluster-wise and hence to lead to long-term economic fluctuations.

In recent years, innovation research has increasingly concentrated on (disaggregate) behavior of individual firms, as one has increasingly become aware of the fact that basic innovations are taking place in a few industries located at specific places (cf. Kleinknecht 1981, Kahdavi 1972, and Nijkamp 1983). Especially on the basis of micro-oriented research, the driving motives of innovations and the impacts of innovations (e.g., labor saving or capital saving technology) can be identified (see also Kamien and Schwarz 1975, and Kennedy 1964).

Basic innovations are generally assumed to cause cyclical economic developments (growth → saturation → recession). In this regard, two different viewpoints may be distinguished:

- the *depression-trigger* hypothesis. This hypothesis claims that the struggle for survival necessitates firms to adopt radical innovations leading to radical changes (Mensch 1979).
- the *demand-pull* hypothesis. This hypothesis assumes that a change in structural economic conditions emerges from drastic impacts from the demand side (final and intermediate products): the market determines the success of innovations (Mowery and Rosenberg 1979).

Translation of the above mentioned ideas to a multi-regional system implies that the development pattern of a spatial system depends on the innovative potential of the regions or cities at hand (cf. Malecki 1979), as the competitive position of regions and cities determines their market share in the national or international economy. Consequently, product cycle theories and regional development theories may be – to a certain extent – similar in nature. The relationship between innovative capacity of a region and its market share in a national or international economy is represented in Figure 1. The shape of this curve is codetermined by the region's competitive power, by its use of R&D investments and its market potential (cf. Schmookler 1966).

In this respect, it may also be meaningful to pay some attention to growth pole theory. This conventional regional development theory regards polarization (scale advantages, interindustrial input-output linkages, and technological innovation) as a necessary condition for an accelerated growth process in a particular location, especially because a diffusion of growth impulses from propulsive to other sectors will favor an integrated regional development (see Nijkamp and Paelinck 1976).

It should be noted however that in growth pole theory innovations are mainly regarded as exogenous tools for obtaining an accelerated growth, while in the Schumpeterian viewpoint innovation is regarded as an endogenous tool in a free-enterprise economy, so that fluctuating economic growth patterns may be expected. Despite these differences, innovation may be regarded as a key factor in spatial and sectoral development processes (see also Dasgupta and Stiglitz 1980, Mansfield 1968, and Nelson and Winter 1977).

PUBLIC POLICY AND SPATIAL ECONOMIC DYNAMICS

Public policy may have a twofold impact on spatial economic dynamics, viz. by creating a *breeding place* for innovations favoring an accelerated growth in space and time (Rosenberg 1976), and by providing the *public overhead capital* (infrastructure) that is necessary for a balanced development (Nijkamp 1982b). Both elements will briefly be discussed here.

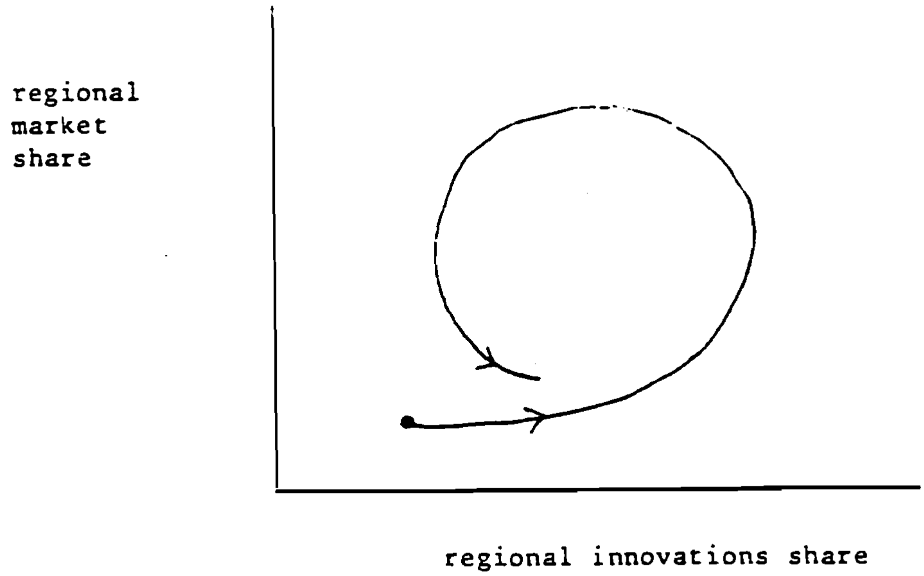

Figure 1 Trajectory of Regional Market Share and Innovations Share

A *breeding place policy* assumes adequate educational facilities, communication possibilities, market entrance, good environmental conditions, a good social climate and a satisfactory locational profile (cf. Olson 1982). The existence of breeding places favoring innovative activities also indicates that monopoly situations and industrial concentrations (including patent systems) are often characterized by a higher technological and innovative potential (e.g., in the field of electronics, petrochemicals and aircraft), although it has to be added also that small firms tend to be an increasing source of various innovations, for instance, in the area of microprocessors (see Rothwell 1979, and Thomas 1981).

Government policies aiming at stimulating the innovative potential may thus concentrate on two fields, viz. direct subsidies on innovation research or indirect creation of innovative breeding places (for instance, by means of local technology transfer centers). The concept of a breeding place can also be identified in the above mentioned growth pole theory, in which innovative behavior and geographical diffusion and adoption of innovations play a crucial role. Whether or not growth pole policy as a spatial development policy in many countries has been marked by spatial economic fluctuations is still an open question, witness the debates in the literature on the existence of 'a clean break with the past' in regard to spatial and urban development trends (see among others, Berry and Dahmann 1977, Vining and Kontuly 1977, and Gordon 1982).

A public overhead policy aims at providing a region or a city with all necessary public endowments that serve to enhance the development potential of a region or city (cf. Hirschman 1958). Examples of such infrastructure capital are: roads, railways, ports, electricity plants, water purification plants, mass transit systems, and the like. The implementation of such public overhead investments may lead to drastic changes in a spatial system. For instance, the invention and use of steam engines in the past century or the exploitation of mass transit systems in our century has had deep impacts on urban and regional growth patterns. Past evidence shows that innovative behavior, public infrastructure investments and spatial economic dynamics are strongly interrelated phenomena. This notion is also reflected in the diffusion process of innovations: many new inventions emerge in major agglomerations (with a great deal of public overhead capital), while often the actual adoption of these inventions may take place somewhere else (e.g., in low-wage peripheral areas).

The impacts of regional public policy (both breeding place policy and public overhead investments policy) on the market share of the region at hand can be represented by means of the following figure (Figure 2). This figure reflects again the notion that competitive power in a spatial system is a major determinant for (un)stable growth processes.

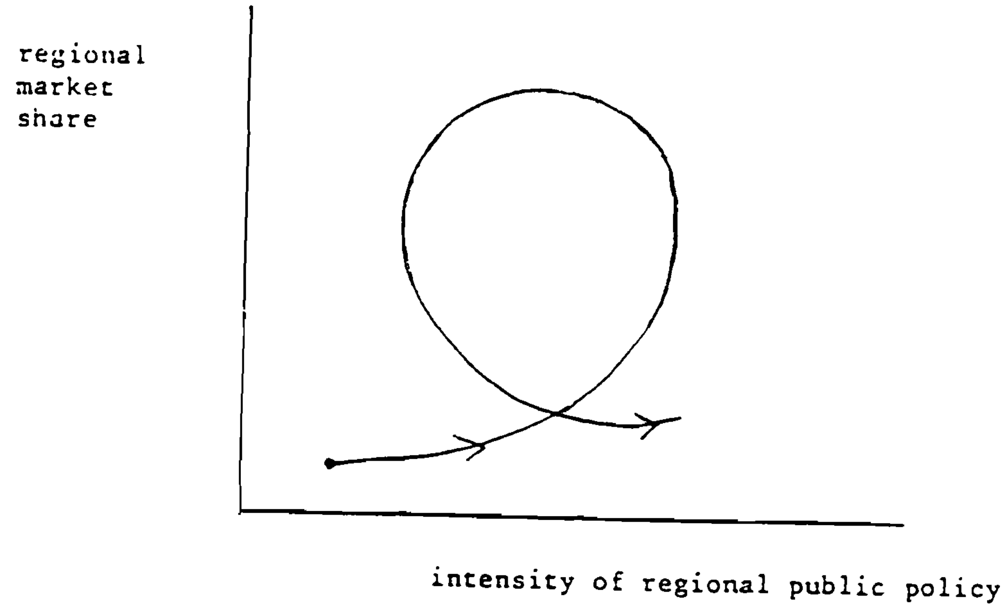

Figure 2 Trajectory of Regional Market Share and Public Policy

Combination of Figures 1 and 2 leads to the evident conclusion that innovation policy and public policy require a fine tuning in order to be fully effective. Spatial economic fluctuations may be induced or stimulated in case of a lack of coordination between these two policies, so that innovative potential, agglomeration size, regional locational conditions and intensity of infrastructure policy are simultaneously determining the structural economic change of cities and regions.

In the literature on agglomeration economies it is often suggested that large scale industrial concentrations and city size favor innovative ability due to higher productivity, more business diversification and better breeding ground for technological progress (see Alonso 1971, Carlino 1977, Kawashima 1981, Nelson and Norman 1977, and Thompson 1977). Malecki (1979) however has recently demonstrated that the innovative potential of traditional large agglomerations is declining, so that apparently innovative activity is suffering from diseconomies of size (cf. also Sveikauskas 1979). Due to filtering down effects caused by agglomeration diseconomies, the innovative capacity of economic centers may be affected and moved to other areas, as soon as a critical bottleneck level (e.g., congestion) in the initial center has been reached. In this regard, we may refer back to the above mentioned notions of threshold values and bottleneck factors.

A SIMPLE MODEL FOR ENDOGENOUS LONG-TERM SPATIAL FLUCTUATIONS

The evolution of a spatial system may exhibit a balanced growth, but also a wide variety of unbalanced growth processes (characterized by cycles or perturbations). As indicated in a previous section, in the recent past various models generating spatial dynamics have been developed.

In the present paper, a simple model for analyzing spatial structural changes will be developed. A central concept in this model is made up by a so-called *quasi-production function*. A quasi-production function is a generalized production function, which – in addition to traditional production factors such as productive capital, labor and land-use – also incorporates infrastructure capital (or public overhead capital) and R&D (or innovative) capital (see Biehl 1980, and Nijkamp 1982b). Infrastructure capital – as a complement to private productive capital – serves to enhance the efficiency of entrepreneurial activities, while R&D capital (both private and public) aims at favoring the innovative potential. Then the following quasiproduction function for a certain area (region or city) may be assumed:

$$Y = f\ (C, S, R)\ . \tag{1}$$

where:

Y = regional share in the national production

C = regional share in the national directly productive capital

S = regional share in the national social overhead capital

R = regional share in the national R&D capital.

By assuming a Cobb-Douglas specification, one may rewrite (1) as follows:

$$Y = \alpha C^{\beta} S^{\gamma} R^{\delta} \tag{2}$$

where the parameters β, γ and δ reflect production elasticities. These elasticities are assumed to be positive on the range (Y^{min}, Y^{max}). Y^{min} reflects a ***minimum threshold level*** of the regional production volume which has to be reached before a self-sustained growth will take place, while Y^{max} reflects a ***bottleneck level*** (or maximum capacity level), beyond which congestion factors lead to a negative marginal product. Consequently, the following conditions hold:

$$\text{if} Y \leq Y^{min}\ , \quad \text{then} \quad \beta, \gamma, \delta = 0 \tag{3}$$

$$\text{if} Y \geq Y^{max}\ , \quad \text{then} \quad \beta, \gamma, \delta \leq 0$$

By assuming now a time-dependent quasi-production function, the shifts in the regional share of the national production volume can be written as:

$$\Delta Y_t = (\beta \tilde{C}_t + \gamma \tilde{S}_t + \delta \tilde{R}_t) Y_{t-1} \tag{4}$$

with:

$$\Delta Y_t = Y_t - Y_{t-1} \tag{5}$$

and:

$$\tilde{C}_t = \frac{C_t - C_{t-1}}{C_{t-1}} \tag{6}$$

$$\tilde{S}_t = \frac{S_t - S_{t-1}}{S_{t-1}} \tag{7}$$

$$\tilde{R}_t = \frac{R_t - R_{t-1}}{R_{t-1}} \tag{8}$$

The economy reflected by (4) will exhibit a stable growth path without structural changes within the range (Y^{min}, Y^{max}). The lower limit Y^{min} is in the present context of innovation and capacity limits less interesting, so that we will focus our attention mainly on the effect of the bottleneck value Y^{max}.

This bottleneck value reflects congestion phenomena due to too high a concentration of productive capital in a certain area leading to diseconomies of scale, environmental decay, and inefficient land use. Beyond Y^{max}, each additional increase in C will have a negative impact on the regional production share. Such a situation of a negative marginal product of capital can be represented as:

$$\beta_t = \hat{\beta} \frac{Y^{max} - \kappa Y_{t-1}}{Y^{max}} \quad , \quad \kappa \geq 1 \tag{9}$$

where $\hat{\beta}$ represents the (fixed) production elasticity of C on the range (Y^{min}, Y^{max}) . Consequently, the adjusted production elasticity has become a time-dependent variable. Similar relationships may be assumed for γ_t and δ_t, so that substitution of β_t, γ_t and δ_t into (4) yields the following result:

$$\Delta T_t = (\hat{\beta} \tilde{C}_t + \hat{\gamma} \tilde{S}_t + \hat{\delta} \tilde{R}_t)(Y^{max} - \kappa Y_{t-1}) Y_{t-1} / Y^{max} \tag{10}$$

$$= \tilde{Y}_t (Y^{max} - \kappa Y_{t-1}) Y_{t-1} / Y^{max}$$

with:

$$\tilde{Y}_t = \hat{\beta} \tilde{C}_t + \hat{\gamma} \tilde{S}_t + \hat{\delta} \tilde{R}_t \tag{11}$$

$\tilde{Y}_t$ may be regarded as the rate of change in the original quasi-production function. Relationship (10) is essentially a Volterra-Lotka-type model, which has often been used in population biology, for instance, to describe predator-prey relationships (see Goh and Jennings 1977, Jeffries 1979, Pimm 1982, and Wilson 1981b). This model in difference equation form has been applied in the past decade among others by May (1974), Li and Yorke (1975), Yorke and Yorke (1975), Dendrinos and Mullally (1983), and Brouwer and Nijkamp (1984).

Relationship (10) has some interesting features. May (1974) has shown that models of this type – despite their mathematical simplicity – may exhibit a remarkable spectrum of dynamical behavior, such as stable equilibrium, stable cycles, stable cyclic oscillations, and chaotic trajectories with a-periodic (but bounded) fluctuations. The behavior of such a model is determined by the initial conditions of the system and by its growth rate (depending on $\tilde{Y}_t$), but in principle this model is able to generate a wide variety of dynamic growth patterns. Consequently, in a spatial context long-term fluctuations depend on the initial values of a spatial system and on its growth rate (which is codetermined by the production elasticities of production capital, overhead capital and R&D capital).

The growth rate however, is a time-dependent variable, which can also be controlled by (private and public) policy measures. If the model is used in the framework of optimal control theory, generalized geometric (signomial) programming algorithms can be used to identify optimal controls (see Duffin and Peterson 1973, and Nijkamp 1972).

A next step may be to introduce an additional relationship for R&D investments, given the assumption that R&D may serve as a tool to remove bottlenecks (the so-called depression-trigger hypothesis). Then we may hypothesize the following relationship, as soon as an area has reached its critical bottleneck level Y^{max}.

$$\tilde{\tilde{R}}_t = \tilde{R}_t \, (Y_{t-1} - \Pi Y^{max}) / Y^{max} \tag{12}$$

where $\tilde{\tilde{R}}_t$ is the rate of change in R&D capital beyond the value Y^{max}. Substitution of (12) into (10) yields:

$$\Delta Y_t = [\tilde{\tilde{Y}}_t + \hat{\delta} \tilde{R}_t \, (Y_{t-1} - \Pi Y^{max}) / Y^{max}] \, (Y^{max} - \kappa Y_{t-1}) Y_{t-1} / Y^{max} \tag{13}$$

with:

$$\tilde{\tilde{Y}}_t = \hat{\beta} \tilde{C}_t + \hat{\gamma} \tilde{S}_t \tag{14}$$

The latter relationship is a nested dynamic model. This model may exhibit even more complicated dynamic growth patterns, depending on the superimposition over two dynamic phenomena. The perturbations caused by the bottleneck factors may be neutralized or reinforced by R&D investments, depending on the fine tuning of new technology investments and spatial fluctuations.

The foregoing model can also be extended with spatial interaction effects, and savings consumption and effect, so that also the demand-pull hypothesis can be incorporated in this spatial systems model.

CONCLUSION

Non-linear dynamics appear to be able to generate complex dynamic trajectories for structural changes. The Volterra-Lotka-type models are able to incorporate some important key factors (innovation, public overhead investments) which act as driving forces for a spatial system. Furthermore, such models allow the study of conditions under which a stable equilibrium may emerge. Thus, long-term economic fluctuations (including long waves) can be studied on the basis of fairly simple notions based on a conventional production theory. The analysis described in Section 5 has also demonstrated that long waves are *not* a necessary phenomenon, but may emerge under certain specific economic and technological conditions in a spatial economic system.

Finally, it should be noted that various research questions have been left open in the present paper:

- policy conflicts emerging from multiple areas linked together in multilevel spatial systems (see Nijkamp 1981);
- detailed analyses of various sectors in the spatial system at hand, for instance, in the field of energy, housing, transportation (see Van Lierop and Nijkamp 1983);
- qualitative impact analysis due to intangible societal effects of technological innovation on a dynamic spatial system (see Nijkamp, et al. 1984);
- integration of disaggregate dynamic behavior (of individuals, groups or sectors) and global dynamic behavior of the system as a whole, for instance, by means of event-history analysis (see Hannan and Tuma 1984);
- integration of dynamic entropy theory, the theory of self-organizing systems and tensor analysis in a long wave context.

REFERENCES

Adelman, I. (1965) Long Cycles – Fact or Artifact? *American Economic Review*, June, Vol.44, pp. 444-463.

Allen, P.M., M. Sanglier, F. Boon, J.L. Deneubourg, and A. de Palma, (1981) *Models of Urban Settlements and Structure of Dynamic Self-Organizing Systems*, US Dept. of Transportation, Washington, D.C.

Alonso, W.A., (1971) The Economics of Urban Size, *Papers of the Regional Science Association*, Vol.26, pp. 67-83.

Andersson, A.E., (1981) Structural Change and Technological Development, *Regional Science and Urban Economics*, Vol.11, No.3, pp. 351-362.

Batten, D.F. (1981) On the Dynamics of Industrial Evolution, Research Paper Umea Economic Studies No.97, University of Umea, Umea.

van den Berg, L., R. Drewett, L.H. Klaassen, A. Rossi, and C.H.T. Vijverberg, (1982) *Urban Europe, A Study of Growth and Decline*, Pergamon, Oxford.

Berry, B.J.L., and D.C. Dahmann, (1977) Population Redistribution in the United States in the 1970's, *Population Development Review*, Vol.3, pp. 443-471.

Biehl, D. (1980) Determinants of Regional Disparities and the Role of Public Finance, *Public Finance*, Vol.35, pp. 44-71.

Bieshaar, H., and A. Kleinknecht, (1983) Kondratiev Long Waves in Aggregate Output, Paper presented at the Conference on Long Waves, Depression and Innovation, Siena, October.

Brouwer, F., and P. Nijkamp, (1984) Qualitative Structure Analysis of Complex Systems, *Measuring the Unmeasurable; Analysis of Qualitative Spatial Data* (P. Nijkamp, H. Leitner and N. Wrigley, eds.), Martinus Nijhoff, The Hague, (forthcoming).

Brown, L.A., (1981) *Innovation Diffusion* Methuen, London.

Carlino, G.A., (1977) *Economies of Scale in Manufacturing Location*, Kluwer Nijhoff, Boston.

Casti, J., (1979) *Connectivity, Complexity and Catastrophe in Large-Scale Systems*, John Wiley, Chichester.

Clark, J., (1980) A Model of Embodied Technical Change and Employment, *Technological Forecasting and Social Change*, Vol.16, pp. 47-65.

Clark J., C. Freeman, and L. Soete, (1981) Long Waves and Technological Developments in the 20th Century, *Konjunktur, Krise, Gesellschaft* (D. Petzina and G. van Roon, eds.), Klett-Cotta, Stuttgart, pp. 132-179.

Dasgupta, P., and J. Stiglitz, (1980) Industrial Structure and the Nature of Innovative Activity, *Economic Journal*, Vol.90, pp. 266-293.

Dasgupta, P., (1982) The Theory of Technological Competition, Paper IEA Conference on New Developments in the Theory of Market Structures, Ottawa, (mimeographed).

Davies, S., (1979) *The Diffusion of Process Innovations*, Cambridge University Press, Cambridge.

Delbeke, J., (1981) Recent Long-Wave Theories: A Critical Survey, *Futures*, Vol.13, No.4, pp. 246-257.

Dendrinos, D.S. (ed.) (1981) *Dynamic Non-Linear Theory and General Urban/Regional Systems*, School of Architecture and Urban Design, Lawrence, Kansas.

Dendrinos, D.A., and H. Mullally, (1983) Empirical Evidence of Volterra-Lotka Dynamics in United States Metropolitan Areas: 1940-1977, *Evolving Geographical Structures* (D.A. Griffith and T. Lea, eds.), Martinus Nijhoff, The Hague, pp. 170-195.

Duffin, R.J., and E.K. Peterson, (1973) Geometric Programming with Signomials, *Journal of Optimization Theory and Applications*, Vol.11, No.1, pp. 3-35.

Dupriez, L.H., (1947) *Des Mouvements Economiques Généraux*, University of Louvain, Louvain.

van Duijn, J.J., (1979) *De Lange Golf in de Economie*, Van Gorcum, Assen.

Forrester, J.W., (1977) Growth Cycles, *De Economist*, Vol.125, No.4, pp. 525-543.

Freeman, C., J. Clark, and L. Soete, (1982) *Unemployment and Technical Innovation*, Frances Pinter, London.

Futia, C.A., (1980) Schumpeterian Competition, *Quarterly Journal of Economics*, Vol.94, pp. 675-695.

Goh, B.S., and L.S. Jennings, (1977) Feasibility and Stability in Randomly Assembled Lotka-Volterra Models, *Ecological Modelling*, Vol.3, No.1, pp. 63-71.

Gordon, P., (1982) Deconcentration without a 'Clean Break', *Human Settlement Systems: Spatial Patterns and Trends* (T. Kawashima, and P. Korcelli, eds.), International Institute for Applied Systems Analysis, Laxenburg, pp. 193-202.

Graham, A.K., and P.M. Senge (1980) A Long Wave Hypothesis of Innovation, *Technological Forecasting and Social Change*, Vol.16, pp. 283-311.

Haag, G., (1983) The Macroeconomic Potential, Paper presented at the Conference on Long Waves, Depression and Innovation, Siena, October.

Hannan, M.D., and N.B. Tuma, (1984) Dynamic Analysis of Qualitative Variables, *Measuring the Unmeasurable* (P. Nijkamp, H. Leitner, and N. Wrigley, eds.), Martinus Nijhoff, The Hague, (forthcoming).

Haustein, H.D., A. Maier, and L. Uhlmann, (1981) Innovation and Efficiency, Research Report RR-81-7, International Institute for Applied Systems Analysis, Laxenburg.

Heertje, A., (1981) Technical Change and Economics, *Man, Environment, Space and Time*, Vol.1, No.2, pp. 59–76.

Hirschman, A.O., (1958) *Strategy of Economic Development*, Yale University Press, New Haven.

Isard, W., and P. Liossatos, (1979) *Spatial Dynamics and Optimal Space-Time Development*, North-Holland, Amsterdam.

Jacobs, J., (1977) *The Death and Life of Great American Cities*, Vintage Books, New York.

Jeffries, C., (1979) Qualitative Stability and Diagraphs in Model Ecosystems, *Ecology*, Vol.55, No.6, pp. 1415-1419.

Kamien, M.I., and N.L. Schwartz, (1975) Market Structure and Innovation: A Survey, *Journal of Economic Literature*, Vol.13, pp. 1-37.

Kawashima, T., (1981) Urban Optimality, *Cities in Transition*, (P. Nijkamp, and P. Rietveld, eds.), Sijthoff and Noordhoff, Alphen aan den Rijn, pp. 141-156.

Kennedy, C., (1964) Induced Bias in Innovation and the Theory of Distribution, *Economic Journal*, Vol.74, pp. 541-547.

Kleinknecht, A., (1981) Observations on the Schumpeterian Swarming of Innovations, *Futures*, August, pp. 293-307.

Li, T., and J.A. Yorke, (1975) Period Three Implies Chaos, *American Mathematical Monthly*, Vol.82, pp. 985–992.

Lierop, W.F.J. van, and P. Nijkamp, (1983) Elements of Metropolitan Change, Discussion paper, Dept. of Economics, Free University, Amsterdam.

Loury, G., (1980) Market Structure and Innovation, *Quarterly Journal of Economics*, Vol.93, pp. 395–410.

Mahdavi, K.B., (1972) *Technological Innovation*, Beckmans, Stockholm.

Malecki, E.J., (1979) Locational Trends in R&D by Large US Corporations, 1965-1977, *Economic Geography*, Vol.55, pp. 309–323.

Mandel, E., (1980) *Long Waves of Capitalist Development*, Cambridge University Press, Cambridge.

Mansfield, E., (1968) *Industrial Research and Technological Innovation*, Norton, New York.

Mass, N.J., (1980) Monetary and Real Causes of Investment Booms and Declines, *Socio-Economic Planning Sciences*, Vol.14, pp. 282-290.

May, R.M., (1974) Biological Publications with Non-Overlapping Generations, *Science*, No.186, pp. 645–647.

Mensch, G., (1979) *Stalemate in Technology*, Ballinger, Cambridge.

Mowery, D., and N. Rosenberg, (1979) The Influence of Market Demand on Innovation, *Research Policy*, Vol.8, pp. 102-153.

Nelson, R.R., and V.D. Norman, (1977) Technological Change and Factor Mix Over the Product Cycle, *Journal of Development Economics*, Vol.4, pp. 3-24.

Nelson, R.R., and S.G. Winter, (1977) In Search of Useful Theory of Innovation, *Research Policy*, Vol.6, pp. 36-76.

Norton, R.D., (1979) *City Life Cycles and American Urban Policy*, Academic Press, New York.

Nijkamp, P., (1972) *Planning of Industrial Complexes by Means of Geometric Programming*, Rotterdam University Press, Rotterdam.

Nijkamp, P., and J.H.P. Paelinck, (1976) *Operational Theory and Method in Regional Economics*, Gower, Aldershot.

Nijkamp, P., (1981) *Environmental Policy Analysis*, Wiley, Chichester/New York.

Nijkamp, P., (1982a) Long Waves or Catastrophes in Regional Development, *Socio-Economic Planning Sciences*, Vol.16, No.6, pp. 262-271.

Nijkamp, P., (1982b) A Multidimensional Analysis of Regional Infrastructure and Economic Development, *Structural Economic Analysis and Planning in Time and Space*, (A. Andersson, and T. Puu, eds.), North-Holland Publ. Co., Amsterdam, pp. 1-24.

Nijkamp, P., (1983) Technological Change, Policy Response and Spatial Dynamics, *Evolving Geographical Structures* (D.A. Griffith, and T. Lea, eds.), Martinus Nijhoff, The Hague, pp. 75-99.

Nijkamp, P., and U. Schubert, (1983) Structural Change in Urban Systems, Collaborative Paper CP-83-57, International Institute for Applied Systems Analysis, Laxenburg.

Nijkamp, P., H. Leitner, and N. Wrigley (eds.) (1984) *Measuring the Unmeasurable*, Martinus Nijhoff, The Hague.

Olson, M., (1982) *The Rise and Decline of Nations*, New Haven.

Pimm, S.L., (1982) *Food Webs*, Chapman and Hall, London.

Pred, A., (1977) *City-Systems in Advanced Economies: Past Growth, Present Processes and Future Development Options*, London: Hutchinson.

Rosegger, G., (1980) *The Economics of Production and Innovation*, Pergamon Press, Oxford.

Rosenberg, N., (1976) *Perspectives on Technology*, Cambridge University Press, Cambridge.

Rostow, W.W., (1978) *The World Economy*, MacMillan, London.

Rothwell, R., (1979) Small and Medium Sized Manufacturing Firms and Technological Innovation, *Management Decision*, Vol.16, pp. 362-370.

Schmookler, J., (1966) *Invention and Economic Growth*, Cambridge University Press, Cambridge.

Schumpeter, J.A., (1939) *Business Cycles*, McGraw-Hill, New York.

Sveikauskas, L., (1979) Interurban Differences in the Innovative Nature of Production, *Journal of Urban Economics*, Vol.6, pp. 216-227.

Thomas, B., (1972) *Migration and Urban Development*, Methuen, London.

Thomas, M.D., (1981) Growth and Change in Innovative Manufacturing Industries and Firms, Collaborative Paper CP-81-5, International Institute for Applied Systems Analysis, Laxenburg.

Thompson, W,.R., (1977) The Urban Development Process, *Small Cities in Transition*, (H.J. Bryce, ed.), Ballinger, Cambridge, pp. 95-112.

Vining, D.R., and T. Kontuly, (1977) Population Dispersal from Major Metropolitan Regions, *International Regional Science Review*, Vol.3, pp. 143-156.

von Weiszäcker, C.C., (1980) *Barriers to Entry*, Springer, Berlin.

Wilson, A.G., (1981a) *Catastrophe Theory and Bifurcation*, Croom Helm, London.

Wilson, A.G., (1981b) *Geography and the Environment*, John Wiley, Chichester.

Yorke, J.A., and E.D. Yorke, (1981) Chaotic Behavior and Fluid Dynamics, *Hydrodynamic Instabilities and the Transition to Turbulence*, (H.L. Swinney and J.P. Gollub, eds.), Springer-Verlag, New York, pp. 112-128.

PART II

COMMENTS ON TOPICS 1 TO 5

COMMENTS ON TOPIC 1: THEORIES OF THE LONG WAVE

Jacob J. van Duijn

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 socioeconomic 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 neoclassicist, 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 previous 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)*

*The names associated here with the various theories serve only as indications of the

If we would also want to include the prewar literature, other groups of theories would have to be added: notably the monetary theories, war theories, and agricultural theories. These are not adhered to any more – 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 Kondratiev) 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 Kondratiev wave. Kondratiev himself sought for a clue to the long wave by pointing at what he called investment in "basic capital" (railroads, bridges, roads, waterworks). I 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 *et al.* is that they can generate long waves by specifying investment behavior, in general, without exclusively relying on capital goods of long duration. Forrester *et al.* 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 its own capacity. Since it has to acquire capital goods from itself, there is "self-ordering".

Forrester *et al.* 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.

Note that Forrester *et al.* 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.

---

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); Kleinkneht has been an associate of Mensch's; while Gordon has done work with Bowles and Weisskopf, and with Edwards and Reich.

(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 that 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 that 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 that 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 versus 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 *et al.* have repeatedly pointed out that, while the moment of introduction of an innovation is of significance, it is the rapid diffusion that 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 that 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 about 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 Kondratiev 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 exploitation 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 that 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, because 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 going down slightly.

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 the 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 that 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 that favored this extension.

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 the Second World War, the synthetic fibers, artificial resins, electronics and aircraft industries were definitely based on technologies that 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. Kondratiev, 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 noneconomic factors, such as wars of conquest, extensions and contractions 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, owing to the disappearance of technological rents (and presumably also 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 "noneconomic" consequences long waves might have. It is probably fair to say 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 and others, 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 organization 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 *et al.* 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, but, according to Gordon *et al.* 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 into the conditions that have to be met before an economy can make the transition from depression back to prosperity.

COMMENTS ON TOPIC 1: THEORIES OF THE LONG WAVE

Revold M. Entov

The hypothesis that presupposes the existence of "long cycles" presumably possesses certain analytical merits. It permits us, 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 generalize elementary technoeconomic processes and overlook the concrete historical forms of their development. The volume and quality (in particular, the 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. Apart from that, there exists 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 the capitalist machine industry emerges on the historical scene, various fluctuations come to be dominated by a regular alternation of recessions and upswings on a macroeconomic (national and, since the latter part of the last century, also international) scale. This process was later called a regular "business cycle".

The cyclical crises[1] already have a century-and-a-half history. In the 1960s and early 1970s some economists doubted whether these uniformities would retain their validity in the second half of this century (see, e.g., *Is the Business Cycle Obsolete*? New York: Wiley, 1969). Today, however, such doubts are expressed more rarely, owing partly to the recessions that occurred in the mid-seventies and early eighties.

The two latest comparatively acute and long recessions and the slack cyclical upswing between them have again drawn the economists' attention to the possible impact of the low-frequency oscillatory component. Under these circumstances the absence of comparative analysis of regular business cycles and long waves seems to be one of the most surprising features of the present "boom" in the long-wave theories. Although various theories and models of regular cycles and long waves frequently employ the similar "building blocks" (the overestimation of future

---

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

demand by capital goods producers, regular overaccumulation of capital in the the form of plant and equipment, the multiplier--accelerator interaction), long-wave theoreticians unfortunately very rarely analyze the specific conditions under which the above-mentioned factors generate not only business cycles but also long waves.

The assumption concerning the interaction of regular business cycles and long waves seems to be especially important. Is it justifiable to believe in simple "mechanical" interference of autonomous fluctuations with different parametric values (frequency, amplitude, etc.) or are the real processes more complex because of the multiform interdependence of these economic processes? The following presentation contains a brief treatment of this subject.

Deviations are being accumulated in the course of business expansion that 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 the case of a comparatively shallow recession. Conditions are being periodically shaped for a cumulative ("transcyclical") development of certain processes restraining growth of the rate of profit. These transcyclical processes are usually manifested in various spheres: perhaps they are directly connected with specific long-term regularities of capital accumulation.

The role of the long-wave generator is most frequently ascribed to "swarming" of technical innovations. One can hardly neglect of the role of this factor. Yet Marxist theory, which considers the development of productive forces to be the primary factor of social dynamics, emphasizes the influence of existing socioeconomic relations on technical progress. The treatment of each cluster of innovations as an exogenous generator of long-term fluctuations leaves the main questions concerning the nature of long waves unanswered. The progress of both fundamental science and research and development seems to be much more steady than the diffusion of these innovations. The inculcation of the most important technical innovations and their impact on economic activity are influenced by several factors, such as the structure of the market and the market situation, relative prices, interest rates, business expectations, etc.[2] The favorable conditions for more or less intensive modernization and/or renewal of productive capacities and for especially rapid growth of new industries arise during every cyclical expansion.

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. For example, at the given level of technical and economic development, a situation may arise under which the market demand has been "saturated" by the output of major traditional industries, while the spasmodic expansion of the consumption of natural resources runs against its limits.[3] In recent years, such

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

[3] Indications of partial saturation or limits of supply of some raw materials do not and cannot mean, of course, that the individual's requirements in some commodities have been fully met, or that some natural resources have been exhausted.

oscillatory contours have also involved direct and reverse connections between economic growth and increasingly acute ecological problems.

Hence it is possible to suppose that the structural distortions and the growth constraints accumulated during several cycles cannot be eliminated by more or less prompt market reaction. The crisis brought about by the cumulative movement of these processes is the crisis of the entire structure of established socioeconomic 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.

The general worsening of the overall economic growth conditions tells directly upon the scale and forms of the investment process: the growth rate of aggregate investments tends to slow down and in some cases a tendency is felt for a decreased rate of investment profitability. These changes would occur in the form of a gradual growth in the investment risk. A sector of the economy marked by an intensive accumulation of nonresidential 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), which 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 long periods 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 forms, 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.

Thus, the relevant estimates can show that the decreasing phase of low-frequency fluctuations is, more often than not, characterized 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 phase. A gradual "shaking" of the structure regulating commodity-money circulation and capital movements further intensifies economic instability.

COMMENTS ON TOPIC 1: THEORIES OF THE LONG WAVE
AN INTEGRATED APPROACH TO THE ECONOMIC LONG WAVE

Jay W. Forrester, Alan K. Graham, Peter M. Senge, and **John D. Sterman**

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 be "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 versus Exogenous explanation

(2). Structural versus Correlative

(3). Disequalibrium/dynamic versus 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. An endogenous theory will explain the upper and lower turning points of the long wave as the natural consequence of the continuous evolution of the system. In an endogenous theory there is no need to explain the turning points of the cycle as the result of a particular exogenous event.

In contrast, an exogenous theory is one in which the long wave is the result of a fluctuation in a variable that is itself outside the boundary of the theory, and therefore unexplained. The 19th 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 variables. 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 that 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 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 4- to 7-year business cycle, an intermediate cycle of approximately 15–25 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 with 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 that 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, and basic materials such as steel from other firms in the private sector. The capital producers differ from other sectors because of 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 that 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 further 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 years 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 owing 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. For more information on the self-ordering mechanisms, see Sterman (1983).

Real Interest Rates and Prices

Self-ordering, though it may be sufficient to generate the long wave, is not the only mechanism at work. Another major mechanism that we believe contributes to the long wave revolves around the dynamics of real interest rates and prices.

Historically, long-wave expansions have been periods of low or even negative real interest rates, especially in the later part of the expansion. Near the peaks, real interest rates have risen sharply and remained at high levels through the downturns and into the depression periods. In the current long-wave downturn, the high level of real interest rates has been blamed on restrictive monetary policies. Yet the National Model generates the same historical pattern (low, then sharply rising real interest rates over the long wave expansion, peak, and downturn) without a tightening of monetary policy.

Early in the long-wave expansion, the demand for goods and especially capital is growing, putting upward pressure on prices. As prices rise, the real interest rate falls, encouraging still more investment. The resulting expansion in investment demand and the demand for assets such as land and housing puts further upward pressure on prices, and the resulting increase in inflation further reduce real interest rates. During the downturn, the process reverses. As demand for capital, land, housing, and other assets falls (because of the buildup of excess capacity), prices soften and inflation subsides. Real interest rates therefore rise, discouraging investment still further, creating still more downward pressure on prices, and reinforcing the rise in real interest rates.

The argument above depends on a lag between a change in inflation and the response of nominal interest rates. If nominal rates rapidly adjusted to inflation, then the real rate would remain quite stable and the process described above would be weak. The historical evidence verifies that nominal interest rates do not immediately adjust to changes in inflation, but rather lag significantly behind (see Senge 1983). To see why nominal interest rates lag behind inflation, consider the situation at the beginning of the expansion period of the long wave. Demand for capital and goods is rising, and beginning to push up prices. At the same time, the borrowing needs of the economy expand, bidding up nominal interest rates. The pressure on interest rates and the pressure on prices arise from the same source

– the surge in investment and consumer demand during the long-wave expansion – and therefore move roughly in phase. Real interest rates, however, are the *level* of nominal interest rates less the fractional *rate* of price change. Price change (inflation) reaches its peak when the pressure to invest is highest, while prices and nominal interest rates reach their peaks later, near the peak of the long wave, when the pressure to invest has been dissipated. The result is that nominal interest rates lag inflation significantly. Thus during the long-wave expansion, nominal rates rise more slowly than inflation, leading to low real interest rates. Near the peak of the long wave, nominal rates again lag behind declining inflation or deflation, leading to a sharp increase in real interest rates.

Simulations of the National Model show these positive feedback loops can be powerful destabilizers of the economy and help contribute to the self-sustaining nature of the long wave by substantially amplifying the basic self-ordering processes described above.

Debt/Deflation Spiral

Another major process that we believe contributes to the long wave, closely related to the behavior of real interest rates, 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 under way, 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, high profitability, and low real interest rates all encourage expansion of external financing.

Toward 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.

During the long-wave downturn, debt is liquidated and prices typically fall. In such a debt/deflation spiral, as described by Irving Fisher, 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. Like the real interest rate 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 50-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, opportunities for basic innovation 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, as a result of 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 satisfied, 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 overriding 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 privileges 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 *terra incognita*. 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.

THE 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 to 1890s. Between 1873 and 1897 there were three great depressions in the USA, 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 dynamics offers one such methodology.

COMMENTS ON TOPIC 1: THEORIES OF THE LONG WAVE

Christopher Freeman and **Luc Soete**

"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 (on the early history of long-wave ideas, see in particular, van Duijn 1983). 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 periodization.

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 (see, for example, Petzina and van Roon 1981). On this level it is extremely unlikely that the debate will ever be finally resolved. The retrospective reconstruction of historical time 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 four "waves" or "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 have 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 (1979) 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. These fluctuations are believed to be of sufficient interest 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 postwar 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 those of 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 (1981). 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 overexpand 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 new-technology theories and the rest. The new technology theories derive from Schumpeter's original interpretation of Kondratiev cycles (Schumpeter 1939) 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 (1981) and Forrester (1981), who regard it as a form of "technological determinism", or as an overestimation of the role of innovative entrepreneurs. Critics of the Schumpeterian approach, from Kuznets (1940) to Rosenberg (Rosenberg and Frischtak 1983), 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 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 that alone could give rise to major fluctuations in the economic system.

Freeman, Clark and Soete (1982), 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 lack 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 business cycle and incorporated by Schumpeter as a central feature of his theory. This erosion of profit margins is attributed by neo-Schumpeterians (with varying degrees of emphasis) to four main factors:

(1) The increased competition associated with the intensive "swarming" and "bandwagon" 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 (1983, chap. II) has clarified this point particularly well. Pasinetti (1981) 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 (Scheininnovationens) 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 substantial differences emerge.

In an important original contribution to the recent London seminar on "Technical Innovation, Design and Long Cycles in Economic Development", Carlota Perez-Perez (1983)[1] emphasizes the importance of a good "match" between the technological "style" or "paradigm" of a long wave and the socio-institutional environment. Depressions, in her analysis, represent periods of mismatch 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 includes 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 worldwide 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 energy intensive materials, and the Tayloristic assembly line production engineering approach. However, these same institutions that were rather well adapted to that mature technological style are rather ill adapted to the requirements of the new technological paradigm, associated with microelectronics 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 (1975) has pointed out that there is in any case reason to expect periods of mismatch between the science–technology system, the socioeconomic institutions, and the political and legal framework. This arises from the simple 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 timelags 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.

[1]And also, of course, in her contribution to this Conference.

COMMENTS ON TOPIC 1: THEORIES OF THE LONG WAVE

Hans H. Glismann

GROWTH MODELS

It may be worth while 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 the case where the exogenous variables of traditional growth models cause long waves of economic development, be it through fluctuations 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 that 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 a few of them are important, at any point in time. 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 the 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 suppressed masses Communism would set an end to the inherently antagonistic development hitherto experienced.

Of course, neither Hegel nor Marx thought about Kondratiev waves of economic development. Indeed the falling rate of profits was regarded to be a trend phenomenon rather 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 fluctuations 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 labeled "monetary". One is related to the Friedman/Schwarz analysis of the monetary history of the United States (especially concerning 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 cause 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 labeled "monetary", is the original Kondratiev 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 Kondratiev who maintained 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 explaining 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 in 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 Kondratiev, Spiethoff, and Schumpeter, long-term fluctuations in investment activity can also result from systematic price distortions and rectifications on product and factor markets that 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 has 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 sluggishness 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

[1]Excerpt from Glismann et al. (1983).

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.

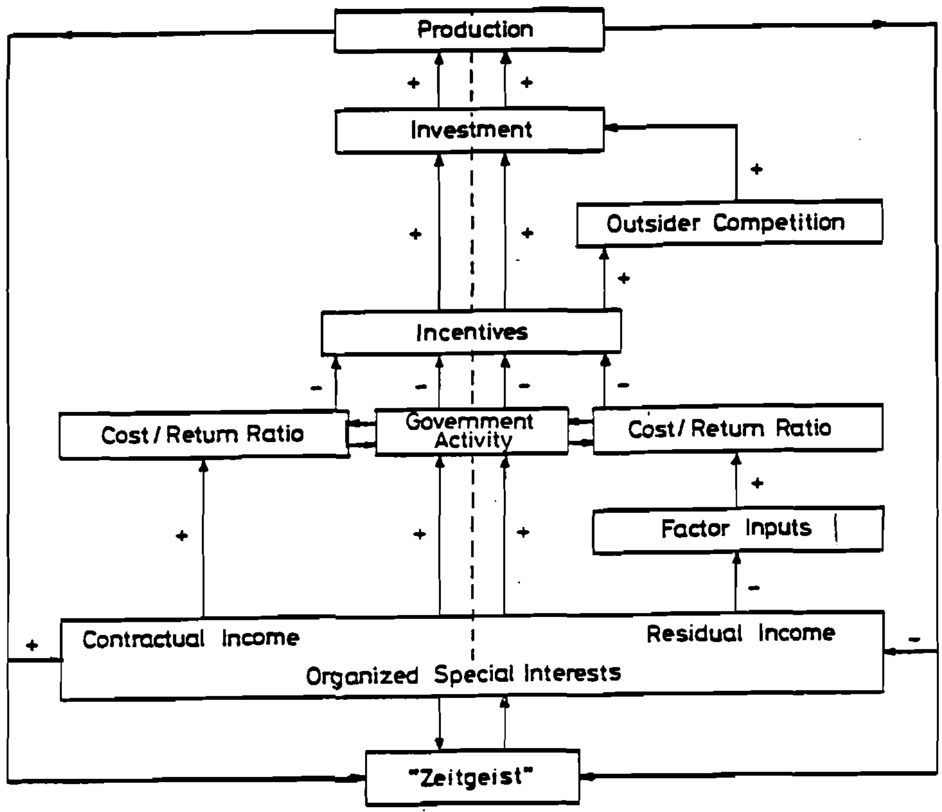

Figure 1 On the theory of long waves in economic development.

A diagrammatical representation of the basic structure of this mechanism might clarify our approach. The right-hand side of Figure 1 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.

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 overall 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 asunder. 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 a cartel to opt for the beaten track internally, and to discriminate against outside producers (and individual cartel members) by securing its position domestically 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 that 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 that 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.

COMMENTS ON TOPIC 2: IDENTIFICATION OF LONG WAVES

Jay W. Forrester, Alan K. Graham, Peter M. Senge, and **John D. Sterman**

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. Koopman'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 50 years obviously does not show that 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 overexpansion. 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 period after the Second World War, 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 50-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 50-year cycle with peaks exacerbated by the wars of 1812, 1860–1865, and 1915–1918. Yet, the 50-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 that can amplify it. These mechanisms may have the ability to generate oscillations independently with periods of roughly 50 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" that 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 of 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 that 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, 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 4- to 7-year business cycle was found to be caused by interactions between inventory management and employment policies. The average period of about 4 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 National Model also generated a 15- to 25-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 20-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 with 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 that 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 cyclical 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 correlation!) 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 as is 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 ten to twenty years, including:

Increasing capital intensity

Replacement of labor by capital

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 the 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 among 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 that 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.

COMMENTS ON TOPIC 2: IDENTIFICATION OF LONG WAVES

Hans H. Glismann

DEFINITIONS

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

Since economics is 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 approximated by the social product, that matters. The rate of unemployment, which is 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 movements *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 potential 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 product 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 disequilibria.

IDENTIFICATION[1]

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 that can be made visible to the observer we adopted and, to our belief, improved Kondratiev'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, smoothing 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 that make 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 one 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,
- the beginning and end of cycles should be the inflection points instead of troughs, and
- detrending plus smoothing 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 from the "real" ones; this argument is all the more relevant the shorter the time series is.

Taking the second argument, 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. Smoothing does not help that much. Thus, one has to contend with troughs and peaks.

As regards the Slutzky effect it may be added that all other smoothing 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 artificially constructed because

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

[1]See also Glismann et al. (1981).

(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, be expected, owing to the two world wars in between the data.

PROBLEMS

Proving causalities and refutation of hypotheses pose 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 really 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 easily made, let alone the case of its determinants. Maybe some day data will be comprehensive enough for us to apply some variant of spectral analysis (allowing, however, for changes in the phases), but we all shall be dead by then.

Problems sometimes accumulate. 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[2] 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 exist first). The real wage position under these circumstances indicates possibilities for wage increases in the depression period that, 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, such a model should be

[2]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 other things, for terms of trade effects) with real wage increases.

(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 that rule 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.

REFERENCES

Glismann, H.H., H. Rodemer, and F. Wolter 1983 Long Waves in Economic Development. Causes and Empirical Evidence. In: Christopher Freeman (ed.), *Long Waves in the World Economy*, London, p. 137.

Glismann, H.H., H. Rodemer, and F. Wolter 1981 Lange Wellen des wirtschaftlichen Wachstums (Replik und Weiterführung). In: Dietmar Petzina, Ger van Roon (Eds.), *Konjunktur, Krise, Gesellschaft*, Stuttgart, p. 66.

COMMENTS ON TOPIC 3: THEORY TESTING AND INTEGRATION

Jay W. Forrester, Alan K. Graham, Peter M. Senge, and **John D. Sterman**

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, until now, 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 wave are not mutually exclusive. Consider, for example, the capital overexpansion 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 a new expansion possible. Both theories may be correct insofar as they identify mechanisms that operate in real life. Both can be integrated into a broader theory that could serve as a basis for assessing their relative capabilities to explain past long waves and for 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 20-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 that 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 that 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 that 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 representation 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 communicating the long-wave theory to the broader community of economists and policy makers.

Several such models have already been developed. Sterman (1983) develops a simple model that 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 important, 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 common, 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 particular, 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 economic 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 feed back and amplify the long wave.

BUILDING CONFIDENCE IN AN INTEGRATED 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 with available information on decision making. Such information will be primarily qualitative, but a model that 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 economics.

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 constantly bombarded by noise. These small random events have a strong influence on the exact path of the system through time. The business cycle, for example, is a damped mode that 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.

COMMENTS ON TOPIC 4: POSSIBILITIES FOR INFLUENCING LONG-WAVE BEHAVIOR

Jay W. Forrester, Alan K. Graham, Peter M. Senge, and John D. Sterman

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 methods. 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?

THE 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 10 to 15 years will be one of the recurring "Great Depressions" that occur at intervals of 40 to 60 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 emerge. 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 lie 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 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 which 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 30 percent or more of the total capital plant. Eventually, the excess is perceived and new construction declines drastically. Several imbalances arise from the overexpansion 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 fall 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, farmland 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, with 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 wave 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 a 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 recognize 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 directions 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 despair 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 difficult situation, there is good reason to believe that wise policy choices can alter the course of events, probably not to a smooth and stress-free utopia but certainly to a less traumatic transition than if counterproductive policies are inadvertently 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 is 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 will be needed in the next 15 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 unused factory capacity, with either deflation or runaway inflation. Under present economic 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.

COMMENTS ON TOPIC 4: POSSIBILITIES FOR INFLUENCING LONG WAVE BEHAVIOR

Christopher Freeman and **Luc Soete**

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-Perez (1983) points out that Schumpeter himself did not develop such an analysis; despite his frequent emphasis on the importance of organizational innovations and the wider sociopolitical 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 (for example, in his vitriolic review of Keynes ("General Theory")) did not predispose him to consider the possibility of neo-Keynesian countercyclical 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 he was resigned to the prospect of a general drift toward socialization (Schumpeter 1943) this was not a welcome prospect for him.

Keynes (1936) 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 that he recommended were sufficiently drastic to cause a major rupture in the theoretical paradigm of neoclassical economics 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 died in 1946, Keynes was in many ways the architect of the "good match" between social institutions and the new technological paradigms that prevailed in the fast-growing industries of this postwar boom. As Carlota Perez-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 postwar 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 counterrevolution, 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 the international level. For Keynesian macroeconomic 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 that has been discussed, however, it matters enormously *which* are the emerging new technologies and industries because the social institutions that most favor their development and diffusion may be very different.

The conditions that will prove most favorable to the achievement of the full potential of the microelectronic 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 issues from the standpoint of putting the world economy back on to the path of high and sustainable rates 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 that will encourage a new wave of public and private investment, involving the rapid worldwide 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 (1859) 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 reconstitution 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 recognized that the capitalist system was capable of finding solutions to the problem of renewed growth through a variety of institutional and legal changes that would at some time permit the resumption of growth of the productive forces. Lenin was one of those who always insisted that ideas of an inevitable breakdown were misconceived, 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* (Lenin 1915) 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.

COMMENT ON TOPIC 4: POSSIBILITIES FOR INFLUENCING LONG WAVE BEHAVIOR

Tommaso Sinibaldi

If we look at the composition of the gross investment in the European Economic Community in the seventies we find that about 40 percent was in home building, 5 percent in agriculture, 25 percent in industry (including the energy sector), and the residual 30 percent in transportation and other public and private services. We can find also that the percentage of investment in industry was much larger (more than 30 percent) in the sixties and that it was constantly declining during the seventies.

In Europe, as is well known, the level of population is now stationary and the phenomenon of great internal migration has practically stopped. Also the demand for a "second home" shows a tendency to decrease. In brief, we shall not need many new homes in Europe in the next decades. Also we shall not need new highways, new refineries, new steel plants, new basic plants. The construction of these plants has required in the sixties and in the seventies a large share of the total industrial investment in Europe (in Italy about 40 percent). In short, it is rather difficult to answer the question: In which sector shall we invest in the years to come?

It is not appropriate to give the standard answer that one should invest in electronics, telecommunications, etc. In fact, the order of magnitude of previous investments was so large that they cannot be replaced by investments in electronics or telecommunications.

On the other hand, our governments will be probably capable of avoiding deep crises: it is reasonable to suppose that the Keynesian lesson has been learned. So we can expect to maintain in the coming years a stationary level of income, at least. Furthermore, the consumption function has had very stable trends for decades. Someone has even recognized stable secular trends. Consequently, also saving will remain at the present levels. In other words, we could have in the next decades a structural excess of saving with respect to investment opportunities. In this situation the real interest rate could decrease until zero and, why not, to negative values. All this will occur, naturally, if governments will not adopt, as it happens for instance in Italy, a policy of financing current consumption with savings.

In the last chapter of the General Theory, Keynes came to conclusions which are now part of our cultural background. However, many other things that he said have been forgotten or, at least, are not so universally known and appreciated. It is relevant to note that Keynes did not give to the latter less importance than to the former. In particular, Keynes asserted that there is no structural and permanent reason why capital must be a scarce resource. He recognized that in his time capital was a scarce resource but that in the future it could not be necessarily so. Are we now in this situation? Or, in other words, are we likely to have real interest rates below zero for a long time?

If it is so and, above all, if this expectation grows and persists for a long period many things could change. Throughout the world engineers and economists of big corporations are making calculations on investments and returns. These people are all "spiritual sons" of Keynes, who was the first to clarify the concept of marginal efficiency of capital and who gave the tools to measure it. In this kind of calculation the leading criterion is to select projects of investment on the basis of high rates of return and short payback periods.

A long-period expectation of negative real interest rates could upset this situation: investments that give returns in years far ahead and/or investments that may give small returns but for long periods of time become in this perspective more interesting than investments that have a short economic life. Upon reflection, all this may imply a return to the original meaning of the word investment.

When the ancient Romans built their roads and aqueducts or when the Florentines began to build their cathedral of Santa Maria del Fiore (it took two hundred years to build it) they certainly were not looking for short payback periods or high rates of return. In spite of this it is rather difficult to affirm that Roman roads or aqueducts were bad investments.

Are we going back to such a situation? Is an era coming for industrialized countries in which cathedrals will be built? These are the questions that I pose to myself and to you.

COMMENTS ON TOPIC 5: NATIONAL AND REGIONAL ASPECTS

Jacob J. van Duijn

(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 nonindustrialized countries are affected by long waves through their participation in world trade

The world economy can be divided into a number of blocs: the OECD, the communist bloc, the oil exporting countries, and the non-oil-exporting developing countries. Among the latter, the new industralized countries (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 the Second World War, and have suffered less from cyclical fluctuations, but it appears that they have not been able to stay clear of the problems of stagnation that 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 – toward 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 Great 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-á-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 "core" countries – Great Britain, France, Germany, and the United States. 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.

Table 1: States in World Manufacturing Output

Period	USA	UK	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

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

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

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 "take-off" as developed by Rostow. Sweden's take-off period, for instance, 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 railroad expansion between 1840 and 1870 (a development often seen as the single best measure 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-wave 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. Cotton textiles were followed by railroad expansion without a long depression in between. France and Belgium did develop on the strength of the same revolution upon which Great Britain took off. 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, and 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 Long-waves and take-off dates

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

Sources for take-off dates:
Switzerland: B.N. Biucchi, The Industrial Revolution in Switzerland, in C.M. Cipolla (ed.), *The Emergence of Industrial Societies*, Fontana Economic History of Europe, 1973, pp. 627-655.
Belgium: W.W. Rostow, *The Stages of Economic Growth*, 2nd edn., Cambridge University Press, 1971.
Sweden, Norway, and Denmark: L. Jörberg, The Nordic Countries, in C.M. Cipolla (ed.), *The Emergence of Industrial Societies*, pp. 375-485.

Netherlands: J.A. de Jonge, *De Industrialisatie in Nederland tussen 1850 en 1914*, SVN, 1976.
Austria: E. März, Zur Genesis der Schumpeterschen Theorie in der Wirtschaftlichen Entwicklung, in *On Political Economy and Econometrics*, 1965, espr. pp. 370-371.
All other countries: W.W. Rostow, *The World Economy*, Macmillan, 1978.
As a general reference I used I.Adelman and C.T. Morris, Patterns of Industrialization in the Nineteenth and Early Twentieth Centuries: A Cross-Sectional Quantitative Study, in P. Uselding (ed.), *Research in Economic History* Vol. 5, JAI Press, 1980, pp. 1-83.

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 that 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 that 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 into 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 Scandinavian 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 USA 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 to 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-off, 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.

COMMENTS ON TOPIC 5: NATIONAL AN REGIONAL ASPECTS

Jay W. Forrester, Alan K. Graham, Peter M. Senge, and John D. Sterman

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, demographic, 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 similar to each other than they are different. Capital goods have approximately the same lifetime and relation to work force. Nations share much the same science and technology. People have about the same lifetime and career length, and so on. Even if the industrialized nations 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 from 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 USA 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 generate a long wave internally. 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 hit equally hard. 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 important, the causes of the long wave are distinct from 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 business cycle.

In a business cycle downturn, workers who are laid 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 that 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 goodwill of their trading partners – both will be in increasingly short supply. We believe it is possible to design policies that can work well not only 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 liquidate the excess debt in an orderly manner. Policies that attempt to stimulate the economy will be counter-productive. For example, in a time of excess physical capacity, an across-the-board investment tax credit will either be 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 because of 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 stabilize 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.

SELECTED BIBLIOGRAPHY OF THE MIT SYSTEM DYNAMICS GROUP PUBLICATIONS ON THE LONG WAVE*

FORRESTER, Jay W.

"Mechanisms of Price Transmission", D-3348, March 9, 1982.

"Innovation and Economic Change", *Futures*, August 1981.

"Evaluation of the Reagan Economic Proposals", July 1981 (with Nathaniel J. Mass).

"National Modeling in the Global Context", D-3325, September 15, 1981.

"Information Sources for Modeling the National Economy", *Journal of the American Statistical Association*, Vol.75, No.371, September 1980, pp.555-566.

"Inflation and Unemployment", D-3259, November 6, 1980.

"Economic Behavior: Implications for the Next Twenty Years", D-3238-1, June 24, 1980.

"Productivity as Affected by Long-Term Economic Changes", D-3139-1, October 2, 1979; published as "More Productivity Will Not Solve Our Problems", *Business and Society Review*, No.35, pp.10-18, Fall 1980.

"An Alternative Approach to Economic Policy: Macrobehavior from Microstructure", in *Economic Issues of the Eighties* (Kamrany and Day, eds.), The Johns Hopkins University Press, Baltimore, 1979.

"Innovation and the Economic Long Wave", *Management Review*, June 1979.

"Changing Economic Patterns", *Technology Review*, August/September 1978.

"Growth Cycles", *De Economist* (The Netherlands) Vol.125, November 4, 1977.

"Capital Investment in the Economy", D-2780-1, September 27, 1977.

"Business Structure, Economic Cycles and National Policy", *Business Economics*, January 1976, pp.13-24.

"Understanding the Changing Basis for Economic Growth", D-2514-1, November 10, 1976.

"Understanding the Changing Basis for Economic Growth in the United States", D-2392-2, August 9, 1976 (with Nathaniel J. Mass).

GRAHAM, Alan K.

"Software Design: Breaking the Bottleneck", *IEEE Spectrum*, March 1982.

"Lessons from the 1920s for the Computer Industry; A Long-Wave Perspective for the R&D Industry", D-3196-1, March 1981.

"A Long-Wave Hypothesis of Innovation", *Technological Forecasting and Social Change*, Vol.17, pp.283-311, 1980 (with Peter M. Senge).

*The notation D-nnnn refers to a working paper of the System Dynamics Group.

MASS, Nathaniel J.

"Behind the Clamor for Reindustrialization", D-3286-1, *Technology Review*, August/September 1981, pp.56-65 (with Peter M. Senge).

"Monetary and Real Causes of Investment Booms and Declines", D-2943-2, *The Journal of Socio-Economic Planning Sciences*, Vol.14, No.6, 1980.

"A Microeconomic Theory of the Liquidity Trap", D-2936-1, September 1978.

SENGE, Peter M.

"A Long-Wave Theory of Real Interest Rate Behavior", D-3470, October 1983.

"The Economic Long Wave: A Survey of Evidence", D-3262-2, April 1982.

STERMAN, John D.

"A Simple Model of the Economic Long Wave", MIT Sloan School of Management Working Paper WP-1422-83, March 1983.

"The Long Wave", *Science* (letter) 219, 18 March 1983, 1276.

"Current Economic Conditions: Where Are We in the Long Wave?" D-3398, October 14, 1982.

"Amplification and Self-Ordering: Causes of Capital Overexpansion in the Economic Long Wave", D-3366, July 1982.

SYSTEM DYNAMICS GROUP

"Capital Formation and the Long Wave in Economic Activity", Report on a Meeting of Corporate Sponsors of the System Dynamics National Project held at MIT on March 11, 1977, July 1977.

"Employment, Labor Productivity, and Wage Change", Report on a Meeting of Sponsors of the System Dynamics National Project held at MIT on October 21, 1977, April 1978.

"Analyzing the Production Sector of the System Dynamics National Model", Report on a Meeting of Sponsors of the System Dynamics National Project held at MIT on July 19-20, 1977, September 1977.

COMMENTS ON TOPIC 5: NATIONAL AND REGIONAL ASPECTS

Christopher Freeman and Luc Soete

There is probably broad agreement amongst most long-wave writers that long waves relate in the first instance to the capitalist, *world* economy, although some writers have also included socialist countries (Pasinetti 1981). As Schumpeter (1939) himself pointed out: "Capitalism itself is, both in the economic and sociological sense, essentially one process, with the whole world as its stage" (p.666). Kuczynski (1978) has dated the emergence of a world capitalist economy around the mid-19th century: "since about 1850 there has existed a capitalist world economy in the true sense of the word, the world economy has come to predominate over national economies. This predominance first became evident during the world economic crises of 1857" (p.81). The precise timing of the establishment of a world capitalist economy is largely an academic question. Many economic historians and development economists have emphasized that even in preindustrial commercial capitalism, trade and financial exchanges between Europe and its colonies were sufficiently significant to warrant its description as a world capitalist economy.

The increase in worldwide international trade, investment, and financial flows is however a distinct feature of the industrial era. In contrast to the preindustrial era these international flows, particularly those emerging from the technologically leading countries, were generally based on a significant "technological advantage" which would take the form of more cheaply produced goods or new commodities. While such trade flows had significant disruptive effects on many of the importing countries, the overall long-term effect resulted in a more interwoven world (capitalist) economy where each country's long-term cycle became increasingly dependent on the world economy's long-term movement.

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&D, static and dynamic economies of scale, and unequal distribution of bargaining power are indeed considerable barriers to overcome.

The dramatic trade-disruptive effect in many European countries related to Britain's early technological trade advantage over the first and second Kondratiev, led, however, to a quite distinct international feature of long waves; that of the crucial importance of the import of foreign technology and the *international* diffusion of technology for autonomous "national" growth and technological leapfrogging. The crucial point about this feature is that it is only indirectly related to the overall long-wave up- and downswings. It is primarily the result of an internal, country-specific autonomous growth process nourished by the existence of a technological gap with the world technological frontier where the technological gap can be thought of as a "pump of diffusion", to use Gomulka's (1971) terminology. The implications for the long-wave debate of this international technology diffusion feature are important. Freeman *et al.* (1982), for example, point out that it is primarily this autonomous growth feature which obscures much of the long-wave evidence, based as it generally is on individual country evidence.

A similar point is made by van Duijn (1983): "National economies have their own 'life cycle of development'. Depending on their take-off date, countries may perform strongly during depression or they may do rather poorly during a long-wave expansion. In the world economy as a whole, the effects of extra rapid and extra slow growth cancel each other out, but the fundamental causes of long waves remain. Over the years, basic innovation life cycles become international phenomena." (pp.140, 141).

This points again to the overriding importance for the long wave debate of the *"diffusion"* process rather than the mere occurrence or frequency of innovations. Whereas the innovating country will try to prevent the competing away of its international technology monopoly position, in the long run it will probably fail to maintain continuous technological leadership. Imitators will appear, the returns to the technology will fall, and radically new technologies including "new technological paradigms" may emerge. While these will probably *originate* from within the technologically leading country, the *internal* national diffusion in these countries may be hampered in various ways, with the new technology competing to some extent on disadvantageous terms. Thus previous investment outlays in the older technology, the commitment to the latter from both management and the skilled labor force, and even the "development" research geared toward improving the existing technology, might well hamper the diffusion of the major new technology to such an extent that it will diffuse more quickly elsewhere, in a country uncommitted, both in terms of actual production, organization and investment, to the old "technological paradigm". Furthermore, these traditional economic factors retarding diffusion might be further exacerbated by institutional retardation factors, which might in the case of a new technological paradigm be as severe for the technological leader as for late industrializers.

In relation to microelectronics, for example, Soete (1983) emphasizes particularly that the newly industrializing 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 that have arisen in relation to other technologies in the developing countries.

However, the scale of international indebtedness, the slowdown 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 pointing to the need for a new international economic framework appropriate to the need of worldwide expansion in the remaining years of the 20th century. The Brandt Report 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 of such an international framework for expansion may prove to be the most difficult challenge 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 that 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 reemergence of Cold War attitudes and politics, and the persistent failure of the North–South dialogues all serve to emphasize the great difficulties of reestablishing 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.

REFERENCES

Delbeke, J. 1981 "Recent Long Wave Theories: A Critical Survey", *Futures*, Vol.13, No.4, pp.246-258.

Dosi, G. 1975 "Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technological Change", *Research Policy* Vol.11, No.3, pp.147-164.

van Duijn, J. 1983 *The Long Wave in Economic Life*, London: George Allen & Unwin.

Forrester, J.W. 1981 "Innovation and Economic Change", *Futures*, Vol.13, No.4, pp.323-332.

Freeman, C., J. Clark and L. Soete, 1982 *Unemployment and Technical Innovation: A Study of Long Waves and Economic Development*, London: Frances Pinter.

Gomulka, S. 1971 *Inventive Activity, Diffusion, and the Stages of Economic Growth*, Skrifter fra Aarhus Universtets Okonomiske Institut no. 24, (Aarhus: Institut of Economics).

Keynes, J.M. 1936 *The General Theory of Employment, Interest and Money*, New York: Harcourt Brace.

Kuczynski, J. 1978 "Special Analysis and Cluster Analysis Mathematical Methods for the Periodization of...Processes". Paper prepared for the 7th International Congress on Economics, Edinburgh.

Kuznets, S. 1940 "Schumpeter's Business Cycles", *American Economic Review*, Vol.30, No.2, pp 257-271.

Lenin, V.I. 1915 *Imperialism, the Highest Stage of Capitalism.*

Mandel, E. 1981 "Explaining Long Waves of Capitalist Development", *Futures*, Vol.13, No.4, pp.332-339.

Marx, K. 1859 Preface to *A Contribution to the Critique of Political Economy*, London.

Mensch, G. 1975 *Das Technologische Patt: Innovationen Uberwinden die Depression*, Frankfurt: Umschau.

Pasinetti, L.Z. 1981 *Structural Change and Economic Growth: A Theoretical Essay on the Dynamics of the Wealth of Nations*, Cambridge.

Perez-Perez, C. 1983 "Structural Change and the Assimilation of New Technologies in the Economic and Social Systems: A Contribution to the Current Debate on Kondratiev Cycles", *Futures*, Vol. 15, No.5, pp. 357-375.

Petzina, D., and van Roon, G., (eds), 1981 *Konjunktur, Krise, Gesellschaft: Wirtschaftliche Wechsellagen und Soziale Entwicklung im 19 und 20 Jahrhundert*, Stuttgart: Klett-Cotta.

Rosenberg, N. and C.R. Frischtak, 1983 "Technological Innovation and Long Waves", Paper presented at Royal College of Art International Seminar on Technical Innovation, Design and Long Cycles in Economic Development, London, April.

Schumpeter, J.A. 1939 *Business Cycles: A Theoretical, Historical and Statistical Analysis of the Capital Process*, 2 vols. New York: McGraw Hill.

Schumpeter, J.S. 1943 *Capitalism, Socialism and Democracy*, London: Harper Row.

Soete, L. 1983 "Long Cycles and International Diffusion of Technology", Paper presented at the Royal College of Art International Seminar on Innovation, Design and Long Cycles in Economic Development, Royal College of Art, London, April.

van der Zwan, A. 1979 "On the Assessment of the Kondratiev Cycle and Related Issues", Centre for Research in Business Economics, Rotterdam.

PART III

ORAL COMMENTS/DISCUSSIONS

ORAL COMMENTS

Hans H. Glismann

On Theories of the Long Wave

Presenting a workable hypothesis of the long wave means explaining past events or predicting future events according to a combination of general rules ("theories") and actual conditions of the period analyzed. It does not mean producing curves – linear or not, logistic or not – that fit the past behavior of some endogenous variables. To give an example: looking at the stock of money in Germany since 1850 reveals, after some recalculations in order to assimilate the zigzag of the real world to the more harmony-oriented eyes, a relatively smooth cyclical movement; no other indicator provides such a good statistical fit. But what follows from this? To make a long story short: nothing. The general Goethean notion that money matters is not a sufficient substitute for a long-wave hypothesis.

Thus, it may well be that explanation of past developments is different regarding, say, 1930 and 1980; it may be, for instance, that in 1930 the artificial shortage of money supply in the United States led to bankruptcies of banks and firms and thereby to too few investments undertaken and, not least, to unemployment because wages did not (or could not) adjust fast enough. Via international trade and international movements of factors of production and through international linkages in the trading system these US developments spread all over the world. In 1980, on the other hand, money supply was ample; rates of inflation rather indicated an abundant stock of money. The hypothesis has been advanced that the slowdown of economic activity in the 1980s has rather been due to exploitation of monopolistic conditions on factor markets, resulting in unemployment because monopolies by their very nature tend to employ less factors than otherwise would be employed. Another hypothesis has been that the significant increase in government consumption during the 1970s led to unemployment because of a corresponding decrease in investment opportunities and because government consumption by itself does not breed additional means for further consumption.

A second point I should like to make refers to my written statement on the theories of the long wave (see Part II).
If the notion is correct that growth cycles are caused by bottleneck factors of development, and that these factors can differ for each cycle or each phase of a cycle, then differences among explanatory approaches may to a certain extent be due to changes in growth conditions. Theories stressing the role of investment (or

of certain types of investment), of innovations (or of entrepreneurial talents), of raw materials, of changes in the material infrastructure, may all be compatible in the case where the bottleneck factors change. However, it is hard to distinguish such "explanations" from random events; refutation of hypotheses is impossible when incidental conditions are turned into explanations and theory is neglected. Therefore, it seems advisable to formulate a theory of the long wave according to the refutability rule. We have tried to do exactly this by referring to the role of relative prices. For example, no matter whether bottlenecks are artificial (as in the case of monopolistic behavior of groups or of governments) or "natural" (as in the case of lagged adjustment to sudden and unexpected changes of important variables), the bottlenecks are concomitant with an increase in the relative price of the bottleneck factor; this again provokes incentives to overcome shortages. This is why finally and in the long run past bottlenecks disappear.

Third, a long-run development hypothesis has to lay ground for the phenomenon of slow adjustments, or else the question would remain unanswered why people do not cope with bottlenecks immediately. Here is where metaeconomic developments become relevant. We have argued that long reaction lags are mainly due to counterproductive behavior of public authorities and to the inherent sluggishness of institutions (organizations).

On Possibilities for Influencing Long-Wave Behavior

Let me please try to rephrase the long-wave theory in such a way as to arrive at some policy conclusions.

Long waves of economic development can also be interpreted as the outcome of a weakening or, rather, of a blocking of homeostatic conditions – conditions of negative feedbacks, that is, which keep systems from exploding or imploding. In economics the price mechanism keeps a society from overdoing anything in any direction; as a matter of fact, this is why I do not think that Jay Forrester's "unstable wave" (in the sense of steadily increasing amplitudes of the wave) is really a long-run phenomenon. Because of the price mechanism economists should be particularly aware of homeostasis.

Blocking of homeostatic conditions does not come naturally. No entrepreneur, no monopoly, and no trade union will achieve this end, unless equipped with governmental force. Such a blocking needs official authority to initiate and substantiate it via laws and regulations.

Now, people pay politicians and public administrators to produce public goods (like internal and external security) – goods that normally do not pay to be produced privately or whose production has external diseconomies. This is another way of saying that governments are to help homeostatic conditions to prevail. One of the public goods whose production is in the hands of governments is competition. Competition makes, e.g., real wages decline when unemployment rises and vice versa. It provides for new entrepreneurship when old lines of production (among which, in the Federal Republic of Germany, are shipbuilding, steel industries, and agricultural production) do not sell sufficiently well any more. And thereby competition dampens fluctuations.

My conclusion therefore is the following. If we experience economic fluctuations that are deemed to be too strong, this is the outcome of governments failing to do their job. And indeed, today we observe governments hindering competition to work instead of strengthening it. Governments pay subsidies to shipbuilding and to steel industries; governments tend to unite economically and then weaken their economies considerably through suppressing competition. The example of the

European Community's Common Agricultural Policy, which absorbs most of the EC's activities, may illustrate this; I do not want to neglect the other fields of the EC's activities but they are quantitatively of minor importance and they are, unfortunately, to a large extent similar to the agricultural policies (steel protection, textile protection).

In a similar vein the workings of other international institutions may be analyzed. One of the main objectives of UNCTAD, e.g., is to redistribute income through artificially high prices of raw materials; this not only means to (partly) abolish price signals but at the same time to give new incentives to the production of raw materials and thus reinforce the much criticized colonial-type international division of labor. Similarly the International Monetary Fund may become a lender in the first resort (instead of its being a lender in the last resort) in the case where it provides countries suffering from severe debt problems with additional financial means. All these institutions – EC, UNCTAD, IMF – seem to be providing stimuli for moral hazard by supporting attempts to prevent negative feedbacks. The feedback from decreasing prices of raw materials would be, for instance, industrial production; the feedback from severe debt problems would be a more restrictive debt policy of both giving and receiving countries.

Thus I disagree with Jan Tinbergen: giving additional funds for the IMF does not solve problems but raises problems by producing moral hazard. I also disagree with Christopher Freeman who says that we need new or additional international institutions to cope with today's economic problems. I feel that the old institutions seem to have failed; so why bother with new ones? One should rather try to change the ways the old institutions work.

ORAL COMMENTS

Richard M. Goodwin

Schumpeter and Long Waves

It seems clear that there are no simple periodicities, either long or short, in economic statistics. The observed fluctuations are highly irregular so that, if they result from various cyclical mechanisms, they are so heavily disturbed that they are difficult to detect, indeed impossibly so for the small number of long waves. Therefore I would like to suggest a more flexible alternative conceptualization. Consider a short-run economic response mechanism, based on the systematic, variable costs of production. The behavior of such a linear system can be fully analyzed, showing its own characteristic motion along with its responses to exogenous events, the result being highly erratic.

In the same year that Darwin published the *Origin of Species*, volume one of Marx's *Capital* appeared. Marx correctly believed that he was doing for society what Darwin was doing for the evolution of plants and animals. Schumpeter seized upon this basic idea to propose a revolutionary conception of economics – morphogenesis through innovations in production. The consequences of this evolutionary view are at least twofold: we cannot posit a single, specific model and then study its endogenous motion over long periods; we cannot use even the most sophisticated econometrics to determine behavioral parameters as a basis for prediction and control.

My hypothesis is that the long swings are the result of the slow perfection and adaptation of major technological innovations, which persisted over a number of shorter fluctuations: the depressed phases come with the substantial completion of the major innovations, followed by only minor or weak ones. To effect increases in productivity there must first come investment, which increases output and employment. This accelerates the spread of the innovation, Schumpeter's "swarms". As the innovation becomes operative, gradually a new equilibrium of the economy is created, with ensuing changes in relative prices. Consequently there will be sequential innovations in a wide range of other industries. These changes in production processes mean basic alterations in the morphology of production, yielding higher productivity.

Such a transformation, e.g. in energy or transport, may last a long time and consist of a great number of successive small improvements and adaptations to different uses, with the result that it will approximate to a smooth process. The economy, however, acts as a frequency converter, i.e. converting a substantially constant flow of technological change into fluctuating growth. It does this in the following way: the initial investments (which are independent of a depressed state of trade and/or excess capacity) bring an increased demand and growth of output and employment, which facilitate the adoption of the innovation. In the case of a major innovation, this will push output increasingly to the capacity limits of existing industry, thus requiring accelerational investment and rendering the economy unstable dynamically, i.e. producing a bifurcation. The economy reacts to the initial stimulus, magnifies it, (the multiplier), and overreacts (the accelerator) in the sense that it grows at a rate which cannot be sustained, since unemployment falls towards zero. The deceleration destroys expectations and cancels the accelerator so that the economy relapses to a new lower level of employment as determined by the more productive, but partly unemployed, structure of production and employment. Innovational investment will be inhibited by the collapse, but since it will not have been exhausted in any one boom, it will recommence once the decline has ceased. The process will then recommence but at a different pace and with the newer, more productive structure. There is no difficulty in explaining the upswing and downswing: firms spend vigorously because demand is high; demand is high because firms spend vigorously. The explanation of the upper turning point is well understood and accepted by most economists. Not so for the lower turning point, for that we require the Marx–Schumpeter thesis that the fierce search for profit by innovation is the continuing engine of capitalist production.

Each boom will be different both because the investments and their distribution by industry will be different, and because the response mechanism has changed because of the technological evolution. A single large innovation, or a constellation of innovations, will mean a prolonged span of vigorous expansions plus high growth rates, along with short, sharp recessions: this constitutes the long-wave boom. Once a major technological advance has been fully incorporated into the economy, there will be a relapse into weak booms and prolonged depressions until a dominating new set of innovations becomes feasible. The hypothesis here is that history, in the sense of extraeconomic events, plays an essential role in the long-run evolution of the economy, but that the impact on short-run behavior can adequately be analyzed with the help of systems analysis. I have intentionally omitted reference to the role of state activity, e.g. wars, social services, efforts at control, but these can easily be introduced into such a flexible model, with no essential modification of its character. How long the present depression will last and how vigorous will be the recovery will surely depend on such extraeconomic factors and not on systematic, economic relations.

Gerald Silverberg

I would like to point out some implications for theorizing about long waves of economic development that followed from a model of technical change and macro-dynamics I have been working on.

First, I would like to characterize this approach in a very general fashion without going into any technical details. I take as my starting point Dr. Goodwin's 1967 growth cycie model, which dynamically interrelates wages, employment, and investment. This results in a pair of equations formally equivalent to the well-known Lotka–Volterra predator–prey model of ecology and thus represents a step in the direction of Professor Nijkamp's call for economists to pay more attention to this kind of modeling. Using a method developed by Peter Allen, a co-worker of Prigogine's in Brussels, it is then possible to incorporate innovations embodied in new capital goods into the model by enlarging the state space. In this way one can derive a criterion for the diffusion of a new technique as well as analyze its consequences for the evolution of the system in terms of a nonlinear interaction unfolding over time between wages, profits, sectoral and aggregate employment, and productivity.

The first implication of this kind of evolutionary approach is that the distinction between innovation, investment, and diffusion is indeed an artificial one. These must be thought of as three phases of a single process indissoluably intertwined with each other, as Professor Freeman in particular has emphasized. For an innovation is distinguished from, for example, an invention in that it is being diffused through the economy by the investment activity of entrepreneurs, a process that involves time and the expense of economic resources and may or may not yield Schumpeterian profits. Once this point has been accepted, that a considerable share of technical change must be embodied in new capital goods and processes, any theory of investment behavior must take explicit account of technical progress and innovation. The latter cannot simply be tacked on to a capital-stock adjustment model, but rather must enter in a fundamental way into the dynamics to create a feedback from the level and composition of investment to the growth of productivity and effective demand.

The second point is the question of distribution raised by Professor Freeman. The relationship between the rate of change of productivity and real wages in a dynamic evolutionary model is critical, as has been emphasized particularly by Rostow and Lewis. Generalizations based on basically short-run theories, whether of a neoclassical or a Keynesian genre, can be very misleading here. The point is that there is no invariant historical relationship between these variables – their interaction is complex and historical and depends in a nontrivial way on the evolution of technology. This can be seen in numerical solutions to the model (see Figures 3 and 4 of my paper, "Embodied Technical Progress in a Dynamic Economic Model: The Self-Organization Paradigm," to be published by Springer-Verlag), where both short- and long-run leapfrogging is taking place between the growth of productivity and wages. Whereas a certain neoclassical trade-off can be seen in the short-term cycles, which are essentially self-correcting, there is also a long-term trend crossing of the productivity growth curve somewhat after the middle of the replacement cycle, which soon combines with the exhaustion of the innovation's productivity potential to precipitate a "long-wave" profitability crisis. At this point no amount of doctoring with the level of real wages will succeed in reviving the economy, contrary to what one might expect from simply observing the previous short-run behavior. This is a warning to all those who see in adjustments in relative prices a panacea for long-wave crises as well.

The third point is a somewhat technical one regarding the implications for trade cycle theory of nonlinearities in the underlying dynamics. Nonlinearity abolishes the principle of superposition, i.e. the ability to add up cycles of different periods, as Schumpeter himself naively presupposed. Instead there is a distinct possibility of, for example, amplitude modulation between long and short cycles, as one can also see in the numerical runs, where the amplitude of the short-period cycle dies out during the long-period upswing and only reasserts itself after the long-period crisis. And if I have understood Professor Piatier correctly, he also implied that there has been frequency modulation as well, such as the short-period downturn that did not take place in 1926 as predicted, but three years later, and then with a vengeance.

My fourth point is a question of modeling philosophy. The striving to endogenize everything into a closed dynamic model may be less a virtue than a straitjacket on our thinking. The contemporary approach to open dynamic systems developed by Prigogine and his group in Brussels and Haken and his co-workers in Stuttgart hinges in an essential way on the nontrivial interaction of stochastic and deterministic elements. It is not simply a question of superimposing noise on a deterministic system to add a bit of realism. In an interdependent nonlinear system, fluctuations, innovations, or changes in external constraints can play a decisive role in triggering bifurcations and changes in regime, and thus serve as the driving force in an evolutionary process. This can be shown for open systems in biology and physics, and there is no good reason why economic processes should be an exception. By applying the order parameter concept it is possible to overcome the apparent indeterminacy of such systems and proceed to conditional prognosis for systems alternating between a well defined behavioral regime and critical instabilities. The advantage of this approach is that it lets history back in without renouncing analytical technique. An overendogenization of our models only leads to a specious appearance of certainty and resignation.

Apart from these more technical considerations I would like to bring up the larger issue that was touched upon by Dr. Sinibaldi and Professor Forrester earlier today and should not be lost sight of in concentrating on long waves proper. Is our policy choice to latch on to the next Kondratiev upswing as quickly as possible to catapult us out of the current or threatening depression, by encouraging and accelerating the process of innovation, overcoming economic and social rigidities, or some other means? Or is it to expedite the transition to some kind of stationary state in which it will be possible to enjoy the fruits of economic growth without being subject to a further growth imperative and the onus of mass unemployment? This is the basic issue as I see it. I do not want to go into the merits of each case now but simply want to emphasize that one should not underestimate the profound implications of the stationary state option if it is to be viable in the modern world, quite apart from its desirability. Industrial capitalism has been subject to what one could call the Red Queen Principle, to borrow a metaphor from Lewis Carroll: it must run as fast as it can just to stay where it is. As irrational as this may seem from a purely technocratic point of view, there are profound structural reasons why this has been the case until now. To break this dynamic permanently will require a radical reorganization of social and economic structures, which one must confront squarely if there is to be any chance of success. Furthermore, technological change is showing no signs of abating and mitigates against any complacent withdrawal from the growth imperative through powerful pressures transmitted both by the world market and potential or real military threats. Historically these pressures have sufficed to compel increasing adherence by most nations to an economic order predicated on the vicissitudes of permanent change, and their merciless logic is perhaps even more evident today than at any previous time in history.

ORAL COMMENTS

Roberto Vacca

The striking regularity of the long economic cycles cannot be construed to indicate the existence of an anthropological time constant of 52 years, as implied by Marchetti. For millennia, before the first Kondratiev cycle, no such regularity was apparent. Other cultures (in Asia and in America before Columbus) also appear not to have been affected by 50-year cycles. It is reasonable to think that cultural interventions (social engineering, mass education) could have deep effects on economic trends, innovation rates, and other socioeconomic events.

Industrial innovations, like steam power, electricity, automobiles, rapid transport, and cheap air travei, have certainly affected the behavior of individuals and of human masses. It is plausible that innovations in communications and information handling and processing may affect human behavior far more. This is not a strict cause—effect relationship. Radio and television have made possible mass communication, but the corresponding cultural impact has been minimal. Cheap computers, easy-to-use software, and telematics are perhaps only necessary, but not sufficient conditions for a massive cultural upgrading of the population. The most significant innovation in the next cycle could be represented by the strategy needed to employ computers and telematics in order to achieve significant cultural results. Strategies and procedures apt to optimize price structures alone would permit enormous benefits to be reaped. These would include elimination of the waste of human resources; increase of productivity; national and international adoption of cooperative stances.

Stepped up efforts in international cooperation adequate to produce the economic take-off of most Third World Countries would also open up a vast market for the products of industrial countries; and provide a trial ground to study the eventual cyclic behavior of new economic systems that up to now have operated at subsistence level with minimal and nonsignificant variations in time.

APPENDIX 1

CONSENSUS OF PARTICIPANTS

At the end of the Conference the participants felt that it would be of interest to present some common understanding of issues, stressing the usefulness of the Conference and the desirability of further cooperation:

"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).

"However, 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 cyclical behavior, all scientists working in this field would agree that one of the foremost tasks of government will lie, in the years ahead of us, in enhancing a climate favorable for innovations, especially if innovation is understood to include institutional and social changes.

"The IIASA–IRPET "Long Waves Meeting" (Siena–Florence, October 26–29, 1983) has brought 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 regional level.

"In this context, the role of innovation has received particular attention. The results of the meeting have convincingly demonstrated the relevance of the theme for theoretical analysis, empirical research, and practical policy making.

"The key concepts, methods and data have developed to the point where existing international resources of the scholarly and policy communities could be mobilized to further understanding and to define action."

FINAL LIST OF PARTICIPANTS AND OBSERVERS

LONG WAVES, DEPRESSION, AND INNOVATION:
IMPLICATIONS FOR NATIONAL AND REGIONAL ECONOMIC POLICY

Siena/Florence, Italy, 26-30 October 1983

AUSUBEL, Dr. J.
National Research Council
Commission on Physical Sciences,
Mathematics, and Resources
2101 Constitution Avenue
Washington, DC 20418
USA

BARUCCI, Prof. Dott. P.
Presidente del Monte dei Paschi
di Siena
Piazza Salimbeni 3
I-53100 Siena
Italy

BECATTINI, Dr. G.
Facolta di Economia e Commercio
Via Curtatone 1
I-50121 Florence
Italy

BIANCHI, Prof. G.
IRPET
Via La Farina 27/29
I-50127 Florence
Italy

BIESHAAR, Dr. H.
Vrije Universiteit
Fakulteit der Ekonomische
Wetenschappen
De Boelelaan 1105
Postbus 7161
NL-1007 MC Amsterdam
Netherlands

BREMER, Dr. S.
Science Center Berlin
Steinplatz 2
1000 Berlin (West) 12

BRUCKMANN, Prof. G.
IIASA
Schlossplatz 1
A-2361 Laxenburg
Austria

CAMAITI, Dr. R.
Redazione "Note Economiche"
Monte dei Paschi
Piazza Salimbeni 3
I-53100 Siena
Italy

CAMPBELL, Dr. S.
Strategic Planning Branch
Alberta Economic Development
10th Floor, Pacific Plaza
10909 Jasper Avenue
Edmonton, Alberta
Canada T5J 3M8

CASINI BENVENUTI, Dr. S.
IRPET
Via La Farina 27/29
I-50127 Florence
Italy

CAVALIERI, Dr. S.
IRPET
Via La Farina 27/29
I-50127 Florence
Italy

CRAIG, Prof. P.
Department of Applied Science
University of California
Davis, CA 95616
USA

D'AMICO, Dr. N.
c/o IRPET
Via La Farina 27/29
I-50127 Florence
Italy

DELBEKE, Dr. J.
Vlaamse Economische Hogeschool
Koningsstraat 284
B-1030 Brussels
Belgium

D'ERCOLE, Dr. A.
Istituto di Economia
Universita di Siena
I-53100 Siena
Italy

DEVICO, Dr. B.
c/o IRPET
Via La Farina 27/29
I-50127 Florence
Italy

DUIJN van, Prof. J.
Graduate School of Management
Prinses Julianalaan 16
3143 LK Maassluis
Netherlands

ELLER VAINICHER, Dr. M.
c/o IRPET
Via La Farina 27/29
I-50127 Florence
Italy

ENTOV, Dr. R.
Department of Economic Cycles
Institute of World Economy and
International Relations
Moscow
USSR

FERRARI, Dr. S.
Dirigente Centro Studi
ENEA
V.le Regina Margherita 125
I-00198 Roma
Italy

FIRRISI, Dr. S.
Assoreni
c.p.15
I-00015 Monterotondo (Roma)
Italy

FORRESTER, Prof. J.
Massachusetts Institute of Technology
Sloan School of Management (E40-294)
50 Memorial Drive
Cambridge, MA 02139
USA

FREEMAN, Prof. C.
Science Policy Research Unit
University of Sussex
Mantell Building
Falmer, Brighton
Sussex BN1 9RF
United Kingdom

FUÅ, Prof. G.
ISTAO
Via delle Grazie 67
Ancona
Italy

GLISMANN, Dr. H.
Institut fuer Weltwirtschaft an der
Universitaet Kiel
Duesternbrooker Weg 120
2300 Kiel
BRD

GOODWIN, Dr. R.
Istituto di Economia
Piazza S. Francesco 2
I-53100 Siena
Italy

GRAHAM, Dr. A.
Massachusetts Institute of Technology
Sloan School of Management (E40-294)
50 Memorial Drive
Cambridge, MA 02139
USA

HAAG, Dr. G.
Universitaet Stuttgart
Institut fuer Theoretische Physik
Pfaffenwaldring 57
7000 Stuttgart 80
BRD

HOLLING, Dr. C.S.
Director
IIASA
Schlossplatz 1
A-2361 Laxenburg
Austria

ISLAM, Dr. S.
Chalmers University of Technology
Fysisk Resursteori CTH
S-412 96 Göteborg
Sweden

KLEINKNECHT, Dr. A.
Vrije Universiteit
Fakulteit der Ekonomische
Wetenschappen
De Boelelaan 1105
Postbus 7161
NL-1007 MC Amsterdam
Netherlands

MAINI, Dr. J.
IIASA
Schlossplatz 1
A-2361 Laxenburg
Austria

MALTINTI, Dr. G.
IRPET
Via La Farina 27/29
I-50127 Florence
Italy

MARCHETTI, Dr. C.
IIASA
Schlossplatz 1
A-2361 Laxenburg
Austria

MENSCH, Prof. G.
Department of Economics
Case Western Reserve University
Cleveland, Ohio 44106
USA

MENSHIKOV, Dr. S.
c/o Committee for Systems Analysis
Presidium of the Academy of
Sciences of the USSR
Prospect 60 Let Octyabria 9
117312 Moscow
USSR

MILLENDORFER, Dr. J.
Study Group for International
Analysis (STUDIA)
Hofstrasse 3
A-2361 Laxenburg
Austria

NAKICENOVIC, Mag. N.
IIASA
Schlossplatz 1
A-2361 Laxenburg
Austria

NARDI, Dr. V.
IRPET
Via La Farina 27/29
I-50127 Florence
Italy

NIJKAMP, Prof. P.
Department of Economics
Free University
PO Box 7161
1007 MC Amsterdam
Netherlands

OLIVIERI, Dr. O.
Technological Forecasting Unit
ENI
Piazzale Enrico Mattei 1
I-00144 Roma
Italy

PENCZYNSKI, Dr. P.
Kraftwerk Union AG
Hammerbacherstr. 12-14
D-8520 Erlangen
BRD

PERCUOCO, Prof. A.
ENEA
V. le Regina Margherita 125
I-00198 Roma
Italy

PEREZ, Dr. C.
Science Policy Research Unit
University of Sussex
Mantell Building
Falmer, Brighton
Sussex BN1 9RF
United Kingdom

PESCAROLO, Dr. S.
IRPET
Via La Farina 27/29
I-50127 Florence
Italy

PIATIER, Prof. A.
Ecole des Hautes Etudes en Sciences
Sociales
63 rue Claude Bernard
F-75005 Paris
France

PUNZO, Dr. L.
Istituto di Economia
Universita di Siena
I-53100 Siena
Italy

REBUTTO, Dr. M.
Ufficio Studi
Monte dei Paschi
Piazza Salimbeni 3
I-53100 Siena
Italy

ROSEGGER, Dr. G.
Case Western Reserve University
c/o Institut fuer Unternehmens-
fuehrung
Universitaet Innsbruck
Blasius-Hueber-Str. 16
6020 Innsbruck
Austria

SCHLIFKE, Mr. P.
IIASA
Schlossplatz 1
A-2361 Laxenburg
Austria

SCHOKKAERT, Dr. E.
Catholic University of Leuven
Centre for Economic Studies
Van Evenstraat 2B
3000 Leuven
Belgium

SCHWEFEL, Dr. H.
Nuclear Research Centre Jülich
(KFA-STE)
PO Box 1913
D-5170 Jülich 1
BRD

SCREPANTI, Dr. E.
c/o IRPET
Via La Farina 27/29
I-50127 Florence
Italy

SENGE, Prof. P.
Massachusetts Institute of Technology
Sloan School of Management (E40-294)
50 Memorial Drive
Cambridge, MA 02139
USA

SILVERBERG, Dr. G.
Universitaet Stuttgart
Institut fuer Sozialforschung
Abt. Sozialoekonomie
Friedrichstrasse 10 (7 Stock)
Postfach 560
D-7000 Stuttgart
BRD

SINIBALDI, Dr. T.
ENI
Piazzale Enrico Mattei 1
I-00144 Roma
Italy

SMYSHLYAEV, Dr. A.
IIASA
Schlossplatz 1
A-2361 Laxenburg
Austria

SOETE, Dr. L.
Science Policy Research Unit
University of Sussex
Mantell Building
Falmer, Brighton
Sussex BN1 9RF
United Kingdom

STERMAN, Dr. J.
Massachusetts Institute of Technology
Sloan School of Management (E40-294)
50 Memorial Drive
Cambridge, MA 02139
USA

VACCA, Dr. R.
3 Via Oddone di Cluny
I-00153 Roma
Italy

VASKO, Prof. T.
IIASA
Schlossplatz 1
A-2361 Laxenburg
Austria

VERCELLI, Dr. A.
Universita di Siena
Via Piazza dei Mantellini 24/A
I-53100 Siena
Italy

WOLD, Prof. H.
Uppsala University
Statistics Department
Box 513
S-751 20 Uppsala
Sweden

WOLTER, Dr. F.
Institut fuer Weltwirtschaft an der
Universitaet Kiel
c/o Centre William Rappard
154 rue de Lausanne
CH-1211 Geneva
Switzerland