Hillinger, Claude:

Evidence and Ideology in Macroeconomics: The Case of Investment Cycles

Munich Discussion Paper No. 2005-16

Department of Economics
University of Munich

Volkswirtschaftliche Fakultät
Ludwig-Maximilians-Universität München

Online at https://doi.org/10.5282/ubm/epub.694

EVIDENCE AND IDEOLOGY IN MACROECONOMICS:

THE CASE OF INVESTMENT CYCLES**

Claude Hillinger*

ABSTRACT

The paper reports the principal findings of a long term research project on the description and explanation of business cycles. The research strongly confirmed the older view that business cycles have large systematic components that take the form of investment cycles. These quasi-periodic movements can be represented as low order, stochastic, dynamic processes with complex eigenvalues. Specifically, there is a fixed investment cycle of about 8 years and an inventory cycle of about 4 years. Maximum entropy spectral analysis was employed for the description of the cycles and continuous time econometrics for the explanatory models. The central explanatory mechanism is the second order accelerator, which incorporates adjustment costs both in relation to the capital stock and the rate of investment. By means of parametric resonance it was possible to show, both theoretically and empirically how cycles aggregate from the micro to the macro level. The same mathematical tool was also used to explain the international convergence of cycles. I argue that the theory of investment cycles was abandoned for ideological, not for evidential reasons. Methodological issues are also discussed.

JEL Classification: E32, C32, C50
September 2005

Key words: business cycle, continuous time econometrics, investment cycle, inventory cycle, maximum entropy spectral analysis, parametric resonance

*SEMECON
University of Munich
Ludwigstr. 33/IV
D-80539 Munich
Germany

E-mail: hillinger@econhist.de

**Paper presented at the session on Recent Developments in Macroeconomics, Eastern Economics Association, March, 2005. For helpful comments I am indebted to session participants and especially to Per Berglund.

The indubitable and public symptom of ineffectiveness of a field is the absence of facts.[1]

1. INTRODUCTION

This paper summarizes research on *investment cycles*, conducted intermittently by the author and associates since the 1960s. The view of economic fluctuations as being predominantly investment cycles was widely held and attracted the attention of prominent economists and econometricians. The work on investment cycles came to a halt around 1960. The reason, as I shall argue below, where shifts in dominant ideologies, not a refutation of the assumed facts.

The pursuit of a line of research that is being abandoned by the mainstream may seem quaint and paradoxical to members of a profession that places the highest value on novelty. My decision to d embark on this path was motivated by deeply felt convictions regarding the scientific method and in particular the need to ascertain and quantify relevant facts and to use them in testing theoretical explanations. I am aware of the fact that discussions of methodology are held in low esteem by economists working in substantive fields and much of this distain is justified. The only way to advance science is by doing it, not by uttering pronouncements regarding the methods that others ought to follow. This has been the style of much of the literature on methodology of the past quarter century that has taking its starting point from the philosophy of natural science. In contrast to this, the methodological discussion of the present paper is concrete and intended to justify a particular path taken that was not traveled by the mainstream.

The basic methodological commitment that shaped my research was that scientific research should start with establishing empirical regularities and do so with as little prior theoretical commitment as possible. Theory comes in at the next level when the purpose is the explanation of the observed regularities, commonly referred to in economics as 'stylized facts'. The research reported here validated the stylized facts as they were described in the theory of investment cycles: Economic fluctuations are in large measure fluctuations of fixed and inventory investment. While these fluctuations have irregular components, due to random and other shocks, they also tend towards an average period length. For inventory investment the period is typically in the 3-4 year range, for fixed investment in the 7-10 year range. The proposed explanation is the *inertia* of investment due to adjustment costs. This inertia is embodied in a second order differential equation referred to as the *second order accelerator* (SOA).

The essential conclusion of the research is that the economy is subject to a strong endogenous out of equilibrium dynamic. Without an understanding of this dynamic, no successful stabilization policy will be possible.

2. SOME ASPECTS OF THE EVOLUTION OF ECONOMIC THOUGHT AND METHODS[2]

2.1 Origins of the Methodologies

The striking difference between the natural sciences on the one hand and economics as well as other social sciences on the other is the cumulative growth of empirical knowledge in the former, but not in the latter. Illustrative of the difference are the criteria employed in selecting Nobel laureates in the natural sciences and in economics.[3] In the former, the criteria are either a. the discovery of an empirical regularity that was subsequently confirmed by other researchers, or b. the provision of a superior explanation of one or more established

[1] Ravetz (1971, p. 367) in a chapter on *Immature and Ineffective Fields of Inquiry.*

[2] Some of the material in this section is treated at greater length in Hillinger (1992b, 1996).

[3] The Nobel Prize in economics was instituted by the Bank of Sweden (Riksbanken) in 1968. Unlike the other fields in which the prize is awarded, economics was not mentioned in the will of Alfred Nobel.

regularities. That these criteria are adhered to with extreme strictness is illustrated by the case of Stephen Hawking, perhaps the greatest living astrophysicist. His most famous prediction is that black holes emit radiation. Thus far, no means for detecting this radiation could be devised and therefore Hawking has not received the Nobel Prize. In economics the criteria are very different; laureates are cited for what they worked on, not what they discovered. Lindbeck (2004) described the criteria that in his view were employed in the selection of the economics Laureates:

> When considering what should be regarded as a "worthy" contribution, it is probably correct to say that the selection Committee has looked, in particular, at the *originality* of the contribution, its scientific and practical *importance,* and its *impact* on scientific work. To provide shoulders on which other scholars can stand, and thus climb higher, has been regarded as an important contribution. To some extent, the Committee has also considered the impact on society at large, including the impact on public policy.

This description suggests that Laureates were picked for their influence, not for any confirmed empirical regularities that they discovered.

A commonly expressed view in this connection is that human societies evolve and change and that consequently there are no 'eternal laws' analogous to those in the natural sciences to be found. The issue of the degree of stability of economic relationships is debatable and essentially an empirical one. However, if there is not enough stability so that useful relationships can be discovered, then there would seem to be no basis for economic research. In fact, human society itself would be impossible since it depends on the ability to anticipate the future at least to some degree.

Of course, economists believe that there are relationships that are sufficiently stable for analysis to proceed. This is particularly true of elementary supply and demand relationships. Another take on the state of economics could then be that the few stable relationships that have been discovered are all that exist. If that were true, further research to uncover new and stable relationships could also be abandoned.

If, as I believe along with most economists, neither of the above is true, than some other explanation for the lack of further progress in uncovering empirical regularities must be sought. To pursue the subject of empirical progress in relation to all fields of economics is clearly impossible as well as unnecessary in the present context. Instead I focus on a set of related issues that are central to this paper as well as to the evolution of economics.

In large measure, the patterns subsequently followed by economics and the natural sciences were established at the times of their origins. The natural sciences resulted from the merger of two distinct traditions: A scholarly tradition, emphasizing abstract and speculative thought, initially located in monasteries and later moving to the newly established universities. An experimental tradition was composed of alchemists, metallurgists and artisans of various kinds. The latter group, being of lower social status had no access to the universities and met with interested theorists outside the universities in scientific societies newly established for that purpose. One of the earliest established in Italy was the Lyncean Society established in 1611, with Galileo as a member. In England, a number of informal societies preceded the official chartering of the Royal Society of London in 1662.

The existing university leadership at the time vigorously opposed the new science. In the exemplary case of Galileo that climaxed with his trial, the main opposition to the new science came not from the religious establishment, as is commonly assumed, but rather from the university establishment that succeeded in instrumentalizing the Church for their purposes. It was only when the prestige of the new science had become dominant, that its representatives, theorists and experimenters, obtained equally prestigious chairs at the universities. The equal status and close connection of theoretical and empirical research having been thus institutionalized in the natural sciences was never thereafter severed.[1]

[1] The origin of modern science is discussed in Mason (1962, Part Three).

Initially, it appeared that economics would develop along the same lines as the natural sciences. Sir William Petty, who along with Adam Smith may be regarded as one of the founding fathers of modern economics, was a founding member of the Royal Society and was intensely committed to the application of natural science methodology in economics. This applied particularly to the need for measurement. His famous statement on that subject is:

> To express my self in Terms of Number, Weight or Measure; to use only arguments of sense, and to consider only such Causes, as have visible Foundations in Nature;[1]

Petty established the discipline that he termed 'political arithmetic'. In producing the first estimates of national income for Ireland, he established a watershed between Mercantilism that measured economic performance in terms of the contribution to the ruler's treasury and modern economics that uses the national income as the fundamental yard stick. His ultimate aim was not measurement for its own sake, but rather the description of society in terms of quantitative laws. In this he did not get very far, nor did subsequent generations of economists. That is one reason why the methodology of Smith, rather than of Petty came to dominate academic economics. An interesting fact from the point of view of this paper is that Petty introduced the term 'cycle' to economics. He averaged observations over the cycle to obtain representative values.

Petty's most important quantitative treatises were *Political Arithmetick* published in 1690 and *The Political Anatomy of Ireland* published in 1691. About 80 years later, in 1776, there appeared *An Inquiry into the Nature and Causes of the Wealth of Nations* giving to its author Adam Smith the distinction of being regarded as the second founder of modern economics, with a prestige and influence that, justifiably or not, far exceeded that of Petty.

Smith established economics as an academic discipline and pointed it in quite a different direction from that envisaged by Petty. None of the central arguments on which the lasting fame of the *Wealth of Nations* and the book's influence on the subsequent evolution of economics are based required quantitative evidence. While the book contains a wealth of empirical observations, these are of a casual and qualitative nature. The *Wealth of Nations* reflects two fundamental differences between the human and the natural sciences. One difference is that physics and chemistry have a larger number of variables that are easily quantifiable and observable. Moreover, these quantities are often related by simple proportionality. In contrast to this, in economics the central utility concept is difficult to measure. Both utility and production functions are complex and context dependent. The second difference is that humans are not distant from themselves, in the same way in which they are distant from, say subatomic particles or cosmological phenomena. We have direct knowledge of ourselves, our motives and interactions with others. For example, our casual knowledge of the social world tells us that people generally prefer to buy cheaply and to sell dearly. It would seem that little of value would be added to this casual knowledge by running experiments, or extensively recording transactions. It is for these reasons that Smith and subsequent generations of economists have remained casual empiricists. This remains true even in today's age of econometrics. Open any current textbook in economics and you will rarely find an assertion that is backed by quantitative evidence.

Subsequent to Smith, economics divided into two broad streams, each with many distinct currents. I will refer to these as 'mainstream economics' and 'critical economics'. Mainstream economics is concentrated in the universities and includes classical economics, marginalism and neoclassical economics. The strength of mainstream economics has been in analyzing the behavior of agents and their interaction in markets. The principal method of analysis has been static optimization and comparative statics. This analysis was continuously refined, but never fundamentally altered.

[1] Quoted in Roncaglia (1987). A broad discussion of the rise of quantitative methods and political arithmetic is given in Spiegel (1971, Ch.6).

Critical economics is more diverse, with the larges common factor being the rejection of the mainstream. By way of a positive characterization, it may be said that the orientation of critical economics is typically towards disequilibrium, macroeconomics, dynamics, quantitative empirical research, and institutional analysis. These elements have different weights in the several currents of critical thought. The contributors to this stream typically were not academic economists and they were critical of the abstract theorizing characteristic of the academic mainstream.

2.2 Mainstream and Critical Economics

The fact that quantitative macroeconomic thinking tended to originate outside of academic economics and most prominently with natural scientists is in evidence even before the times of Petty and Smith. The first formulation of a quantitative macroeconomic relationship is due to Copernicus, better known for his advocacy of the heliocentric theory. In a statement to the Polish king, based on an address to the Prussian diet four years earlier, he writes: “Money usually depreciates when it becomes too abundant.” Regarding this earliest rough formulation of the quantity theory of money, the economic historian Spiegel (1971, P.88) wrote:

> Copernicus's tract was not published until the nineteenth century and may not have had much influence on the thought of his contemporaries. In any event, his discovery, whatever its range and effect may have been, is especially remarkable because chronologically it antedates the large-scale movement of precious metals from America to Europe. By the power of reasoning and by the ability to invent fruitful hypotheses, a great mind may discover relations that ordinary people can recognize only if driven by the stimulus of observation.

Define macroeconomics as the study of the flows of goods and services and of the associated payments between major sectors of the economy. The first analytical macroeconomic model was the *Tableau Economique* published by Quesnay in 1759. Quesnay was a physician and the Tableau was inspired by an analogy with the circulation of the blood.

Moving forward to the period of classical economics, we encounter an outstanding figure of critical economics in the person of the clergyman Thomas Robert Malthus. His fame is based on two books: *An Essay on the Principles of Population,* published in 1798 and *Principles of Political Economy* published in 1820. In the first book he argued that diminishing returns to a fixed quantity of land would inevitably push the standard of living of a growing population down to the subsistence level. With this book, Malthus countered the usual optimistic tinge of the mainstream, but did not leave it; his essential argument was accepted by both Ricardo and Mill. Unfortunately, economists did not pick up on the method of quantitative population analysis. To the loss of economics, this became the separate discipline of demography. In the *Principles* he argued the possibility of a depression due to a general glut of demand. The significance of this anticipation of modern macroeconomics was recognized by Keynes who rescued it from the “underworlds” of economics. Malthus exemplified also the social concerns characteristic of critical economics.[1]

The towering figure of critical economics is Karl Marx. Regarding those aspects of his thought that are most relevant in the present context, I can do no better than quote Spiegel (1971, p.473):

> Since it was the pathology of economic life that attracted so much of Marx's attention, it is not surprising that his work abounds with suggestions about instability, crises, and cyclical disorders. In his vision of an economic evolution replete with dialectic relationships and contradictions, and indeed generated by these, many ideas were foreshadowed that found systematic development in later business cycle theories: underconsumption and overproduction, short and intermediate cycles of ten-year duration, the instability of investment, disproportions in the structure of an unplanned production, variations of profits, and the cyclical character of replacement expenditure.

[1] See Ch. 3, The principle of effective demand, in Keyes (1936). The famous passage on the underworlds is on p. 32.

The above should suffice to confirm that critical economics, at least for the time-span discussed, conforms to the description that I gave in the beginning. Apart from Smith, I have not discussed the mainstream of this era, since it is well known and the features that I stressed were passed from the classical school to the marginalists and ultimately to the current school of neoclassical economics.

2.3 Merging of the Streams: 1920-1960

In the period roughly from 1920 to 1960 the two streams intermingled and for a while flowed together. Two major forces pushed them together; the impact of the Great Depression and the rise of socialism. Following the Great Depression, departures from full employment equilibrium could no longer be regarded as minor and transitory frictions. Therefore a shift from microeconomic equilibrium analysis to macroeconomic disequilibrium analysis was indicated. This was to be accomplished by Keynes in his *General Theory of Employment, Interest and Money*, published in 1936.[1]

The impact of socialism was due to the fact that it regarded itself as a scientific enterprise devoted to social improvement. It was recognized that this required socio-economic data and the scientific analysis of that data. Governments established statistical agencies generating large quantities of data. Many prominent economists and statisticians of this era worked on the theoretical foundation of economic measures such as price and quantity indexes, consumer surplus and national income.[2] Closely related to these general tendencies was also the rise of econometrics, signalled by the founding of the Econometric Society in 1930.

2.4 Early Econometric Work on Business Cycles

Unfortunately, work done on disequilibrium and on business cycles during this period was disparate and largely consisted in isolated contributions that never converged to a generally accepted paradigm analogous to microeconomic optimization theory. Cobweb models of agricultural cycles could not directly be applied to the national economy, but they were methodologically important in that they led the way to the modeling of expectations, first as adaptive and then as rational.[3] Cobweb models also provided the inspiration for cycle models formulated by the pioneers of econometrics.

Tinbergen (1930) on the ship-building cycle is the seminal econometric cycle paper. It was the first to formally model a cycle in industrial investment. It introduced the idea of a gestation lag in the form of the time lag between starting to build a ship and finishing it. Since the other relationships of the model were formulated in continuous time, the result was a system of mixed difference-differential equations. This analytical scheme was also adopted by the two authors that will be discussed next. The mathematical difficulty of mixed difference-differential equations may be one reason why their approach did not find followers.

Both Frisch (1933) and Kalecki (1933, 1935) took the decisive next step of constructing business cycle models meant to apply to a national economy rather than and isolated market. The key variable of their models is the volume of fixed business investment. Frisch demonstrated that for plausible parameter values his model generates two cycles concerning which he writes:

> The primary cycle of 8.57 years corresponds nearly exactly to the well-known long business cycle…Furthermore, the second cycle obtained is 3.50 years, which corresponds nearly exactly to the short business cycle. (p. 170).

---

[1] One may quibble about whether Keynes' theory should be called one of disequilibrium, since markets are not clearing, or equilibrium, since there is no automatic tendency to move away from the equilibrium point; in any case, it is not a theory of full employment equilibrium.

[2] These contributions are discussed in a series of papers on measurement by the present author, Hillinger (2001, 2002, 2003a, 2003b).

[3] This is discussed by Pashigian, (1987).

That the short cycle is an inventory cycle was not known at the time, nor were aggregate data on inventory investment available. Frisch's article was path breaking also from a methodological point of view. He analyzed the behavior of a system with an endogenous cyclical dynamics that is subject to exogenous disturbances. This level of sophistication has been missing from much subsequent and even contemporary macroeconomics. Economists have far too often assumed that the irregular nature of economic time series is evidence for the absence of cycles.

Of the early econometricians, Kalecki (1933, 1935, 1954, 1966, 1971) is the one who devoted the most intensive and sustained effort to the explanation of macroeconomic fluctuations. Regarding the investment process, he distinguishes between orders for investment goods, actual investment, which takes place subsequently for the duration of the gestation lag, and additions to the capital stock, which occur at the end of the gestation period. He made a considerable effort to obtain range estimates of the parameters and showed that, for plausible parameter values, the model generates cycles which lie in the observed range of 8-12 years. In subsequent publications (particularly Kalecki 1954) he tested his model against different data-sets and obtained generally plausible results.

The rest of Kalecki's model is rather unsatisfactory. He assumes that workers do not save and that they consume a constant amount. Capitalists base their investment decision on their gross profit without an accelerator effect or the consideration of capacity utilization. Gross profits in turn are in his model a simple accounting consequence of the level of investment. The early econometric work on cycles, and particularly the models of Frisch and Kalecki, clearly fell within the investment cycle theory, advanced that theory substantially, and moved it methodologically in the direction of the natural sciences. The main weakness of their models is that they are unsatisfactory as closed models of an economy, both in accounting for the circular flow of income and in distinguishing between ex ante and ex post variables. In this they are truly pre-Keynesian.

The careers of these three pioneering econometricians illustrate both the temporary joining of the two broad streams of economic analysis, as well as the remaining tensions. Tinbergen obtained his PhD in mathematical physics, Frisch in mathematical statistics, while Kalecki was trained as a civil engineer. The first two became influential mainstream economists, while Kalecki, a Polish Jew and Marxist remained forever outside the mainstream. He returned to Poland in 1955 and devoted himself to economic planning.[1]

2.5 Keynes

As the son of the Cambridge economist John Neville Keynes and student of Marshall and Pigou, John Maynard Keynes was destined for a prominent role in the economic mainstream. In fact, he transcended the received mainstream by creating a synthesis between it and critical economics. By doing so he created a new mainstream that was dominant for several decades.

Two forces compelled Keynes beyond the confines of received mainstream economics towards the new synthesis of *The General Theory of Employment, Interest and Money*. One was the impact of the Great Depression on an economist with strong social concerns, already evidenced in *The Economic Consequences of the Peace*. The other force is Keynes' strong empirical interest, particularly his desire for quantitative data. He strongly supported the work that led to the construction of the national income and product accounts (NIPA). The sectors into which the accounts are divided are analogous to those discussed in the General Thory. Even today, applied macroeconomic analysis is based on the NIPAs and on the causal connections between them postulated in the General Theory. This is a lasting contribution of Keynes.

[1] Regarding these three scientists, there are good entries in Eatwell et al. (1987).

In discussing the General Theory, I am primarily concerned with its relationship to the theory of investment cycles that will be elaborated later in this paper. The General Theory was motivated by Keynes' belief that the Great Depression had heralded a fundamental and permanent structural change in the economies of industrialized nations. It was a change from the old business cycle with its permanent ups and downs to a state of permanent under employment. Formalized and reduced to its bare bones by Hicks in the form of the IS-LM model, this became the macroeconomics taught to generations of budding economists. Keynes postulated various pathologies to explain the none-clearing of markets. Of these, price rigidity is common also to the theory of investment cycles. For the purpose of this theory, price rigidity does not have to be total, as in the static Keynesian model. It suffices to assume that price adjustment is slow so that the initial response to disequilibrium is in terms of quantity.

I have stressed that the General Theory was motivated by Keynes' vision of a post-Depression world of mature capitalism, characterized by stagnation and chronic deficient demand. Most of the General Theory elaborates a model of such an economy. However, in Chapter 22, *Notes on the Trade Cycle*, Keynes cast a backward glance at a world which he thought had ceased to exist. He attempted a brief explanation of economic cycles which he explicitly described as a "nineteenth-century phenomenon".

The building blocks for Keynes's dynamic theory are contained in Chapters 5 and 12 on short- and long run expectations. The entrepreneur is described as making his current decisions on the basis of his expectations regarding the future. Future expectations are based on extrapolations from the past, but these may be strongly influenced by irrational and volatile factors of individual or mass psychology. Keynes discusses two fundamental decisions of the firm. In Chapter 5 it is the decision on how much to produce, which is related to short-term expectations regarding the demand for the product and also to current inventory levels. Chapter 12 is devoted to the firm's decision to invest in fixed capital. Here the decisive consideration is the relationship between the current cost of capital and its expected long-term yield. The current cost depends on the price of capital goods and the rate of interest, on the expected long run evolution of market demand and on costs of producing with old or new capital.

Keynes's attempt in Chapter 22 to construct an endogenous dynamic theory of economic cycles based on these building blocks, has remained rudimentary. The main reason appears to be that he devoted little effort to the task, since he regarded the chapter as no more than an historical aside. Also relevant is the fact that a logically tight description of the dynamics of an oscillatory process is virtually precluded by the rather diffuse verbal style of Keynes and earlier writers on economic cycles.

Considering the three chapters together, Keynes made a substantial contribution to the explanation of economic fluctuations, which was firmly in the tradition of the theories of investment cycles.

2.6 Business Cycles, Definitional Issues

In this subsection I try to isolate a strand of a vast and diffuse literature. Clarity requires dealing at the outset with some definitional issues. A dictionary definition of 'cycle' is 'a recurrent period of definite duration'. Petty, as mentioned above, had referred to economic fluctuations as "cycles", but without the implication of periodicity. As described by Schumpeter (1954) the recognition of the recurrence of economic depressions as part of a periodic process developed gradually in the course of the Nineteenth Century and replaced the earlier view of them as isolated and unrelated events.

> One of the most important achievements of the period under survey, and one of the few that were truly original, was the discovery and preliminary analysis of business cycles. It is true that the crises of 1815, 1825, 1836-9, 1847-8, 1857, and 1866 pressed the phenomenon upon the attention of even the most academic of economists. But similar breakdowns had occurred, with similar regularity in the eighteenth century, and nevertheless nobody had gone deeply into the matter: nobody had distinguished them clearly

from the effects of war and other external disturbances or seen in them anything but chance misfortunes or the results of manias or errors or misconduct. (p. 738).

The precise meaning of 'business cycle' had then as now a certain amount of obscurity. Schumpeter writes:

From the first, writers used the term 'cycle' or 'commercial cycle' in order to denote the units of this movement and spoke of a 'periodicity' of these cycles, by which most of them meant not more, however, than a definite sequence of phases irrespective of duration. Some, however, did suggest approximate, if not exact, equality of duration and among these the 'ten-year cycle' eventual1y gained a certain popularity… (742).

In a footnote he continued:

Some confusion about this has arisen from the fact that some modem writers who use the phrase 'periodicity' in the strict sense – recurrence in constant periods – attribute the same sense to all writers who use the word and then speak of assertion or denial of periodicity when they should speak of assertion or denial of periods of constant duration.

This clarification is itself not very clear. The durations of business cycles are never exactly the same; the issue can therefore only be between periods of *approximately* constant duration and fluctuations without any periodicity. Such confusions have persisted. Thus Lucas (1975, 1981, p. 217) writes:

Let me begin to sharpen the discussion by reviewing the main qualitative features of economic time series which we call "the business cycle." Technically, movements about trend in gross national product in any country can be well described by a stochastically disturbed difference equation of very low order. These movements do not exhibit uniformity of either period or amplitude, which is to say, they do not resemble the deterministic wave motions which sometimes arise in the natural sciences.

Analogously to Schumpeter, Lucas seems to believe that exact sinusoidal or entirely non-periodic movements are the only alternatives.

The most sophisticated discussion of business cycle stylized facts that I have found in the modern macroeconomic literature is that provided by Sargent (1979). Following a condensed, but high powered exposition of stochastic difference equations and their spectra he gives the following discussion that, because of its importance, I quote at some length:

We have already encountered two definitions of a cycle in a single series that is governed by a stochastic difference equation. According to the first definition, a variable possesses a cycle of a given frequency if its covariogram displays damped oscillations of that frequency, which is equivalent with the condition that the nonstochastic part of the difference equation has a pair of complex roots with argument … equal to the frequency in question. A single series is said to contain a business cycle if the cycle in question has periodicity of from about two to four years (NBER minor cycles) or about eight years (NBER major cycles).

A second definition of a cycle in a single series is the occurrence of a peak in the spectral density of a series. As we have seen, this definition is not equivalent with the previous one, but usually leads to a definition of the cycle close to the first one.

It is probably correct however that neither one of these definitions is what underlies the concept of the business cycle that most experts have in mind. In fact, most economic aggregates have spectral densities that do not display pronounced peaks at the range of frequencies associated with the business cycle. The peaks that do occur in this band of frequencies tend to be wide and of modest height. The dominant feature of the spectrum of most economic time series is that it generally decreases drastically as frequency increases, with most of the power in the low frequency, high periodicity bands. This shape was dubbed by Granger (1966) the "typical spectral shape" of an economic variable and is illustrated by the logarithms of the spectral densities of real GNP, the unemployment rate, the real wage, the Baa rate, and output per man-hour in Figure 1. The generally downward sweeping spectrum is characteristic of a covariogram that is dominated by high, positive, low-order serial correlation. Notice that the inflation rate and change in the real money supply do not display the typical spectral shape, a characteristic that might have been anticipated from our study of the effects of applying the first difference filter. (p. 254).

This statement calls for a considerable amount of discussion. The first two paragraphs give a perfectly acceptable definition of business cycle. My only quarrel here is with the terminology "NBER minor cycles" and "NBER major cycles". I have encountered this terminology before, always without a specific reference. Zarnowitz (1992), the most authoritative current source on business cycle analysis in the NBER tradition, discusses short and long cycles as part of the general investment cycle tradition, without attaching the 'NBER' label. The NBER tradition will be discussed further below.

The third paragraph, dealing with the empirical evidence for cycles is much less satisfactory than the theoretical discussion. Sargent claims that no pronounces spectral peaks at business cycle frequencies are to be found in empirical date. The empirical evidence that he presents to support this claim is depicted in his Figure l. The time series involved are listed in his paragraph above. Notably, these do not include the two investment series in which the cycles have traditionally been observed: fixed investment for the long, inventory investment for the short cycle. These variables make only an indirect appearance as elements of real GDP. Sargent's computed spectrum fro real GDP is reproduced as Fig. 1. There actually is a clear peak at about 4 years. To the left of the spectrum, as the period length goes to infinity, so does the spectral power; a clear indication of insufficient detrending as a result of first differencing. First differencing has the effect of accentuating the high frequencies and is probably responsible for the high power at 2 years.

Figure 1 about here

Granger's often cited 'typical spectral shape' mentioned by Sargent also deserves a comment. In the course of the many spectra computed in connection with the research reported in the next section, we have come to attribute the 'typical spectral shape' to two factors. One is insufficient detrending as just discussed. The other is the use of 'classical' spectral methods with little ability to separate cycles in a short time series. The consequence is that the power of the trend, the long cycle and the short cycle all merge. Of these, the trend has the most power and the long cycle has more power than the short cycle. The end result is Granger's 'typical spectral shape', displaying declining power in moving from the low to the high frequencies.

Clarity requires both precise concepts and a clear and definite terminaology. In the following I refer to a 'quasi-cycle' when referring to the output of a stochastic process with complex roots. When speaking of 'business cycles', or 'investment cycles' I mean a quasi-periodic phenomenon.

I discuss next a view of business cycles that, through no fault of its author, has led to much confusion in macroeconomics. I am referring to the theory of the aggregation of random causes due to Slutsky (1937). The most relevant result was that if a stationary random variable is aggregated by means of a moving average, the spectrum of the resulting sum may have peaks at certain frequencies and thus exhibit quasi-periodic behavior.

The reception of this result in macroeconomics has been extremely confused. The result can only be of relevance if a plausible argument can be made to the effect that macroeconomic variables are moving averages of random shocks. I don't believe that such an argument has, or can be made. Slutsky's result is usually interpreted (as in the example given below) to mean that economic time series may be pseudo periodic, in the sense that they *look* as though they were quasi-periodic, while in reality they are not. While it is true that a low order AR or MA process may appear quasi-periodic without actually being so, this was not Slutsky's result; he had shown that averaging may lead to *genuine* quasi-periodicity.

A result of total, if not untypical, confusion with regard to Slutsky's contribution is found in the recent textbook by Sorensen and Whitta-Jacobsen (2005). They write:

> The perspective on business cycles adopted here is sometimes referred to as the Frisch-Slutsky paradigm, named after the Norwegian economist and Nobel Prize winner Ragnar Frisch and the Italian statistician Eugen Slutzky ([1]) who first introduced this way of interpreting business cycles. The Frisch-Slutzky paradigm distinguishes between the impulse which initiates a movement in economic activity, and the propagation mechanism which subsequently transmits the shock through the economic system

[1] The reference should be to the Russian economist and statistician Eugene Slutsky.

over time. In our model framework, the impulse is a sudden exogenous change in one of the 'shock' variables determining the position of the aggregate supply and demand curves. The propagation mechanism is the endogenous economic mechanism which converts the impulse into persistent business fluctuations. The propagation mechanism reflects the structure of the economy and determines the manner in which it reacts to shocks and how long it takes for it to adjust to a shock. (p. 558).

"The Frisch-Slutzky paradigm" is entirely due to Frisch. On p. 572 of the same chapter they write:

> To illustrate Slutzky's fundamental insight, suppose the variable a_t evolves according to the difference equation:
>
> $a_t = 0.9a_{t-1} + e_t$,
>
> Where e_t is a random variable following the standard normal distribution with a zero mean and a unit variance, and being independently distributed over time.

Their Fig. 19.10, depicting the result of a simulation of this process is reproduced here as Fig. 2. The authors' interpretation is that:

> …we see that the simple difference equation…is able to generate a time series which qualitatively looks remarkably like the recurrent business cycles of the real world.

The figure does display a minimum property of economic fluctuations, which is serial correlation and the consequent and the consequent tendency of persistence above, or below the mean. That the series lacks quasi-periodicity is particularly evident from the irregularity of the durations in the positive/negative segments of the graph. The appearance of this time series differs markedly from the quasi-periodic investment cycles analyzed in Sections 4-11.

Figure 2 about here

2.7 Business Cycle Theory and Investment cycles

My purpose in this subsection is to describe the origin of the hypotheses that my associates and I have tested and elaborated further in the substantive research described in Section 4. I am not attempting a description of the evolution of a vast literature, but rather will quickly move to what may be regarded as in some sense the endpoint of an evolution, that was aborted around 1960 by other tendencies in macroeconomics.

The literature on business cycles, and before that on crises, emphasized financial aspects that were evident in such spectacular events manias and banking crises. The manias, in today's terminology bubbles, focussed attention on the extreme price movements involved.[1] Recurring banking crises, involving bank failures and 'banking holidays', focused attention on the money-credit nexus. Kindleberger (1987) writes:

> …the suggestion that lending standards grow more lax during a boom and that the banking system on that account becomes more fragile has strong historical support. It is attested, and the contrary rational-expectations view of financial markets is falsified, by the experience of such a money and capital market as London having successive booms, followed by crisis, the latter in 1810, powerful record of failing to learn from experience.

In the late Nineteenth and early Twentieth Centuries attention shifted towards the real sectors of the economy, spurred by the increased availability of data, particularly on fixed investment and consumption. The relationship between the existing capital stock on the one hand and the demand for output on the other became was recognized as central for the explanation of investment cycles. This was reflected in a growing literature on the 'acceleration principle'. Somewhat later, as data on national inventory investment became available, attention came to be focused on inventory fluctuations and the inventory cycle. The

[1] The most famous manias are the Mississippi bubble in Paris in 1719-20, the contemporaneous South Sea bubble in London, the Tulip mania in Holland in 1636 and the Railway mania in England in 1846-7.

role of money and credit over the cycle was not ignored, but came to be regarded as being of secondary importance.[1]

With the advent of Keynesianism, accelerator-multiplier interaction came to be the mechanism at the heart of formal business cycle models. A start was made by Samuelson (1939). Metzler (1941) used the mechanism to explain the inventory cycle. In one form or another, accelerator-multiplier interaction became a key feature of Keynesian macroeconomic models. The theoretical models were inspired by empirical findings regarding investment cycles, in the sense that each involves investment as key component and each generates a cycle. The fact that consumption and investment play equally central roles in these models is contradicted by the empirical observation that the cycles occur predominantly in investment. By the time of the large scale macro-econometric models belief in cycles had faded and they were not analyzed in this respect.

A more empirical, less formal approach to the description and explanation of business cycles continued, only loosely connected to the developments in Keynesian Macroeconomics and macro-econometrics. For example, the US Congress (1961) held extensive hearings on inventory fluctuations. Matthews (1959) summarized what was known, or believed, about business cycles at that time. In essence, the argument was that business cycles are investment cycles and that there are three types. An inventory cycle in the 3-4 year range, an equipment cycle of 8-10 years and a building cycle of about 20 years. The evidence given was impressionistic, consisting of a few graphs of relevant time series. The explanation given was informal and involved the lagged adjustment of capital stocks to their desired levels. This adjustment is slowest for buildings, resulting in the longest cycle. For equipment, the adjustment speed is intermediate and so is the length of the cycle. The most rapid adjustment occurs with inventories so that here the cycle has the shortest period.[2]

With my dissertation[3] I started a research program aimed at formalizing both the evidence and the explanation of investment cycles. This is the subject of Section 4. The macroeconomic mainstream went in quite a different direction. This is the subject of the next section.

3. CONFLICTING IDEOLOGIES IN POSTWAR MACROECONOMICS

The question of why the investment cycle theory of economic fluctuations was not pursued beyond the 1960s can only be answered by looking at the motivations of the new mainstream that came to dominate macroeconomics. Also, the question which of these radically different approaches is in better accordance with reality can only be answered in terms of such a comparison.

I shall argue that the evolution of macroeconomics in the post World War II era was dominated by various ideologies. I define ‘ideology’ more broadly than is common as a broad set of beliefs and attitudes that are so firmly held as to be highly resistant to any real world evidence. Specifically, I will discuss the impact of both political and methodological precommitments on the evolution of contemporary macroeconomics. One caveat: I make no attempt at a balanced account. I believe that science advances in terms of the clash and mutual criticism of alternative theories, with the partisans of each making the strongest possible case. Certainly, the advocates of successive paradigms in macroeconomics have not been shy in pushing their views; I do the same for the theory of investment cycles.

---

[1] A classic review of business cycle theories is Haberler (1958). A more compact review is Schumpeter (1954, Part III, Ch. 7).

[2] Matthews did not discuss the Kondratieff cycle, or long wave phenomenon. That this is a genuine cycle with a defined periodicity is controversial. Moreover, the explanation generally given in terms of the diffusion of innovations is different from the capital stock adjustment principle.

[3] Hillinger (1963); the main results wer4e also reported in Hillinger (1966).

A described above, investment cycles played an important role in early Keynesian macroeconomics and econometrics. During the 1960s this interest evaporated. What had happened? The early post war decades had seen the coincidence of strong growth with only mild fluctuations and the heyday of Keynesianism. Keynesians attributed this good performance to Keynesian demand management, the success of which was also taken as a validation of Keynesian macroeconomics generally. Furthermore, it was thought that the advent of large scale macro-econometric models would make micromanagement of the economy possible, thereby relegating business cycles to the history books. For a policy oriented discipline this meant that business cycles were dropped as a subject of active research, being replaced by the study of equilibrium growth and 'golden rules'.

The episode just described was driven by Keynesianism that had become a self serving ideology. When declining growth, increasing inflation and macroeconomic instability became apparent in the late 1960s and early 1970 Keynesianism went into decline.

The dominant strand of post-Keynesian macroeconomics consists of Chicago monetarism, rational expectations and real business cycles. My discussion will concentrate on these. For lack of a better term I will refer to the entire sequence as *neoclassical macroeconomics*, even though the term does not fit monetarism very well. Also the term must be clearly distinguished from Samuelson's 'neoclassical synthesis' that it replaced.

The shift from Keynesianism to neoclassical macroeconomics cannot be understood without reference to the tectonic shift from the ideologies of the left, to those of the right. The earthquake that established the new political landscape was the collapse of communism that began with the Russian perestroika of the late 1980s. However the welfare states of Europe and of the socialist economies of the Third World had shown signs of dysfunction much earlier. For the ideologies of the left, ranging from Marxism to social democracy I will use the blanket term *socialism*. For the contemporary right wing ideology I will use the internationally established *neoliberalism* rather than 'neoconservatism' used in the US.

Socialism, being the dominant ideology of much of the Twentieth Century, impacted all areas of intellectual life, including the social sciences and economics. In mainstream economics the result was a compromise. The defects of unregulated markets were acknowledged, but they were regarded as corrigible by state intervention, leading to the restoration of market efficiency and a better outcome than with central planning. At the micro level intervention was required in uncompetitive markets and to internalize externalities. At the macro level, an economy assumed to be inherently unstable required an active stabilization policy. In addition, social welfare programs were needed to help those who could not help themselves. This is what Samuelson referred to as the neoclassical synthesis and popularized in his *Economics*, the most successful introductory economics book of all time.

One major research center that had remained largely untouched by the Keynesian revolution was the economics department at the University of Chicago, commonly referred to as the Chicago School. The Chicago challenge to Keynesianism centered on monetarism. Friedman (1968) writes:

> Keynes offered simultaneously an explanation for the presumed impotence of monetary policy to stem the depression, a nonmonetary interpretation of the depression, and an alternative to monetary policy for meeting the depression. His offering was avidly accepted. If liquidity preference is absolute or nearly so – as Keynes believed likely in times of heavy unemployment – interest rates cannot be lowered by monetary measures. If investment and consumption are little affected by interest rates – as Hansen and many of Keynes' other American disciples came to believe – lower interest rates, even if they could be achieved, would do little good. Monetary policy was twice damned….But there was available an alternative – fiscal policy. Government spending could make up for insufficient private investment. Tax reductions could undermine stubborn thriftiness.
>
> The wide acceptance of these views in the economics profession meant that for some two decades monetary policy was believed by all but a few reactionary souls to have been rendered obsolete by new economic knowledge. Money did not matter. Its only role was the minor one of keeping interest rates low, in order to hold down interest payments in the government budget, contribute to the "euthanasia

of the rentier," and, maybe, stimulate investment a bit to assist government spending in maintaining a high level of aggregate demand.

> These views produced a widespread adoption of cheap money policies after the war. And they received a rude shock when these policies failed in country after country, when central bank after central bank was forced to give up the pretense that it could indefinitely keep "the" rate of interest at a low level. In this country, the public denouement came with the Federal Reserve-Treasury Accord in 1951, although the policy of pegging government bond prices was not formally abandoned until 1953. Inflation, stimulated by cheap money policies, not the widely heralded postwar depression, turned out to be the order of the day. The result was the beginning of a revival of belief in the potency of -monetary policy.

Central to the Chicago challenge was the empirical work done on the quantity theory of money. [1] Friedman and Schwartz (1963, 1982) went a step further. They argued that not only does the money supply determine inflation is the long run, but in addition that it is the main source of short run instability of the real sector. They showed that clearly identifiable exogenous disturbances of the money supply caused observable repercussions of the real economy. More specifically, they claim that major depressions had their origins in major monetary disturbances. The general finding is unobjectionable; no one denies that major disturbances can emanate from the monetary sector, or that a major disturbance would impact the real economy. Whether major depressions are simply caused by monetary disturbances has remained controversial, as evidenced by the voluminous and continuing literature on the Great Depression in the US.

Regarding the more usual regular fluctuations of the economy Friedman (1963) is more cautious:

> A fully satisfactory explanation of the minor movements would require an explicit and rigorously stated theory, which could take the form of a series of simultaneous differential equations describing the reaction mechanism of the economy, together with a specification of the joint distribution function of the random disturbances impinging on it, and a specification of the systematic disturbances that could be introduced into it. Our belief that money plays an important role in minor movements is equivalent to asserting that some of these differential equations would contain the stock of money as a variable; that disturbances in the stock of money are among the random or systematic disturbances impinging on the system; and that these disturbances alone would be capable of generating a path for such major economic variables as money income, prices, output, and the like, comparable to the path they actually follow during mild depression cycles.

My personal experience suggests that Friedman's opinion of the subject was actually stronger than expressed in the above passage. As an advanced graduate student at Chicago I attended his Workshop in Money and Banking. When I decided to make a test of Metzler's model of the inventory cycle my dissertation topic I told him about it. He replied that it was always good to test a theory. However, "of course" the result would be negative. Subsequently, He did not attend my defense of the dissertation. Evidently, he felt that the research program that he had advocated above was in reality superfluous.

It seems like a fair summary of Friedman's overall position that all fluctuations are to a large extent the result of monetary disturbances, more precisely of misguided monetary policies conducted by central banks. The proposed solution was to end active stabilization policies and to have the money supple expand at a constant rate. A further proposal made by Friedman to reduce monetary instability was his advocacy of 100% bank reserves.[2]

Two other lines of research also challenged the feasibility of active macroeconomic policies, either in principle, or at the level of practical implementation. The best known of these by far is the attack on the Phillips curve by means of the concept of a 'natural rate of unemployment'.[3] Secondly, Friedman (1961) argues that "…monetary actions affect economic conditions only after a lag that is both long and variable." Clearly, a long and

---

[1] Collected in Friedman (1956). Cagan (1965) reviews various issues at conflict between monetarism and Keynesianism.
[2] Cf. Friedman (1960).
[3] Initiated by Friedman (1968), Phelps (1968).

variable lag will make successful discretionary monetary policy very difficult, if not impossible.

Leeson (2000) describes the concerted efforts of Stigler and Freedman to propagate the neoliberal ideology[1] both within the economics profession and in the larger political realm. Stigler's task was to argue that perfect competition was a more accurate model of real economies than the theories of imperfect competition. If this is accepted, regulatory policies become superfluous, likely doing more harm then good. Friedman took on the task of defeating Keynesianism with its interventionist policy recommendations. To this end he postulated an intrinsically stable economy disturbed by shocks emanating mainly in the monetary sector. The solution: avoidance of discretionary anticyclical policy and other reforms. The possibility of an endogenous dynamic, specifically of investment cycles, was never explicitly denied by Friedman, but it was pushed to the margins of the research agenda to such an extent as to become virtually invisible.

Monetarism of the Friedman type was succeeded first by rational expectations and then by real business cycle theories. These theories have dominated academic macroeconomics from the 1970s to the end of the century. While these theories may now be fading due to lack of empirical success, no alternative paradigm has taken hold. Given the dominance of these theories and the fact that arguments pro as well as con are well known, I will not discuss the theories in any detail. My concern is with two related questions: How can the enormous success of the theories, given their generally unsatisfactory empirical performance, be explained? What is the impact of the mind set created by these theories on the possibility of objectively dealing with the empirical evidence for and theoretical explanation of investment cycles?

The rational expectations/real business cycles success has gone hand in hand with an enormous expansion of neoclassical economics into fields formerly dominated by traditional political or sociological though, or else not treated in a scientific manner at all. In the Keynesian-neoclassical synthesis, the neoclassical assumptions of rational agents and frictionless perfectly competitive markets had been applied only to microeconomics. By basing macroeconomics on neoclassical assumptions, rational expectations/real business cycle theories contributed to making all of economics neoclassical.

The prestige of the neoclassical paradigm is closely allied with the prestige of mathematics. Generations of macroeconomists and econometricians employed themselves with the technical problems generated by rational expectations/real business cycle theories. These included the stochastic-intertemporal optimization problem assumed to face the representative agent as well as the econometric specification and estimation of rational expectations models. Recently, much technical effort has gone into the identification of residuals as being either monetary or real shocks.

Friedman's 'methodology of positive economics'[2] has played a significant role in immunizing neoclassical macroeconomics against criticism of its assumptions. According to Friedman, only the predictions of a theory are relevant for its evaluation, not the realism of its assumptions. The evident aim of this methodology at the time of its publication was to immunize the theory of perfect competition against just this kind of criticism from the camp of the advocated of theories of imperfect competition. In macroeconomics decisive predictive tests have not been in evidence. Lifting the requirement of realistic assumptions opens the door to the acceptance of fairytales that only have to embody neoclassical assumptions and a display of technical skills. There has been much discussion of Friedman's methodology. In my view, it involves a simple logical flaw. Why would an assumption be labeled 'unrealistic' unless its predictions violated some observations? These predictions remain when the

[1] Leeson does not use these or related terms.

[2] Ch. 1 in Friedman (1953).

assumption is incorporated in a larger model. A model with unrealistic assumptions is therefore also a predictive failure.

Criticism of ra6tional expectations/real business cycle models has centered both on predictive failures and on the lack of realism of specific assumptions. I wish to make a more general and less recognized criticism. It concerns the assumption of a representative agent that is needed to bring the neoclassical apparatus into play. It has long been know that, to put it bluntly, the representative agent does not exist. In other words, there are no reasonable assumptions that allow us to infer from the assumption of individually rational agents the conclusion that aggregates behave as though they were the outcome of the decisions of a single rational agent.[1] The vaunted rigor of neoclassical macroeconomics is selective; it ignores a chasm over which there is no bridge.

4. THE CONTRIBUTIONS OF FIXED AND INVENTORY INVESTMENT TO CYCLICAL FLUCTUATIONS

The principal topic of this paper, specifically of the next section, is the analysis of investment cycles, defined as quasi-periodic cyclic movements of these variables. Before doing so, it is useful to ask the more primitive question of what the contribution of these variables to aggregate fluctuations is. An answer can be given in many ways, for example in relation to year to year changes, for NBER defined recessions, with or without detrending, etc. Regards less of the precise path taken, the computations involved are likely to be rather simple, certainly compared to the analysis of quasi-cycles. Moreover, investigations of this type have in the past directed attention to investment and subsequently to the recognition of quasi-cycles. Unfortunately, this type of analysis was not done often and when it was done, the results were usually not published in prestigious and easily available journals. Fortunately, two excellent papers in this vein were published in Gordon (1986). From these I extract some highly condensed stylized facts that are relevant to the argument of this paper.

I begin with the work on fixed investment in Gordon and Veitch (1986). They analyze how much fixed investment contributed to the decline in output during 13 US recessions between 1920 and 1982. The NBER dating is used for the timing of peaks and troughs. The variables are real quarterly GNP and fixed investment. Fixed investment is defined as the sum of the four categories: producer's durable equipment, nonresidential structures, residential structures and consumer durable expenditures. Both variables were detrended by an estimate of the trend value of real GN P.

Table 1 about here

The principal conclusion is that measured as either a mean, or a median, the average contribution of fixed in vestment to the decline in detrended real GDP is above 40 percent and in some recessions around 60 percent.

Next I turn to Blinder and Holtz-Eakin (1986) on inventory fluctuations. Here the focus is on the contribution of the change in real inventory investment to the change in GNP. Both variables are detrended by Gordon's estimated trend of real GNP. Key results are shown in Table2. Looking at this table and seeing that the three largest contributions average near 200 percent, the reader is likely to rub his eyes in disbelief. This disbelief will be even greater when he recalls that inventory investment is on average only about one percent of GDP. The results do call for some explanation.

Table 2 about here

[1] The relevant literatures are reviewed by Kirman (1992) for the consumer and by Fisher (2003) and by Felipe and Fisher (2003) for the producer.

Let me say first of all, that having long worked on inventory fluctuations the results are not surprising to me. Both in the work done at my University of Munich seminar SEMECON and in other studies that I have seen, the contributions of inventory fluctuations to short run fluctuations in GDP tend to lie between 50 and 100 percent, with the 100 percent mark sometimes passed. A contribution of more than 100 percent means that other components moved predominantly in a contrary direction to GDP. The median contribution of 74.5 percent is quite typical.

The three very large contributions are not plausible descriptions of reality; their genesis can be explained as follows: Inventory investment is by far the most unreliably estimated component of GDP. Essentially it is computed as the difference between output and final sales, so that errors on both sides of the accounts enter. Many countries do not report a statistical discrepancy for the NIPAs, simply amalgamating the discrepancy with the inventory investment. Note that the three largest discrepancies occur when the changes in GNP are smallest. An error of given magnitude has the biggest impact on the contribution measure in these cases.

The two tables cover the same recessions, though with different data sets, as is indicated by slight differences in the dating of turning points. It is interesting to add the two kinds of contributions to get a measure of the contribution of total investment. When this is done, excluding the three recessions with very large inventory contributions, we find a mean contribution of 78 percent and a median contribution of 64 percent.

A conservative summary of these results is that investment accounts on average for more than 60 percent of cyclical fluctuations. This despite the fact that fixed investment averages only about 20 percent of GDP and inventory investment only about one percent. An empirically oriented theory of economic fluctuations must start with such elementary observations and proceed by refining and explaining them. The traditional theory of investment cycles has done this, albeit in an unsystematic manner.

5. INTERMEZZO: BUSINESS CYCLE FACTS AND FICTIONS

In the preceding sections I have tried to explain why at the start of my career I felt that the theory of investment cycles was the proper starting point for the scientific study of economic fluctuations. In this connection I gave no thought to ideology. I was well aware of the potency of Marxism, even though by that time its hold on reasonable people had loosened. I was largely unaware of the rising ideological forces within the economic mainstream. The rise of neoclassical macroeconomics made my subsequent research a rather lonely endeavor and created barriers to publication. A consequence was that much of the research was published in book form. This is particularly true of the later phase that took place at my seminar SEMECON at the University of Munich. Two of the books grew out conferences. They are: Hillinger (1992) and Barnett et al. (1996). Other books are based on dissertations written at SEMECON. They include: Reiter (1995), Woitek (1995), and Süssmuth (2003). The description of the SEMECON research on investment cycles in the next section draws largely on these sources.

The research covered four broad areas that arte successively treated in the next four sections. The first is a quantitative analysis of the quasi-periodic properties of investment cycles on the basis of international data sets. The second is a theory to describe the observed regularities. The proposed mechanism is a second order difference equation in the capital stock termed the *Second Order Accelerator* (SOA). It can be derived on the assumption of adjustment costs both to deviations of the capital stock and the rate of investment from their desired levels. Third is an intuitive explanation of invest5ment cycles bassed on the SOA and using the concepts of *inertia* and *kinetic-* and *potential energy*. Fourth is the incorporation of the SOA in structural macro-econometric models estimated in continuous time. The final research area was designed to remove a remaining defect of the SOA models, that when applied to aggregate data, they are principal agent models. It is shown that firms that have similar, though not identical, SOAs and are influenced by a common input, for example total investment, tend to *resonate,* i.e. move towards a common frequency and phase that can be seen in the aggregate.

This theory, which can explain the investment cycles, is seen to be completely different from the paradigmatic neoclassical model. In the latter, unemployment is the voluntary leisure of the representative agent, unused capacity is a 'technology shock', prices adjust instantaneously and, following a shock, the economy instantaneously achieves a new equilibrium. The difference between the two approaches corresponds to the difference between fact and fiction.

6. THE EVIDENCE FOR QUASI-PERODIC INVESTMENT CYCLES

6.1 Spectral analysis and the identification of cycles.

Here and in subsequent sections I give condensed and informal accounts of the SEMECON research on investment cycles in industrialized economies. Major publications in which this research is described in detail are: Hillinger and Sebold-Bender (1992), Woitek (1995, 1996) and Süssmuth (2003). In this subsection the topic is the spectral analysis used at SEMECON in order to identify and quantify the stylized fact of investment cycles, specifically their quasi-cyclical features. Extensive formal expositions of this methodology are found in the sources cited above. An extensive exposition of maximum entropy spectral estimation is Süssmuth (2004).

In the natural sciences the usual description of a quasi-periodic process is by means of its *spectrum*. The classic application is to radiation. The spectrum of a radiation emitting source shows the amount of power (energy) emitted in a specified frequency interval. Hence, the term 'power spectrum' that is frequently used. The total area under the spectrum gives the total energy emitted. Usually this area is normalized to unity so that a frequency interval gives the fraction of total energy emitted.

Of more direct interest to us is the fact that a linear stochastic process, i.e. an ARMA process can also be descried in terms of its spectrum. It can be shown that such a process can also be interpreted as a superposition of an infinite number of sine and cosine curves with stochastic coefficients. A frequency interval under the (standardized) spectrum can now be interpreted as giving the share of the total process variance that is contributed by the sine and cosine functions in that interval. A peak of the spectrum implies a complex root of the process. The larger the modulus r (real part) of the complex root, in the interval (0, 1), the sharper the peak and the more distinct the periodicity of the series.[1]

The theoretical spectrum is the Fourier transform of the process autocovariance function. Accordingly, traditional spectral analysis computes the empirical spectrum from the Fourier transformation of the observed autocorrelations. This procedure is flawed, particularly in small samples. Let a series of observation be $x_1,...,x_N$. The empirical autocovariances are $\gamma_h = Ex_t x_{t-h}$, for $h = 0,1,...,N-1$. There are N observations for the γ_0 variance, N-1 for γ_1, down to a single observation for γ_{N-1}. The estimates of the autocovariances become increasingly unreliable. Moreover, the unobserved autocovariances are implicitly set equal to zero, which is unreasonable. The periodogram, which is the unsmoothed Fourier transform of the empirical autocorrelations, is therefore erratic. Statisticians have proposed many so called 'windows' for smoothing either the periodogram or the autocorrelation function. When the number of observations is large, this procedure leads to a solid estimate of the spectrum, but it is highly unsatisfactory when only few observations are available, as is typically the case in economic applications.

[1] Properties of the theoretical spectrum are discussed in Granger and Newbold (1977).

A solution to this conundrum was published by Burg (1968); a good exposition is Ulrych and Bishop (1975); a recent SEMECON paper on the subject is Süssmuth (2004). His idea was to assign to the unobserved autocorrelations values that are best compatible with the observed ones. These would contain no additional information and hence, in comparison to all other possible assignments of values, would maximize the entropy of the autocorrelations. The remarkable result of Burg was that this is accomplished by a least squares estimate of an AR process of appropriate order. This is true even when the process is actually ARMA.

The problem is then to determine the appropriate order. There are two answers: One is that, unlike the arbitrariness involved in the construction of traditional spectral windows, there are well known statistical tests to determine the order of an AR process. [1]A second answer is that the estimated spectrum tends to be robust in relation to the chosen order. Of course, a minimum order is required to capture a given phenomenon. For example, if we believe that there are two cycles we need at least an order of four; one or two extra terms to improve the fit may also be desirable. But the order can be increased substantially without materially altering the spectrum.[2]

Since the publication of Burg's article, maximum entropy spectral estimation has swept the natural and engineering sciences where many applications involve small data sets.[3] I learned about it initially in a conversation with Arnold Zellner.

6.2 Investment Cycles of the Major industrialized Economies

The empirical evidence reported in this subsection is a summary of Table 4.2 in Süssmuth (2003). The countries examined are the G7: Canada, France, Germany, Italy, Japan, UK and USA. Annual deflated figures were obtained from EUROSTAT for the main components of the NIPAs: consumption (CON), total private investment (TPI), gross fixed capital formation (GFCF), inventory investment (II), exports (EXP), imports (IM), and government (GOV). TPI is the sum of GFCF II. A modified Baxter-King filter was used to detrend the series. The sum of detrended components defines detrended GDP.

The order of the fitted AR-process was determined by the Bayesian order statistic of Heintel (1998). The statistic determined orders ranging from 2 to 5. There was not a single series that had no cycle, most had two. The longest cycle estimated was the 9.7 year fixed investment cycle in Canada. The shortest was the 2.8 year inventory cycle in Japan. Both period and modulus of each cycle were computed from the relevant roots of the AR-process. The precision of the estimates, as measured by the standard error, was quite high throughout.

Table 3 reports the median values of the principal parameters. The first line refers to the long, the second to the short cycle. Two cycles, with the typical periods of the fixed investment cycle and the inventory cycle are in evidence in almost all series. The associated moduli near 8, in some cases 9, indicate quite pronounced cycles. The R-squares are low, but it must be remembered that the series fluctuate about zero.

Table 3 about here

The table confirms two theoretical predictions made in later sections: that the long cycle is present in II, but not the short cycle in GFCF and that the GFCF cycle will have a period of twice the length of the II cycle.

A further interesting result presented by Süssmuth pertains to the estimated combined GDPs of the G7 and EURO-15[4] countries. The results are reproduced in Fig. 3.

---

[1] Traditional tests have a tendency to either over- or underestimate the order of an AR process. A better criterion developed and employed at SEMECON is reported in Heintel (1998).

[2] This is demonstrated in Süssmuth (2004).

[3] For example, analyzing the shock waves from an earthquake or from an explosion set during oil exploration.

[4] The Euro zone before the latest accessions.

Figure 3 about here

Both cycles are clearly evident in the aggregate GDPs. The estimates are highly significant and the moduli large. A precise 2:1 relationship is again found between the long and the short cycle.

The evidence for investment cycles as quasi-cycles presented here is clear cut. It is duplicated in the other studies quoted above.

FORMELABSCHNITT 77. DERIVATION OF THE SECOND ORDER ACCELERATOR

The second order accelerator (SOA) is meant to be the behavioral explanation of the observed quasi-cyclical behavior of investment. Three derivations will be discussed here in increasing order of both complexity and economic content. Fixed investment will always be discussed first, followed by inventory investment. In essence, the SOA is a second order differential equation in fixed investment, or in output in the case of the inventory cycle.

The SOA generalizes the first order flexible accelerator that has been a workhorse of applied econometrics where it has been used to model investment in fixed capital. The SEMECON research has used the SOA for modeling both fixed and inventory investment. A substantial literature derives the flexible accelerator from the assumption of adjustment costs.[1] A derivation of the SOA based on adjustment costs is given in Hillinger, Reiter and Weser (1992). The derivations given here are more intuitive and simpler.

First Derivation

The simplest derivation of the SOA is to regard as a transformation from the observed cycles in the frequency domain to a dynamic equation in the time domain that is capable of generating the cycles. Such equations are required both for purposes of modeling and for prediction.

The fixed investment cycle has generally been observed in gross fixed investment. From time to time the statistical agencies also publish data on the stock of fixed capital. Differencing yields net investment and differencing again gives the change in investment. If K_f is the stock of fixed capital, the continuous time analogues are K_f, DK_f, D^2K_f. Relating these in a linear differential equation gives

(7.1) $$D^2K_f = \alpha DK_f + \beta K_f .$$

as the SOA equation for fixed investment.

To model the inventory cycle, let $K_{i,t}$ now be the stock of inventories at the beginning of period *t*. The change in inventories is the difference between output and sales: $K_{i,t+1} - K_{i,t} = Q_t - S_t$. For an individual manufacturing firm *S* would be sales and *Q* production; for a national economy, *S* is final sales and *Q* is total output, i.e. GDP. The equation then states the national accounts identity that inventory investment is the difference between GDP and final sales. In continuous terms, $DK_i = Q - S$.

The crucial difference to fixed investment is that the firm only controls its output, which is the input to its inventory stock; sales, the outflow from the inventory stock is determined by the firm's customers. Accordingly, the SOA equation for inventories is written as a differential equation in *Q*:

(7.2) $$D^2Q = \alpha DQ + \beta Q .$$

[1] For a review see Maccini, Louis J. (1987), Adjustment costs, in Eatwell et al. (1987).

Second Derivation

A derivation of the SOA that has more economic content involves a generalization of the standard flexible accelerator, a work horse of much empirical econometrics. In a continuous formulation it is

(7.3) $$I_f = DK_f = b\left(K_f^* - K_f\right),$$

where I is net investment and K^* the desired capital stock. That a capital shortage or surplus cannot be instantly removed is particularly evident in the continuous case, since investment would have to be infinite. The SOA goes one step further to assume that the dependent variable in (7.3) should be desired investment I_f^* and that actual investment adjusts to it in a further equation. There are many reasons why investment cannot make sudden jumps. Production equipment is usually made to order and takes time to produce, particularly if the supplier is already operating at capacity. In the case of surplus capital, it would be unwise to immediately junk a machine when it is not fully utilized. The SOA model thus is

(7.4) $$I_f^* = b(K_f^* - K_f),$$

(7.5) $$DI_f = c(I_f^* - I_f)$$

Since $I_f = DK_f$, the two equations can be combined to give a second order equation in K_f:

(7.6) $$D^2K_f + cDK_f + cbK_f = cbK_f^*.$$

The roots are

(7.7) $$x_{1,2} = \frac{1}{2}\left[-c \pm i\sqrt{4bc - c^2}\right].$$

The solution is periodic for $c < 4b$ and always damped.

An interesting special case occurs when $b >> c$. Then the homogeneous part of (7.6) can be approximated by

(7.8) $$D^2K_f = a(K_f^* - K_f), \quad a = bc.$$

This is referred to as the single parameter SOA. It implies, in the absence of shocks, a constant amplitude cycle with period

(7.9) $$p = \frac{2\pi}{\sqrt{a}}.$$

This is the simplest formulation that reproduces the key stylized fact that the period of the cycle is inversely proportional to the speed of adjustment.

The SOA for Inventory Investment

The intuitive derivation of the SOA for inventory investment is similar, but a bit more complicated, because now production Q must be considered as an inflow to the inventory stock and final sales S as an outflow. The stock of inventories in this model is K_i. With suitable operationalizations of the variables, the model can be applied to a firm, a sector, or a national economy.

(7.10) $$Q^* = S^* + b(K_i^* - K_i),$$

(7.11) $$DQ = c(Q^* - Q),$$

(7.12) $$DK_i = Q - S.$$

The first equation states that the desired level of output is equal to the medium term expected level of final demand plus a component to adjust actual inventories to the desired level. The second equation stipulates that production is adjusted towards the desired level. The final equation is an identity that gives the actual rate of change of the inventory stock as the difference between production and final sales.

Differentiating (7.12), making various substitutions and taking S, S^* and K_i^* as exogenous, we find the same homogeneous equation in K as in (7.6). The dynamic analysis is therefore exactly the same as in the case of the fixed investment cycle.

Third Derivation

The third derivation of the two SOA equations was given in Hillinger, Reiter and Weser (1992). It is based on the assumption that the firm minimizes a stream of expected discounted quadratic adjustment costs. Given a sufficiently high discount rate, it is shown that an SOA with complex roots is implied both in the case of fixed investment and in the case of inventory investment.

FORMELABSCHNITT (NÄCHSTER)8. EQUIPMENT CYCLE AND INVENTORY CYCLE INTERACTION

The two SOA mechanisms can be combined in a simple macroeconomic model. For this purpose, S_r is residual demand which now excludes I_f and is taken to be exogenous. All variables are again to be considered as deviations from trend so that we have a pure cycle model. The desired stock of fixed capital K_f^* has been set at its equilibrium level of zero. The desired inventory stock is given by $K_i^* = v\left(S_r + I_f\right)$. Inventory investment having a shorter horizon than fixed investment, K_i^* is allowed to fluctuate with current demand. The model incorporating the two SOA equations is

$$\begin{aligned} &DI_f = -b_f c_f K_f - c_f I_f \\ &DK_f = I_f \\ &DQ = b_i c_i \left[v\left(S_r + I_f\right) - K_i \right] - c_i (Q - S_r - I_f) \\ &DK_i = Q - S_r - I_f . \end{aligned} \tag{8.1}$$

In matrix notation this can be written as

$$D\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{B}\mathbf{s}, \tag{8.2}$$

where

$$\begin{aligned} &\mathbf{x} = \left[I_f, K_f, Q, K_i \right]^T \\ &\mathbf{s} = S_r \\ &\mathbf{A} = \begin{bmatrix} -c_f & -b_f c_f & 0 & 0 \\ 1 & 0 & 0 & 0 \\ c_i\left(1 + b_i v\right) & 0 & -c_i & -b_i c_i \\ -1 & 0 & 1 & 0 \end{bmatrix} \\ &\mathbf{B} = \left[0, 0, c_i\left(1 + b_i v\right), -1 \right]^T . \end{aligned} \tag{8.3}$$

The model has a particularly simple structure. The first two equations do not have an input from the rest of the system and produce the pure fixed investment cycle. The remaining two equations generate the inventory cycle. Since I_f is an input to this second subsystem, the fixed investment cycle will also be present in output and inventory investment. This feature was pointed out to me by Klaus Schueler shortly after I had first formulated the model. It is confirmed by the evidence summarized in Table 3 as well as by other data that we have examined. This is what is usually meant by a predictive confirmation in science: The prediction by a model of certain features of the data that had not been noticed previously.

A particularly simple version of the model results if for both SOA equations the single parameter version is used. The system matrix becomes

$$\mathbf{A} = \begin{bmatrix} 0 & -a_f & 0 & 0 \\ 1 & 0 & 0 & 0 \\ a_i v & 0 & 0 & -a_i \\ -1 & 0 & 1 & 0 \end{bmatrix}. \tag{8.4}$$

The eigenvalues in this case are the same as for the two single parameter SOAs.

9. THE SOA AND THE CONCEPTUALIZATION OF DISEQUILIBRIUM DYNAMICS

In physics, there are elementary conceptualizations that underlie the understanding of dynamic phenomena. The basic concept is *inertia*, the property of a moving object to continue unchanged motion unless acted upon by an external force. For periodic motions, as of a pendulum, the key concepts are *kinetic energy*, due to the bodies' inertia, and *potential energy*, a form of stored energy capable of exerting a subsequent force. The SOA allows an interpretation of investment cycles in precisely these terms.

In my theory of investment dynamics, the investment flow is the analog of kinetic energy and the capital stock provides the potential energy. Firms plan their investment over a long horizon. This involves such activities as developing new products, entering new markets, or building new production facilities. Once embarked upon, such activities are difficult and costly to change. Firms invest because they wish to increase their capital stock. The inertia of investment typically leads to an overshooting of the target. Excess capacity develops and exerts a downward pressure on investment.

Schematically the situation is depicted by a phase diagram in Fig. 4a. The capital stock is on the horizontal, net investment of the vertical axis, both in deviations from equilibrium. In quadrant I, there is excess capital, so investment, while positive, is slowing down and becomes zero where excess capital is at a maximum. Analogous to potential energy, the excess capital stock continues to decelerate investment into the negative range in quadrant II. When the equilibrium capital stock is reached, disinvestment continues in quadrant III so that a capital shortage develops. The point at which disinvestment ceases corresponds to the maximum capital shortage. Investment is positive in quadrant IV and the capital shortage is gradually eliminated. Investment is now maximal and the economy passes again into quadrant I in which excess capacity is built up. The phase diagram was drawn for a constant amplitude cycle, but an explosive or damped cycle is equally possible.

Figure 4ab about here

Fig. 4b plots an empirical phase diagram based on German fixed capital and net investment, 1970-1989, in deviations from trend. With some very minor exceptions near the bottom of the second cycle, the movement is exactly as predicted by the theoretical phase diagram. The first cycle is damped, the second of constant amplitude.

The ME spectrum of German fixed investment is shown in Fig. 4c. There is a sharp peak at 8.33 years. A measure of the importance of the peak is the peak power. It gives the fraction of the total power (area) of the spectrum in a range of plus, minus 10% of the peak frequency. The peak power in this case is almost 70%. A second cycle at 4.2 years has vanishing power and cannot be identified visually.

Figure 4cd about here

To take the analysis one step further, a second order differential equation was fitted to the data. The result was

(8.5) $$D^2K_f = -0.221DK_f - 0.526K_f.$$

The spectrum of this equation is given in Fig. 4d. The period at 8.7 years is close to that of the ME spectrum. The peak power at 0.3 is lower, indicative of more damping as is also evidenced by the broader peak.

My conclusion from the analysis of this section is that that the analyzed data set has a cyclical pattern and that is clearly revealed by the visual methods employed in the physical sciences.

An analysis of the inventory cycle can be given along similar lines, but it is more complex because inventory investment is equal to production minus sales and is therefore not under the complete control of the firm.

In Hillinger and Konrad (1993), similar ideas were applied to the analysis of foreign exchange disequilibria. The 'potential energy' in this case is a country's stock of net foreign assets and the 'kinetic energy' is the current account balance of trade in goods and services. Here the main complication is the so called 'J-curve' phenomenon according to which an exchange rate movement in response to a trade imbalance will actually worsen the imbalance before it can improve. A calibration of the model yielded a 10 year cycle, in rough agreement with the plots shown in Fig. 5. Currently, the huge and persistent US deficit is again at the center of the international economic agenda. I believe that our model provides a better basis for analyzing this phenomenon than neoclassical models of instantaneous adjustment of foreign trade and capital markets.

Figure 5 about here

10. STRUCTURAL ECONOMETRIC MODELING OF INVESTMENT CYCLES

As briefly stated in the introduction, the methodology underlying the research reported in this paper was inspired b that of the natural sciences, particularly concerning the separation of description and explanation with respect to observed empirical regularities. The borrowing from the natural sciences went beyond this general principle to the use of specific mathematical/statistical tools that are used especially in physics and engineering when dealing with dynamical systems. One descriptive tool that has already been described is maximum entropy spectral analysis. At the descriptive level it can be used to summarize salient features of the observations. A proposed model can serve as an explanation of the observed regularities if the model output has the same characteristic spectrum as the observations.

In this context it is illuminating to discuss the different meanings of the terms 'prediction', and 'confirmation', in natural science and in econometrics. In econometrics, 'prediction' refers to observations on a time series that are predicted by a model. In natural science 'prediction' refers to a *pattern* that is generated by a model and is confirmed if found in the data. A proposed explanatory model is refuted if the patterns that it predicts are not found in the data. In contrast to this, econometrics uses a statistical concept of confirmation based on significance tests.[1]

Explanatory dynamic models in the natural sciences take the form of differential equations, i.e. they are formulated in continuous time. In the econometric mainstream models are formulated as discrete difference equations. This assumption of discreteness was apparently adopted without much reflection as a seemingly obvious reflection of the discreteness of the observations. Discreteness is equally a property of observations in the natural sciences and there are weighty reasons why econometric models should be formulated

[1] A critical view of the statistics based econometric methodology is offered by Keuzenkamp (2000).

in continuous time. These have been elaborated in a substantial literature on *continuous time econometrics*. Since the SEMECON econometric models of investment cycles are I this tradition, it is discussed in the next subsection.

10.1 Continuous Time Econometrics

The history of continuous time econometrics and its relationship to mainstream econometrics is a strange one. Elementary common sense suggests that economic dynamics, both theoretical and empirical, should be formulated in terms of differential equations. A discrete model implicitly assumes that firms make all decisions at the end of a period, say a quarter, for the following period. In between, the decision making staff presumably goes fishing or falls into a Rip Van Winkle like stupor. In reality decisions, big or small, are made on a daily, some even on an hourly basis. Moreover even if all firms made their decisions at fixed intervals, these would not be the same for different firms. For consumers the situation is not different; each day some loose their jobs, others find one; some are born, other die and many other events affect consumer behavior, individually or collectively. The overall result is surely that if we could observe economic time series at very close intervals we would see a continuous movement.[1]

The objection that, since economic observations are discrete, it makes sense to model them in discrete time has been refuted in a vast literature reviewed in Bergstrom (1996). Here I will only touch on what I regard as the most central issue. Suppose the true model of the economy is a vector/matrix differential equation $Dx = Ax$ and that instead a difference equation system $x_t = Bx_t$ is estimated. The difference equations are a solution of the differential equations involving the exponential matrix $B = \exp A$. There is no simple relationship between the elements of *A* and of *B*, so that theoretical restrictions applied to *A*, such as zero restrictions, or identities, do not apply to *B*. In large scale econometric models, zero restrictions are enforced on almost all of the elements of *B*, resulting in a massive misspecification. This is one of the reasons for the failure of these models.

During the period of large scale, structural macro-econometric modeling, mainstream econometric theory was occupied in dealing with the consequences of the decision to model in discrete time. The typical model was of the form $x_t = Bx_t + Cx_{t-1}$, and further terms involving exogenous and random variables. The dependent variable of one equation thus appeared as an explanatory variable in another. Simultaneity was viewed as the principal problem and such solution concepts as two-or three stage least squares, partial- or full information maximum likelihood were offered as solutions. Already Strotz (1960) had pointed out that simultaneity is the consequence of the specification error involved in discrete modeling. In the natural sciences, where dynamic phenomena are modeled as differential equations, simultaneity was never an issue.
of mainstream econometrics.

Post 1950s mainstream econometrics evolved from traditional, discrete statistical theory and this mold proved to be impervious to the arguments referred to above. After the rise of neoclassical macroeconomics, an additional barrier between mainstream econometrics and continuous time econometrics arose from the fact that, in empirical applications, the latter employed a disequilibrium framework[2], incompatible with rational expectations and real business cycle macroeconomics.

The SEMECON research described in the present paper may be regarded as a confluence of the two streams of traditional investment cycle theory and continuous time econometrics.

---

[1] In financial markets very high frequency data have actually become available and are being modeled in continuous time.

[2] A thorough discussion of disequilibrium continuous time econometrics is Wymer (1996).

A significant contribution to continuous time econometric theory was made at SEMECON by Michael Reiter and is the basis for the empirical results of the next subsection. Estimation in continuous time econometrics had been highly computationally intensive and consequently restricted to mainframe computers. Reiter's contribution was based on the continuous time Kalman filter developed in Harvey and Stock (1985). This led to two substantial advantages. A pragmatic advantage was a dramatic reduction in computation, allowing the estimation to be done on a desktop computer. A more fundamental gain was the possibility opened by the Kalman filter to differentiate between errors in the equations and errors in the variable. As expected, inventory investment showed large errors in the variable. The two types of error have entirely different implications for dynamics.[1]

10.2 Structural Econometric Modeling of Investment Cycles

The following examples, taken from Hillinger and Reiter (1992) aimed at testing the simplest possible models of the equipment cycle, the inventory cycle and their interaction. The criterion of simplicity has been at the heart of the progress of the natural sciences. It is diametrically opposed to the idea on which the large scale macroeconomic models were based, that including ever more detail increases 'realism' and hence model performance. Moreover, that fact that a very simple model, in which the stock of fixed capital is the driving force, can explain the dynamics of fixed investment justifies the designation 'fixed investment cycle. Similarly, the term 'inventory cycle' is justified by the simple model with the inventory stock as driving variable. The simple model of their interaction is capable of generating the stylized facts mentioned earlier.

For each model two alternative specifications were considered. If the two parameter SOA model implied a modulus near unity, the single parameter version was tried and if satisfactory adopted.

Fixed Investment Cycle in Germany

Results for the two-parameter SOA will be presented. Important parameters are:

$$R^2 = 0.81, \quad Period = 8.1, \quad Damping = -0.08.$$

For a variable expressed in deviations from trend, the R^2 is very high The period is close to what is found in ME spectra computed from the data. The damping is quite low and implies that, in the absence of inputs, the cycle would loose half of its amplitude in about 9 years.

The excellent properties of the model are graphically confirmed in Fig. 6. The within period year ahead forecasts almost always point in the right direction. Beyond the vertical line, is a six year ahead forecast based on the observed state in 1981. The lower turning point is predicted, though a year later than in the data. The predicted path is much more regular than the observed path, suggesting some disturbing factors in German fixed investment around this time.

Figure 6 about here

Inventory Cycle in the UK

Modeling the inventory cycle is considerably more difficult than modeling the fixed investment cycle. It is a heterogeneous aggregate containing raw materials, intermediate- and finished goods. Also, inventories at retailers, wholesalers, manufacturers and extractors. Inventory investment is the most volatile and irregular component of GDP. As explained earlier, it is also the least accurately measured component. In evaluating a model of the

[1] This work is described in Reiter (1995, Chs. 12, 13).

inventory cycle, these difficulties should be kept in mind. Key estimates for the two parameter model for the UK are:

$$R^2 = 0.57, \quad Period = 3.45, \quad Damping = -1.33.$$

For such a volatile series, the R^2 is satisfactory. The period is in the typical range for the inventory cycle. The high damping rate is unsatisfactory.

The visual analysis presented in Fig. 7 suggests that the basic dynamics of the inventory cycle has been captured. The out of period forecast identifies the lower turning point, but with a year's delay. Again with a year's delay, even the slight dip of 1984-85 is forecast. Inspection suggests that in the second half of the observation period the longer fixed investment cycle is prominent in the data also. This suggests that a model of the interaction of both cycles would have been appropriate.

Figure 7 about here

Reiter (1995, Section 5.5) found that the estimates for the inventory cycle could be significantly improved by including an error in the variables term.

Cyclical Interaction in the US Economy

For the US economy the results are from the model of cyclical interaction with the single parameter SOA, corresponding to equation (7.8). The main parameters are

$$R_f^2 = 0.69, \quad R_i^2 = 0.49, \quad P_f = 6.53, \quad P_i = 2.38.$$

Apart from the fact that the period of the inventory cycle is somewhat too short, the values are all satisfactory.

Figure 8 about here

The visual analysis is presented in Figures 8 and 9. The modeling of the fixed investment cycle in Fig. 8 is highly satisfactory. The out of sample forecast accurately predicts not only the lower turning point, but also the following upper turning point which is forecast five years ahead of its occurrence. The modeling of the inventory cycle in Fig. 9 is also satisfactory, particularly given the irregular nature of the series. The out of period forecast accurately predicts the next three turning points of the cycle.

Figure 9 about here

EQUATION SECTION 1111. THE MICROECONOMICS OF CYCLICAL FLUCTUATIONS

11.1 The Problem of Cyclical Aggregation

I had long been aware of a fundamental problem that affects neoclassical macroeconomics but also my own work on investment cycles. I am not the first to notice the problem; there are in fact substantial, but generally ignored, literatures on it. What I have in mind is the difficulty of justifying representative agent models. Two types of representative agent models have been studied. One involves the standard static model of a utility maximizing consumer who, in the form of a representative agent is assumed to have given rise to aggregate consumption demand. This literature was reviewed by Kirman (1992). He concluded that there is no reasonable justification for the representative consumer model, nor any valid deduction that can be made from it. The other type of representative agent is a cost minimizing firm with a given production function. Franklin Fisher has been the principal critic of this assumption and he reviewed the argument in Fisher (2003). A more extensive treatment is Felipe and Fisher (2003). Here again the conclusion is that no reasonable assumptions to justify the use of an aggregate production function exist.[1] The representative agent of neoclassical macroeconomics is a Robinson Crusoe who optimizes his intertemporal consumption/leisure tradeoff. Even if such agents existed at the micro level, which is not the case, they could not be aggregated to a representative agent. A major claim of neoclassical macroeconomics has been that macro relationships were being put on a microeconomic foundation. Such a claim can only be meaningful if by it is meant that the macro relationships are being deduced from the behavior individual agent at the micro level. This the neoclassical school has not even attempted.

The point of these preliminary remarks is that I realized that a similar criticism could be levied against the SOA assumption to explain aggregate investment cycles. In the following I will first explain the problem and then describe the solution.

11.2 Parametric Resonance and the Aggregation of Cycles

The SOA equations can be plausibly justified as explanations of the investment and production behavior of individual firms. It will be shown below that they have a good fit to highly disaggregated data. However, even if many firms have SOA's with similar periods, these would not add to visible cycles at the aggregate level. Even small differences in period lengths imply constantly changing phase differences between the cycles of individual firms. Firm specific shocks would also lead to a random distribution of the phases of cycles at the firm level. The result at the aggregate level would be essentially random.

I had been long aware of the problem and also had thought that the answer must come from physics in the form of a *resonance* model. Resonance phenomena in physics are well known. For example, if a number of tuning forks with similar, but not identical, inherent frequencies are placed close to each other, they tend to agree on a common frequency and phase. The opportunity to explore this conjecture presented itself in 1993 when a young man named Thilo Weser presented himself at my office. He had just obtained his Ph.D. in physics and wanted to obtain one in economics as well. For his dissertation in economics he took on the problem just described. It turned out that there are many resonance models in physics. One of these appeared promising, the model of *parametric resonance*. Before going into some detail regarding the mathematics of this model, I first state why the resonance problem does not have a simple solution. Then I state the predictions of the parametric resonance model and examine some of the more readily available evidence regarding these predictions. Finally, I report on an econometric study of cyclical aggregation by means of parametric resonance.

The simplest way of joining two dynamic systems is linearly, with the output of one becoming the input of the other. This however merely leads to a superposition of cycles, with each retaining its original period. The resonance phenomenon requires a nonlinear interaction. In the parametric resonance model, the nonlinearity takes the form of the output of one oscillator directly impacting the parameters of the other.

If several oscillators are connected as specified by the parametric resonance model, the following predictions can be deduced:

First Prediction:

Oscillators whose initial periods and phases are sufficiently close to each other will resonate, in the sense that they will 'agree' on a common average period and a common average phase. Resonance also leads to an increase in the amplitudes of the individual oscillations, possibly converting stable to unstable oscillations.

[1] Fisher assumes that dada on real capital and labour inputs are available at the level of the individual firm. I would challenge even that assumption.

Second Prediction:

Resonance involving a phase reversal is also possible. In this case two cycles agree on an average period, with the peak of one corresponding to the trough of the other.

Third Prediction:

Resonance is also possible among oscillators whose frequencies are integer multiples of each other. The larger the multiple separating the two cycles, the weaker is the effect. The only case that we have considered is the 2:1 relationship between fixed investment and inventory cycles that has already been mentioned.

11.2 Macro Evidence

Regarding the third prediction, I have already mentioned that the fixed investment cycle and the inventory cycle have an approximate 2:1 relationship in the G-7 countries. Hillinger and Sebold-Bender (1992) investigated the two types of cycle for 15 OECD countries. They found median values of 6.3 years for the fixed investment and of 3.0 years for the inventory cycle. again, this is very close to the 2:1 ratio.

The second prediction has not played any role in our research. However, Matthews (1959), discusses at some length that the building cycle in the UK and the US had the opposite phase. When the UK was depressed, the flows of both capital and immigration from the UK to the US peaked, contributing to the boom there. An aspect of this is illustrated in Fig. 11 which shows UK fixed capital formation against the balance of payments current account, a measure of capital export. Both series exhibit a period of about 20 years, characteristic of the building cycle, with an inverted relationship of the phases.

Figure 10 about here

11.3 An Econometric Study of the Aggregation of Cycles

In a first study of the aggregation of cycles vie parametric resonance Weser (1988) employed simulations in order to demonstrate the first and third predictions of the model in the context of the fixed investment and inventory cycles. The analysis was carried forward by Süssmuth (2003) who studied aggregation empirically, both with disaggregated US data, as well as with data on the international aggregation of cycles. The following discussion is based on his work. In particular, I will describe the aggregation of the fixed investment cycle within the US economy and leave out the part that deals with the international aggregation of the inventory/output cycle.

The foundation of the analysis is the SOA of fixed investment modified to incorporate the parametric resonance effect as defined in Weser (1992). The basic idea is that the investment behavior of the individual firm is affected by the level of aggregate investment. The individual firm tends to invest more when the investment of other firms is high and it will invest less if the investment of other firms is low. This is an instance of what in the modern literature is referred to as "herding". There are several explanations that are not mutually exclusive. One is simply mass psychology; Keynes' "animal spirits". Another reason is managers'. If a manager's decision to invest misfires, he is in a better position if he can say that most managers had acted similarly. Finally, firms are very concerned about market share. A firm may fear to lose market share if it invests less aggressively than others.

To motivate the resonance equation, I first give another derivation of the SOA for fixed investment of the individual firm:

$$DI = b\left(I^* - I\right), \qquad (11.1)$$

$$I^* = a\left(K^* - K\right).$$

Combining these gives

$$DI = b\left[a\left(K^{*} - K\right) - I\right] \\ = ba\left(K^{*} - K\right) - bI. \tag{11.2}$$

In the case of resonance, the fixed investment of firm h is given by

$$DI_h = a_h \left\{1 + \chi_h \Psi\left[\left(\left(K_h^{*} - K_h\right)\sum_j I_j\right)\right]\right\}\left(K_h^{*} - K_h\right) - b_h I_h + \varepsilon_h, \quad \chi_h > 0. \tag{11.3}$$

The term added to model the resonance is

$$\chi_h \Psi\left[\left(\left(K_h^{*} - K_h\right)\sum_j I_j\right)\right], \tag{11.4}$$

Where χ_h gives the strength of the resonance effect and Ψ is defined as

$$\Psi(x) = \begin{cases} +1 & for \quad x > 0 \\ 0 & for \quad x = 0. \\ -1 & for \quad x < 0 \end{cases} \tag{11.5}$$

The variable causing the resonance phenomenon in equation (11.3) is aggregate investment $\sum_j I_j$. The function Ψ is defined in such a way that, for example, if the firm desires to invest on the basis of its own situation $\left(K_h^{*} > K_h\right)$, then positive (in deviation from trend) aggregate investment would stimulate it to speed this investment up while negative aggregate investment would induce a slowdown. Conversely, the firm would disinvest more slowly if aggregate investment is positive, more rapidly if aggregate investment is negative. The strength of the effect is determined by the resonance parameter χ_h and ε_h is a firm specific shock.

The empirical study used annual data from 1958-1962 on real capital spending for 450 SIC 4-digit industries.[1] The objective was to explain the cyclical properties of the aggregate, i.e., of manufacturing fixed investment (MFI), which is a component of total private investment (TPI), which in turn is a component of GDP. The business cycle components of these series, normalized by dividing each series by its standard deviation, are shown in Fig. 12. The movements are closely matched, indicating that an explanation of the cyclical movements of MFI is also an explanation of the dominant cycle in GDP. The spectra of the three series (not shown here) also match closely.

Figure 11 about here

A first step in the analysis of the disaggregated date was to fit an AR(2) process of 2.5-7.6 years and a mean of 4 years. The moduli were in the range 0.23-0.96 with a mean of 0.6. The remaining 20 series, mainly in the textile and food industries, were excluded from subsequent computations. Their contribution to the aggregate variance is negligible. The fact that around 95% of manufacturing industries exhibit an endogenous cyclical dynamics in line with CBC theory strongly contradicts the position of the neoclassical mainstream.

To simplify the computations, 135 series were selected that together explained 82% of the aggregate variance. Using the spectral measure of squared coherency (sc), 110 of the 135 were selected as highly coherent with the aggregate and therefore as being logical candidates for a coherent group exhibiting the resonance phenomenon.

[1] Taken from the NBER-CES/Census US Manufacturing Productivity Database.

In order to be able to calibrate the resonance parameter χ_h, a common value $\bar{\chi}$ was postulated as a first step and a search over this parameter conducted to obtain the best aggregate properties. As a second step, the following linear relationship was postulated:

(11.6) $$\chi_h - \bar{\chi} = \gamma\left(sc_h - \overline{sc}\right).$$

A stronger coherency with the aggregate is assumed to follow from a stronger resonance as implied by a larger value of the resonance parameter. This formulation allows the remaining calibration of the resonance parameters to be reduced to the determination of the proportionality factor γ.

The random shocks for the simulations were drawn from a normal distribution with the variance covariance matrix taken from the AR estimates and multiplied by a scale factor ϑ. For a given MC simulation the pair (γ, ϑ) was fixed. The sectoral SOA equations were then simulated, with the aggregate computed at each step and used in computing the next step. Mean values of relevant aggregate parameters were computed from 1000 iterations for each MC simulation.

Figure 12 reports on a single simulation run with optimized parameter values. The simulated aggregate, obtained from the addition of the simulated sectoral SOA equations tracks the empirical aggregate closely. The spectrum of the simulated series has at 5.63 years a somewhat longer period than the empirical data. The damping coefficients are quite close and the variances of the two series are almost identical.

Figure 12 about here

The conclusion must be that the parametric resonance model used in conjunction with the SOA equations is able to demonstrate CBC stylized facts at both the sectoral and aggregate levels and is able to explain how one gets from the lower to the higher level.

SUMMING UP: SUBSTANCE AND METHOD AND POLICY

I have presented key results of a long term project to describe and explain investment cycles. The underlying motivation was to apply to this problem the scientific method as practiced in the natural sciences. Comments received on earlier versions of the paper have confirmed that the natural science view of the scientific method is alien to most economists. This, in turn, led to various misinterpretations of my results. For the sake of greater clarity, I give in the following a succinct description of the methodological precepts that guided the research, and of the implications for economic policy. This is followed by answers to some of the questions concerning the paper that have been raised.

The Methodology of the Natural Sciences

The essence of the scientific method in the progressive empirical sciences has been first, the discovery and precise description of significant patterns, called empirical regularities, and secondly, their explanation. The scientific method is hierarchical, progressing from the empirical regularities to low order laws that explain some empirical regularities to more general laws that explain those of a lower order. The culmination of this process in physics is the current search for a unified theory to encompass both relativity and quantum theories.

In economics, contributions tend to be judged in terms of their immediate usefulness to such tasks as forecasting, or improving economic policy. Such practical considerations have played a subsidiary role in the advance of science. Discoveries such as Pasteur's, that milk can be sterilized by heating; have had important practical consequences, but hardly any for the general advance of science. Conversely, if physicists do discover the unified theory, it is hardly conceivable that this will have any practical consequence. A comparison of the histories of economics and natural science suggests that ultimately the quest for pure knowledge yields greater practical benefits than attempts at reaping these benefits directly. Rather than immediate usefulness, a central evaluative criterion used in natural science is *simplicity*.

The Copernican revolution illustrates the points just made.[1] Copernicus postulated three movements of the earth: a daily spin on its axis, an annual orbit around the sun, and a slow gyration of the axis of the earth's axis of spin to account for the precession of the equinoxes. In the Ptolemaic system these movements were projected onto the sun and the planets in order to make the earth appear to be stationary. For the modified Ptolemaic system of Copernicus' time, this involved about 80 circular motions. Copernicus' assumptions reduced the required number of circular motions to 48. Important for the present discussion is that while Copernicus' system simplified astronomical calculations, it yielded no gain in predictive accuracy. The next great simplification was due to Kepler who abandoned the assumption of uniform circular motion, replacing it by his three laws of planetary motion. Kepler required only seven elliptical planetary orbits and they fit the data more accurately than either the Ptolemaic or Copernican systems. The final great simplifier of classical physics and astronomy was Newton. His inverse square law of gravitation explained now only Kepler's laws of motion, but also Galileo's law of falling bodies.

Science and Policy

Modern societies have been shaped by applied science and engineering, that are in turn based on advances in the pure sciences such as physics or biology. It is often forgotten that many practical problems in the past and in the present have been solved by common sense and knowledge derived from practical experience, without the aid of any formal science. Egyptian pyramids and Roman roads and aqueducts are obvious examples. Equally, Pasteur's method of sterilizing milk by heating it was of great importance for public health, but did not involve any basic science.

Modern states have created institutions charged with harnessing science to serve national or transnational goals. Public health agencies at different levels can serve as an example. Such agencies employ professional staffs with academic degrees in recognized scientific disciplines that are relevant to the tasks for which the agency was created. With respect to the institutions created for the purpose of macroeconomic policy making, the situation is quite different. The basic consensus that exists in natural science is here missing. Even where there is some unity of theory, as in the neoclassical macroeconomic mainstream, there is a great divide between the theory and institutional practice. The neoclassical mainstream largely denies the need for, or even the possibility of, countercyclical policies; the institutions, particularly central banks feel compelled to engage in such policies in order to justify their existence.

What is the implication of the existence of investment cycles in this context? The most direct implication is a strengthening of the Friedman-neoclassical position against an active anticyclical policy, even though the argument leading there is quite different. Monetary and fiscal policies may well be effective; the problem is that given the endogenous dynamics, there is no simple way of calculating what the actual effect will be. For example, an attempt at inflating a currently sluggish economy may only contribute to the excess of an investment boom that was already in the making.

If in the future the theory of investment cycles follows the course of normal science, in the sense of being tested, confirmed and elaborated by other scholars, the possibility would arise of computing optimal stabilization policies in relation to econometric models of investment cycles. Such a goal is still some distance away.

[1] An excellent discussion of the Copernican revolution and its motivation by the criterion of simplicity is given in Mason (1962, Ch. 12). The role of simplicity generally in science is discussed by Frank (1957, 351-353).

Business Cycle Stylized Facts and Explanations: Some Questions and Answers

In this subsection I discuss some of the objections and questions that have been raised in relation to the substantive findings, underlying methodology and implications of the paper. I summarize and reply to those comments that seem to me to be of general significance.

Comment: The paper implies that the non-investment components of GDP are of minor importance in explaining cyclical fluctuations of output.

Reply: I would describe the role of the non-investment components in fluctuations as *passive* rather than minor. All components of GDP are obviously connected and the non-investment components, constituting about 80 percent of the total, can contribute a substantial amount of the total fluctuations. According to Table 1, fixed investment, which averages about 20 percent of GDP, accounts for above 40 percent of the declines in recessions. More dramatically, inventory investment, averaging only 1-2 percent of GDP, accounts for about 75 percent of the declines. Even when regarded as no more than rough orders of magnitude, these figures speak for themselves. Additional descriptive evidence is the fact that the fixed investment cycle and the inventory cycle appear much more clearly in the series after which they are named than in other series. The final evidence comes from the explanatory structural models. These are based on the idea of the *inertia* of investment and consequent overshooting, leading to cycles. These simple models were shown to reproduce the stylized facts.

Comment: A major weakness of this paper is that it does not compare the proposed investment model with other, established investment models, such as the flexible accelerator model, Tobin's 'q' model, financial accelerator models, etc. The lack of comparison makes it hard to say whether your proposed scheme involves any real improvement of the other, already existing schemes.

Answer: My sole purpose has been to formalize and explain the stylized facts of investment cycles as they are described in detail in this paper. Generations of economists have done the same, before the neoclassical ideology came to dominate macroeconomics. I have attempted to revive the older tradition, in a more systematic and formal manner. The literatures mentioned in the comment take no notice of investment cycles and thus evidently do not try to explain them.

Comment: If cycles are damped, what underlying factors give rise to the cyclical fluctuations? Clearly a damped investment cycle cannot give rise to itself, but must get started and then kept alive by systematic (cyclical) disturbances elsewhere? What are these disturbances?

Answer: The answer is contained in Ragnar Frisch's classic 1933 article: Propagation problems and impulse problems in dynamic economics. He gives the example of a pendulum whose endogenous behavior is described by a damped periodic differential equation. Subject to random shocks, the pendulum will exhibit an erratic, but still periodic motion; a quasi-cycle in the terminology of the present paper. Similarly, as long as the endogenous adjustment mechanisms of fixed and inventory investment exhibit complex roots, disturbances of any kind can produce the observed quasi-cyclical behavior.

Comment: What is the scope of this theory? Does the paper propose an alternative paradigm in economics, or merely an alternative specification of the investment module of a general macroeconomic model?

Answer: The proposed alternative paradigm for economics is not the specific theory of investment cycles, but rather the general scientific method as employed in the natural sciences. The theory of investment cycles is designed to explain some specific observed patterns of fixed and inventory investment, nothing more and nothing less. The idea that one must necessarily construct general macroeconomic models including all the sectors regarded as having some relevance is pure ideology and has in fact been largely abandoned in practice.

Comment: The paper appears to be based on the notion that the financial side of the economy is of little or no importance, and can therefore be safely omitted from the models. This reminds of the allegedly Keynesian position that “money doesn’t matter”.
Answer: The paper tries to give the simplest possible descriptions and explanations of certain observed investment patterns; it does not aim for the best possible fit. Deviations from the ideal patterns are caused by the fact that the theory is not perfect and that shocks disturb the ideal pattern. Undoubtedly, such shocks sometimes originate in the financial sectors. My aim has been to model the patterns, not the deviations from it. The idea that “money doesn’t matter” generally is absurd. The validity of the quantity theory of money in the long run is well established.[1] It is another example of the specific explanation of a specific observable pattern.

Comment: The paper seems to presume that price and wage inflexibility can be taken for granted and that there is no real need for a theoretical explanation of these phenomena.
Answer: That short run adjustments occur in quantities, not prices, is a basic assumption of the theory of investment cycles and marks a great divide to the neoclassical paradigm. Like all assumptions it is intended to mirror a stylized fact, not an absolute truth. Explaining price stickiness has been a major concern of Neo-Keynesians. These efforts have not, as far as I know, led to any interesting novel predictions.

12. CONCLUSIONS

The paper demonstrates the continued existence and relevance of investment cycles in aggregate data for the industrialized economies. Specifically, these take the form of an inventory cycle of about four years duration and a fixed investment cycle lasting eight years on average. The cycles are explained by models that focus on the inertia of investment and consequent overshooting. The mathematical theory of parametric resonance is employed in order show how cycles at the firm level come to resonate, in the sense that they converge on an average period and phase so that they become visible in aggregate data. The aggregation process is modeled econometrically in relation to disaggregated US data.

An implication of the empirical findings is that the cycles are generated by an endogenous dynamics. Essential insights regarding these dynamic processes are found in the traditional literature. They have been formalized and tested econometrically in the course of the SEMECON research reported here. Strong predictions made by the theory could be confirmed.

The theory of investment cycles contradicts virtually all aspects of the currently dominant school of neoclassical macroeconomics, particularly the assumptions of instantaneously reached equilibrium, of price rather than quantity adjustment and of movements that are dominated by exogenous chocks.

I have argued that the victories first of monetarism and then of neoclassical macroeconomics were not based on evidence but on a variety of ‘ideologies’ both political and with regard to methodology.

The advance of macroeconomics, in my view, requires a major shift, away from abstract theorizing towards the investigation of empirical regularities as the foundation on which relevant theories can be built. Also required in this connection is a shift away from the

[1] Comprehensive evidence on the validity of the quantity theory is found in Capie (1991) and in Fisher, Sahay and Végh (2002).

emphasis on novelty towards replication. In a meaningful empirical science, novelty becomes accepted only after replication by other scientists. Novelty without replication leads to trivia instead of scientific advance.

REFERENCES

Barnett, William A., Gandolfo, Giancarlo and Hillinger, Claude (eds.), (1996), *Dynamic Disequilibrium Modeling*, New York, Cambridge University Press.

Blinder, Alan S. and Holtz-Eakin, Douglas (1986), Inventory fluctuations in the United States since 1929. In Gordon (1986).

Burg, John P. (1968), A new analysis technique for time series data. Presented at the *NATO Advanced Study Institute on Signal Processing with Emphasis on Underwater Acoustics.* Reprinted in Childers (1978).

Cagan, Phillip (1965), Current issues in the theory of monetary policy. In: Brennan, M. J. ed. *Patterns of Market Behavior: Essays in Honor of Philip Taft*, Providence, Brown University Press. Reprinted in Entine (1968).

Childers, Donald G. (ed.), (1978), *Modern Spectrum Analysis*, New York, John Wiley.

Capie, Forrest H. (ed.), (1991), *Major Inflations in History*, Aldershot, Edward Elgar.

Eatwell, John, Milgate, Murray, Newman, Peter (eds.), (1987), *The New Palgrave: A Dictionary of Economics*, London, Macmillan.

Entine, Alan D. (ed), (1968), *Monetary Economics: Readings*, Belmont, Wadsworth.

Fischer, Stanley, Sahay, Ratna and Végh, Carlos A. (2002), Modern hyper- and high inflations, *Journal of Economic Literature,* XL, 837-880.

Fisher, Franklin M. (2003), Comments: Cambridge Capital Controversies, *Journal of Economic Perspectives*, 17, 4, 228-229.

Felipe, Jesus and Fisher, Franklin M. (2003), Aggregation in production functions: What applied economists should know, *Metroeconomica,* 54, 2, 208-62.

Frank, Philipp (1957), *Philosophy of Science*, Englewood-Cliffs, Prentice-Hall.

Friedman, Milton (1953), *Essays in Positive Economics*, University of Chicago Press.

(ed.), (1956), *The Quantity Theory of Money*, The University of Chicago Press.

(1960), *A Program for Monetary Stability*, New York: Fordham University Press.

(1961), The lag in effect of monetary policy, *Journal of Political Economy*, 69, 5. Reprinted in Friedman (1969).

(1963), Money and Business Cycles, *Review of Economics and Statistics*, 45, 1, part 2, supplement. Reprinted in Friedman (1969).

(1968), The role of monetary policy, *American Economic Review,* 58, 1, 1-17.

(1969), *The Optimum Quantity of Money and Other Essays*, Chicago, Aldine.

Friedman, Milton and Schwartz, Anna J. (1963), *A Monetary History of the United States, 1867- 1960*, Princeton University Press

(1982), *Monetary Trends in the United States and the United Kingdom*, University of Chicago Press.

Frisch, Ragnar (1933), Propagation problems and impulse problems in dynamic economics, *Essays in Honor of Gustav Cassel*, London, George Allen and Unwin. Reprinted in: Gordon and Klein (1965).

Gordon, Robert A., and Klein, Lawrence R. (1965), *Readings in Business Cycles*, Homewood, Richard D. Irwin.

Gordon, Robert J. (ed.) (1986), *The American Business Cycle: Continuity and Change*, University of Chicago Press.

Gordon, Robert J. and Veitch, John M. (1986), Fixed investment in the American business cycle. In: Gordon (1986).

Granger, C. W, J. and Newbold, Paul (1977), *Forecasting Economic Time Series*, Academic Press, New York

Haberler, Gottfried (1958), *Prosperity and Depression*, Harvard University Press. Originally published 1937 by the League of Nations.

Harvey, Andrew and Stock, James H. (1985), The estimation of higher-order continuous time autoregressive models, *Econometric Theory*, 1, 97-117.

Heintel, M. (1998), A note on a Bayesian order determination procedure for vector autoregressive processes, *Statistical Papers*, 39, 213-221.

Hillinger, Claude (1963), *A Theory of the Inventory Cycle*, Dissertation, University of Chicago.

(1966), An econometric model of mild business cycles, *The Manchester School of Economic and Social Studies*, 34, 269-284.

(ed.) (1992a), *Cyclical Growth in Market and Planned Economies*, Oxford University Press

(1992b), Paradigm change and scientific method in the study of economic fluctuations. In Hillinger (1992a).

(1996), Dynamic disequilibrium economics: history, conceptual foundations, possible futures. Ch. 2 in Barnett et al. (1996).

(2001), Money metric, consumer surplus and welfare measurement, *German Economic Review,* 2, 2, 177-193.

(2002), Consistent aggregation and chaining of price and quantity measures. *Journal of Economic and Social Measurement*, 28, 1-20.

(2003a), The money metric, price and quantity aggregation and welfare measurement, *Contributions to Macroeconomics*, 3, 1, article 7, 1-34.

(2003b), Output, income and welfare of nations: Concepts and measurement, *Journal of Economic and Social Measurement,* 28, 4, 219-237.

Hillinger, Claude. and Konrad, Anton. (1993), The Disequilibrium Dynamics of the Balance of Payments, and the Dollar Cycle, *Journal of International and Comparative Economics, 2, 279-299.*

Hillinger, Claude, Reiter, Michael and Weser Thilo (1992), Micro foundations of the second order accelerator and of cyclical behavior. Ch.8 in Hillinger (1992).

Hillinger, Claude and Sebold-Bender, Monika (1992), The stylized facts of macroeconomic fluctuations. Ch. 3 in Hillinger (1992).

Hillinger, Claude and Reiter, Michael (1992), The quantitative and qualitative explanation of macroeconomic investment and production cycles. Ch. 4 in Hillinger (1992).

Juglar, Clémont (1862), Crises commerciales et leur retour periodique en France, en Angleterre et aux Etats-Unis, second edition, Paris, Guilaumin, 1889.

Kalecki, Michal (1933), Outline of a theory of the business cycle. Originally in Polish; English translation in Kalecki (1966, 1971).

(1935), A macrodynamic theory of business cycles, *Econometrica*, 3 327-44.

(1954), *Theory of Economic Dynamics*, London, George Allen & Unwin.

(1966), *Studies in the Theory of Business Cycles 1933-1939*, Oxford, Basil Blackwell.

(1971), *Selected Essays on the Dynamics of the Capitalist Economy*, 1933-1970, Cambridge University Press.

Keuzenkamp, Hugo A. (2000), *Probability, Econometrics and Truth: The Methodology of Econometrics*, Cambridge University Press.

Keynes, John Maynard (1936), *The General Theory of Employment Interest and Money*, London, Macmillan.

Kindleberger, C. (1987), Bubbles: In Eatwell et al. (1987).

Kirman, Alan P. (1992), Whom or what does the representative individual represent? *Journal of Economic Perspectives,* 6, 2, 117-136.

Leeson, Robert (2000), *The Eclipse of Keynesianism: The Political Economy of the Chicago Counter-Revolution,* New York, Palgrave.

Lindbeck, Assar (2004), The Sveriges Riksbank (Bank of Sweden) Prize in Economic Sciences in Memory of Alfred Nobel 1969-2004. Downloadable at http://nobelprize.org/economics/articles/lindbeck/index.html

Lucas, Robert E. (1977), Understanding Business Cycles. In: Brunner, K. and Melzer, A. H. (eds.), *Stabilization of the Domestic and International Economies*, Amsterdam, North-Holland. Reprinted in: Lucas (1981).

(1981), *Studies in Business-Cycle Theory*, Oxford, Basil Blackwell.

Maccini, Louis J. (1987), Adjustment costs, in Eatwell et al. (1987).

Malthus, Thomas Robert (1798), *An essay on the Principle of Population*. Reprinted: Oxford University Press, (1999).

(1820), *Principles of Political Economy*, London, John Murray. Reprinted: Cambridge University Press, 1989).

Mason, Stephen, F. (1962), *A History of the Sciences,* revised edition, Macmillan, New York.

Matthews, R. C. O. (1959), *The Business Cycle*, University of Chicago Press.

Metzler, Lloyd A. (1941), The nature and stability of inventory cycles, *Review of Economic Statistics*, 23, 113-29. Reprinted in: R. A. Gordon and L. R. Klein (1965).

Pashigian, B. Peter (1987), cobweb theorem. In Eatwell et al. (1987).

Petty, William (1691), *The Political Anatomy of Ireland*. Reprinted in Hull, C. (ed.), *Economic Writings,* 2 vols. Reprinted: New York, A. M. Kelley, 1964.

Phelps, Edmund S. (1968), Money-wage dynamics and labor market equilibrium, *Journal of Political Economy*, 76, 4, 687-711.

Roncaglia, Alessandro (1987), Petty, William. In: Eatwell et al. (1987).

Ravetz, Jerome R. (1971), *Scientific Knowledge and its Social Problems,* Oxford University Press.

Reiter, Michael (1995), *The Dynamics of Business Cycles: Stylized Facts, Economic Theory, Econometric Methodology, and Applications*, Heidelberg, Physica.

Samuelson, Paul A. (1939), Interaction between the multiplier analysis and the principle of acceleration, *Review of Economic Statistics*, 4, 75-8.

Sargent, Thomas J. (1979), *Macroeconomic Theory*, New York, Academic Press.

Schumpeter, Joseph A. (1954), *The History of Economic Analysis*, Oxford University Press. Paperback edition: George Allen & Unwin, London, 1986.

Slutsky, Eugen (1927), The summation of random causes as the source of cyclic processes (in Russian). Revised English version in *Econometrica*, 5, 1937, 105-46.

Sorensen, Peter B. and Whitta-Jacobsen, Hans J. (2005), *Introducing Advanced Macroeconomics: Growth and Business Cycles*, New York, McGraw-Hill.

Spiegel, Henry W. (1971), *The Growth of Economic Thought*, Englewood Cliffs, Prentice-Hall.

Strotz, Robert. (1960), Interdependence as a specification error, *Econometrica*, 28, 428-42.

Süssmuth, Bernd (2003), *Business Cycles in the Contemporary World*, Heidelberg, Physica.

(2004), To be or not to be of Maxentropic Type? An Appraisal of Parametric Spectral Analysis in Econometrics. The paper can be downloaded at http://ssrn.com/abstract=517783.

Tinbergen, Jan (1930), Ein Schiffsbauzyklus? Weltwirtschaftliches Archiv. Reprinted in Klaasen, L. H. et al. (1959), Selected Papers, Amsterdam, North-Holland.

Ulrych, Tad J. and Bishop, Thomas N. (1975), Maximum entropy spectral analysis and autoregressive decomposition, *Review of Geophysics and Space Physics*, 13, 183-200. Reprinted in Childers (1978).

Weser, Thilo (1992), The aggregation Problem for economic cycles. Ch. 9 in Hillinger (1992).

Woitek, Ulrich (1995), *Business Cycles: An International Comparison of Stylized Facts in a Historical Perspective*, Heidelberg, Physica-Verlag.

(1996), The G7 Countries: A Multivariate description of the Business Cycle Stylized Facts. Ch. 10 in Barnett et al. (1996).
Wymer, Clifford R. (1996), Continuous time disequilibrium models in macroeconomics. Ch. 3 in Barnett et al. (1996).
Zarnowitz, Victor (1992), *Business Cycles: Theory, History, Indicators and Forecasting*, University of Chicago Press.

Table 1
Contribution of Change in Real Fixed Investment
to Change in Real GNP:
Eight US Recessions, 1948-1981*

Period	Percent
1948:4-1949:4	18.8
1953:2-1954:2	12.7
1957:3-1958:2	45.8
1960:1-1960:4	61.4
1969:3-1970:4	43.1
1973:4-1975:1	55.2
1980:1-1980:2	59.2
1981:3-1982:4	34.0
Mean	41.3
Median	44.5

*Source: Gordon and Veitch (1986), Table 5.1

Table 2
Contributions of Inventory Investment to Changes in Real GNP:
Thirteen Recessions, 1948-1981*

Period	Change of Real GNP	Change of Inventory Investment	Percent Contribution of Inventories
1948:4-1949:4	-7.1	-13.0	183
1953:2-1954:2	-20.2	-9.2	46
1957:3-1958:1	-23.0	-10.5	46
1960:1-1960:4	-8.6	-18.0	209
1969:3-1970:4	-7.3	-12.3	168
1973:4-1975:1	-60.7	-38.0	63
1980:1-1980:2	-35	-1.6	5
1981:3-1982:4	-45.1	-38.8	25
Mean	-25.9	-17.7	93
Median	21.6	-12.7	74.5

Source: Blinder (1986), Table 3.1

Table 3
Median Statistics of Investment Cycles in G-7 Economies*, **

	GDP	CON	TPI	GFCF	II	EXP	IM	GOV
PERIOD	7.1	7.3	8.1	6.5	6.2	6.2	6.0	7.1
	3.6	3.7	3.9		2.8			3.9
MODULUS	0.8	0.8	0.9	0,9	0.8	0.8	0.8	0.8
	0.8	0.8	0.8		0.8			0.8
R-SQ	0.3	0.3	0.2	0.4	0.2	0.3	0.3	0.3

*Source: Süssmuth (2003).
**Most countries had no short cycle in GFCF, EXP and IM.

Figure 1
Real GDP, Log of estimated spectrum
(Sargent)

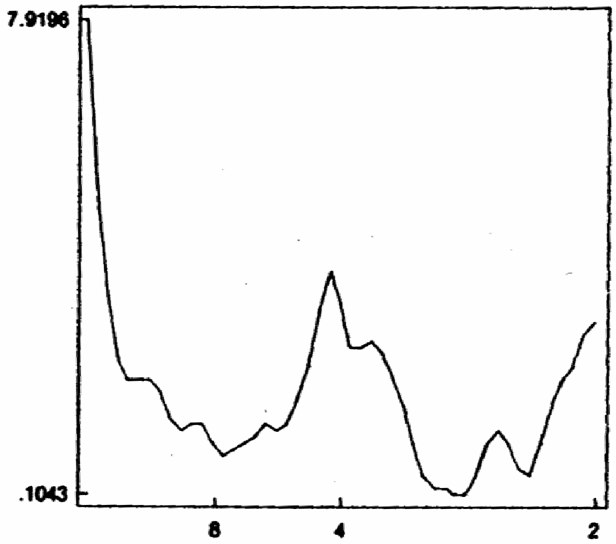
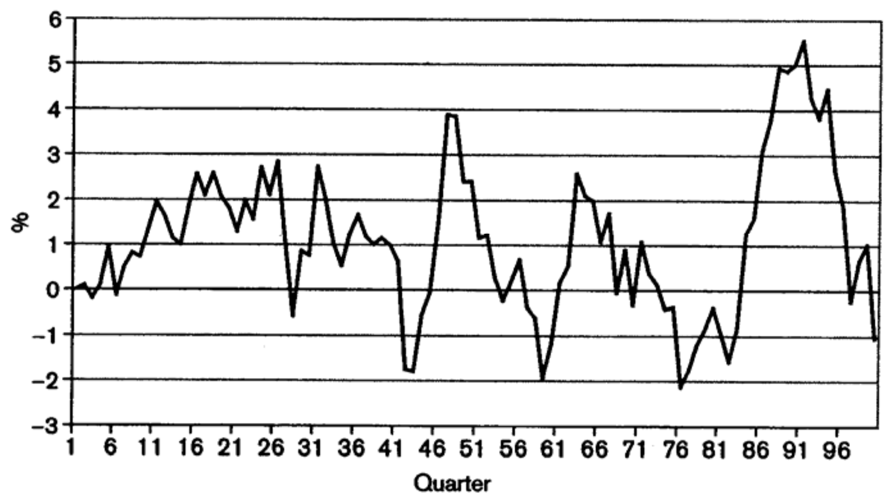


Figure 2
Simulation of First Order AR Process

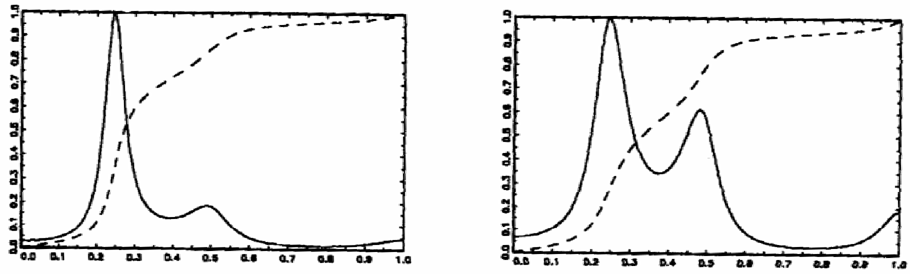


Source: Sorenson and Whitta-Jacobsen (2005), Figure 19.10

Figure 3
Spectra of G-7 and EURO-5 GDPs*

Supranational GDP series' spectra (filter: MBK)

G7 GDP-Cycle | EURO15 GDP-Cycle



G7 GDP-Cycle

per.[a]	mod.[a]	adj. R^2	ord.
8.206 (3.203)	0.906 (0.001)	0.389	5
3.963 (1.084)	0.804 (0.027)		

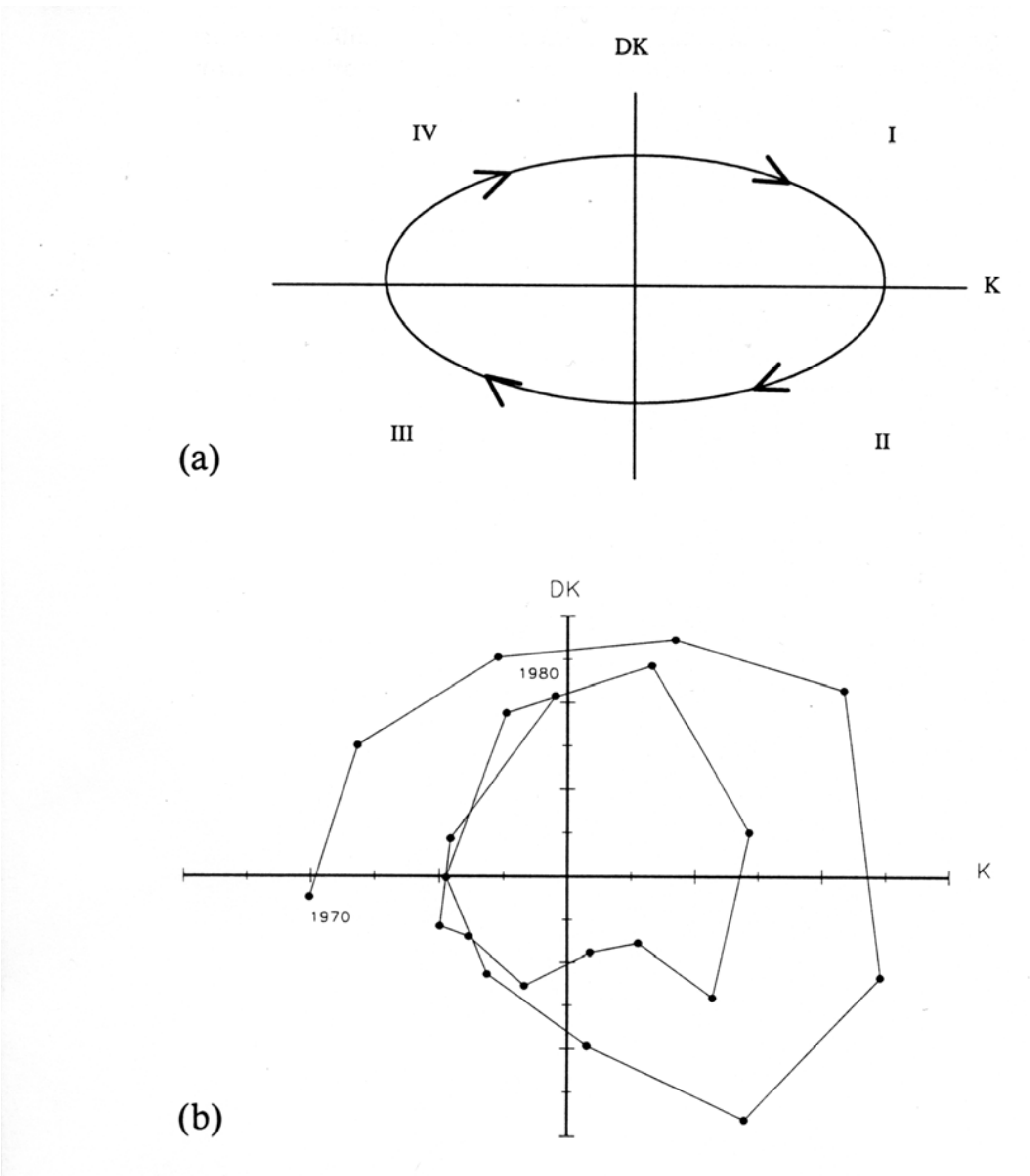
EURO15 GDP-Cycle

per.[a]	mod.[a]	adj. R^2	ord.
8.324 (1.048)	0.854 (0.012)	0.307	5
4.076 (1.259)	0.833 (0.014)		

Note: a. standard errors in brackets

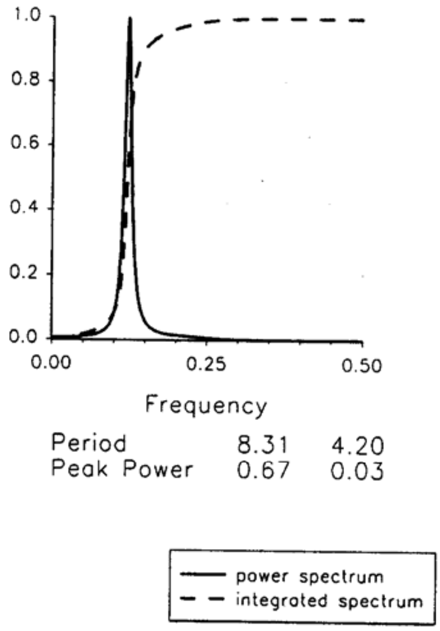
*Source: Süssmuth (2003)

Figure 4ab
Visual Analysis of the Equipment Cycle for Germany 1970-1989*
(a) Abstract Phase Diagram
(b)Empirical Phase Diagram

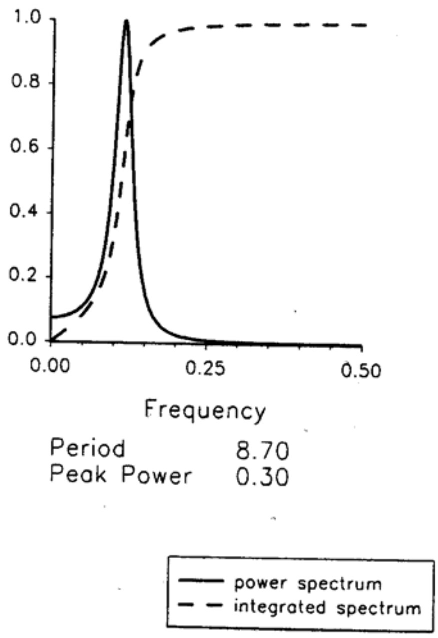


Source: Hillinger (1996).

Figure 4cd
(c) Data Spectrum (Maximum Entropy
(d) Model Spectrum

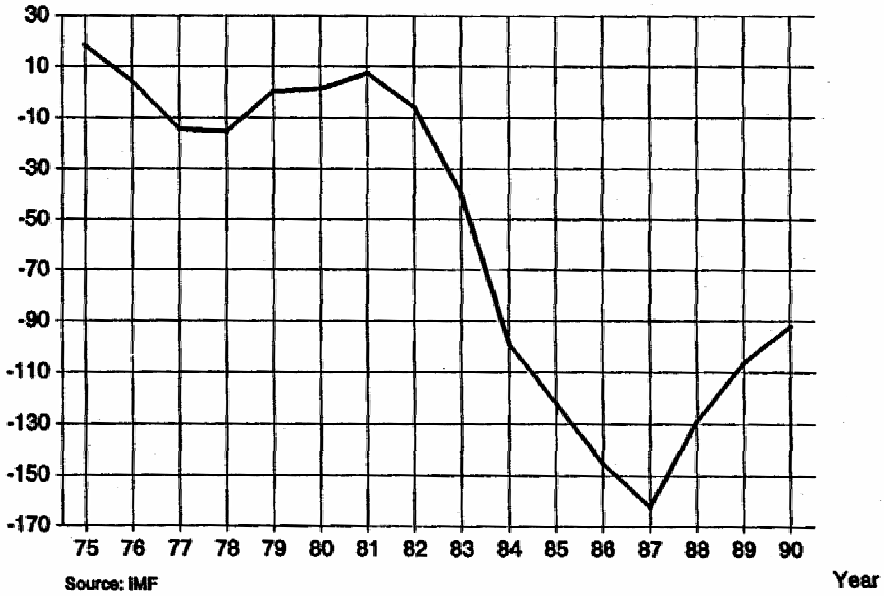


(c)

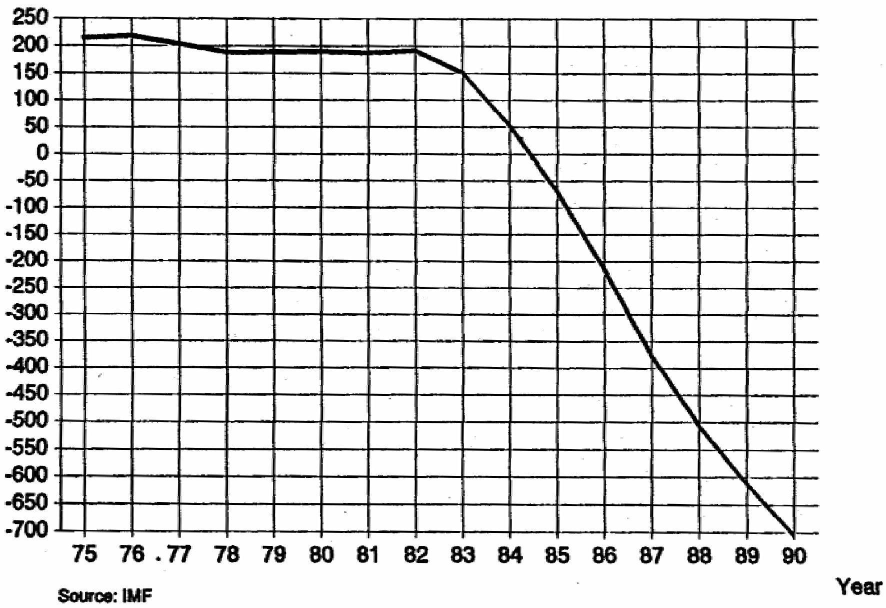


(d)

Figure 5
US Current Account and Net Foreign Asset Position:
1976-1990*



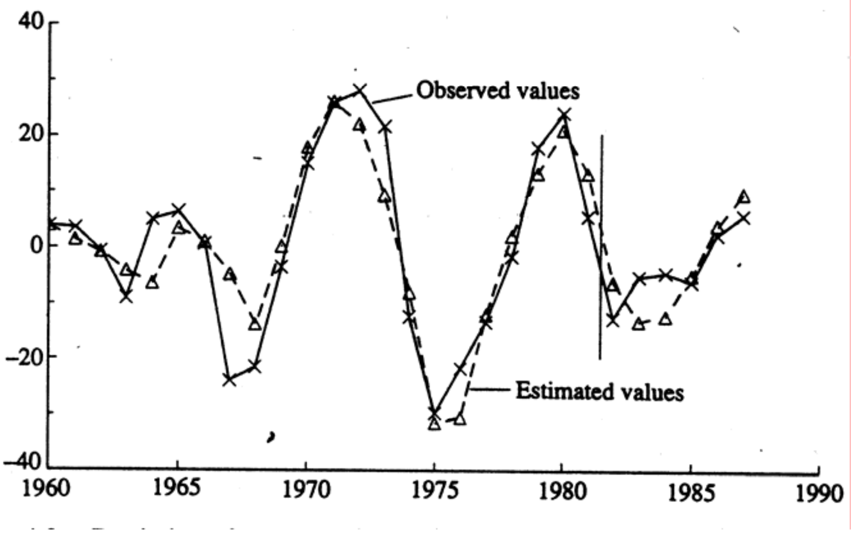
Current account (Billions of US Dollar).



Net international investment position (Billions of US Dollars).

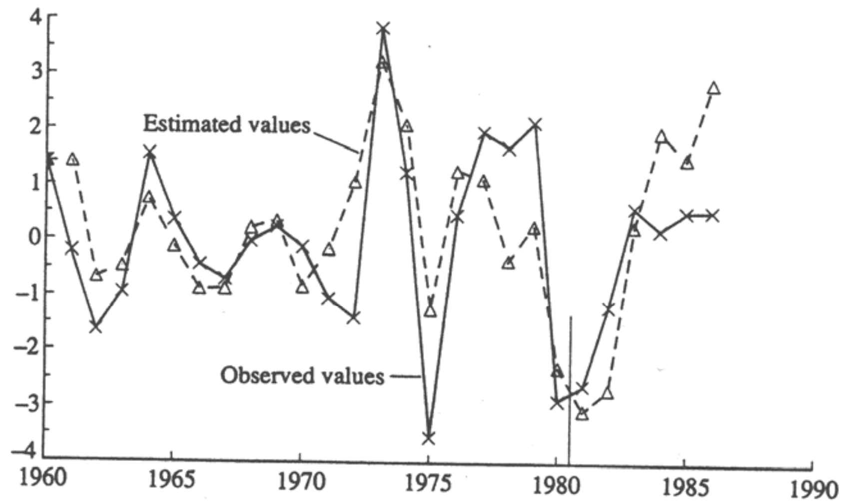
*Source: Hillinger and Konrad (1993).

Figure 6*
Germany: Two Parameter Fixed Investment SOA
Estimates 1960-1981, Forecasts 1982-1987



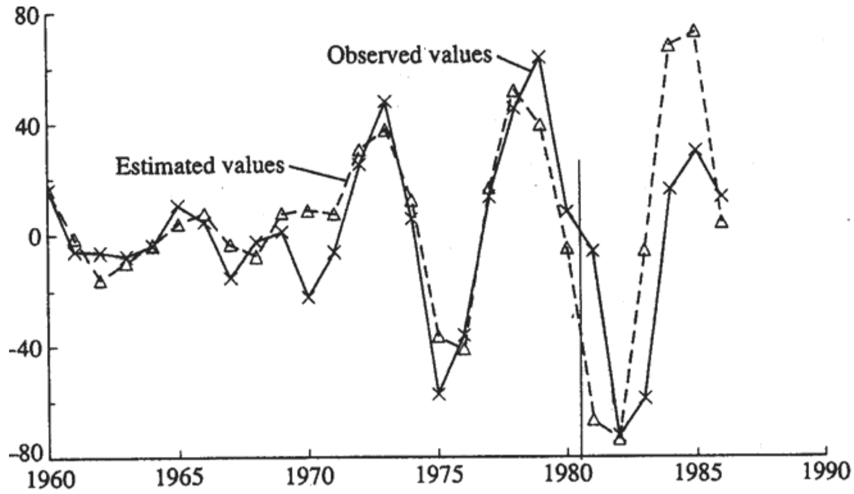
*Source: Hillinger and Reiter (1992)

Figure 7*
UK: Two Parameter SOA for Inventory Investment
Estimates 1960-1980, Forecasts 1981-1986



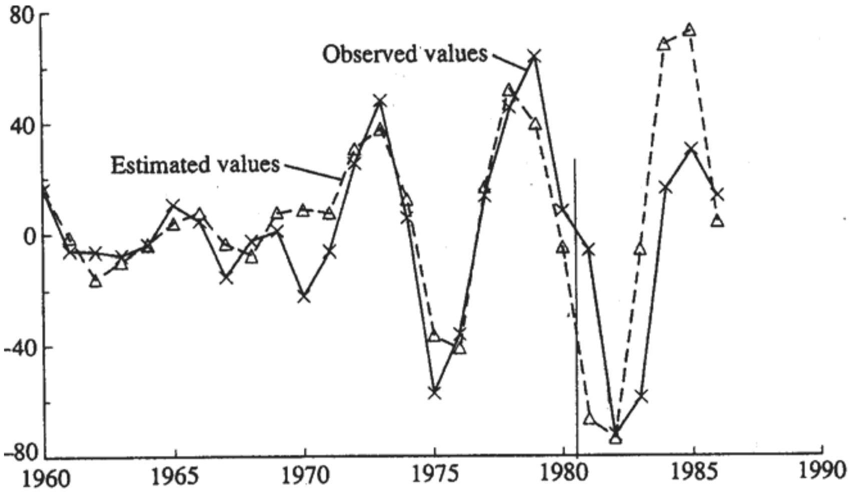
*Source: Hillinger and Reiter (1992)

Figure 8*
USA: Private Net Fixed Capital Formation
Model of Cyclical Interaction, Single Parameter Version
Estimation 1960-1980, Forecasts 1981-1986



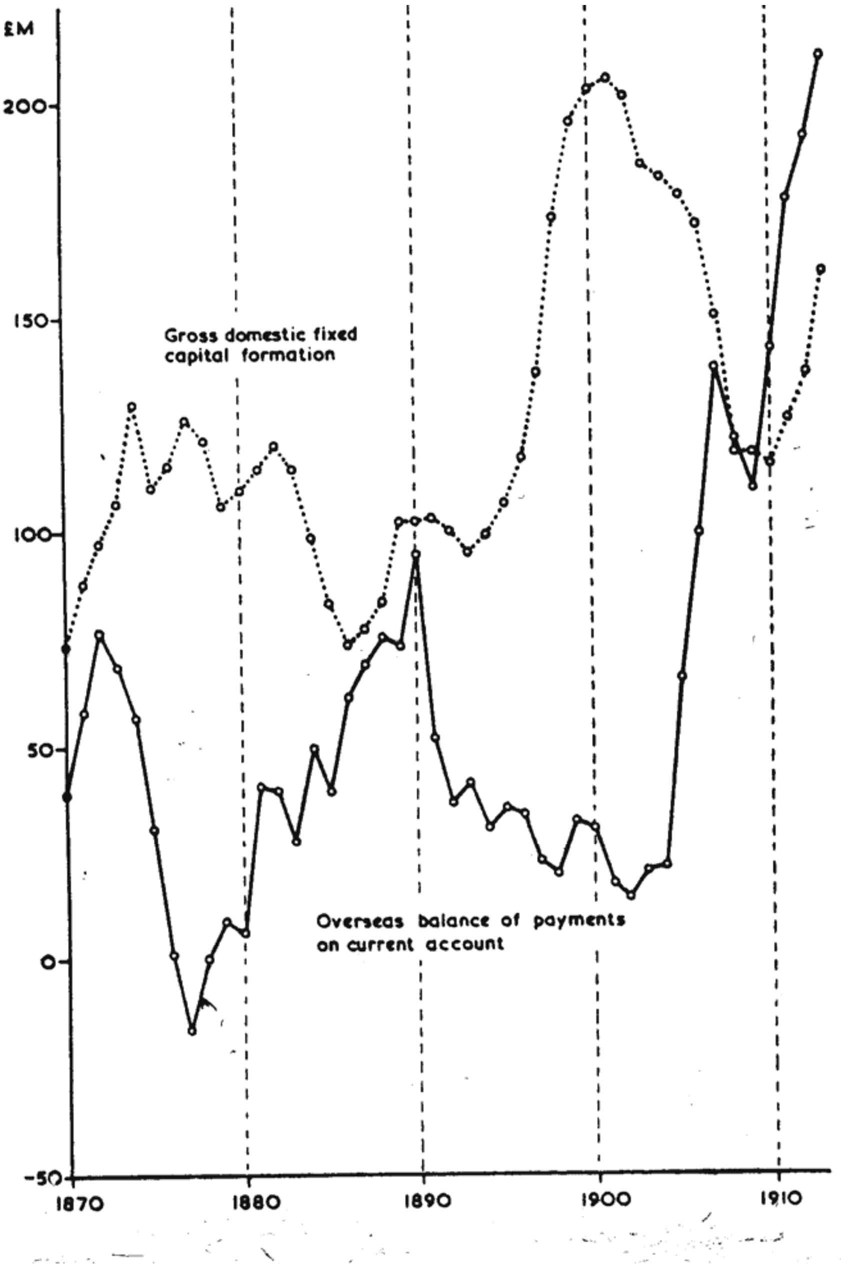
*Source: Hillinger and Reiter 1992

Figure 9*
USA: Inventory Investment
Model of Cyclical Interaction, One Parameter Version
Estimation 1960-1980, Forecasts 1981-1986



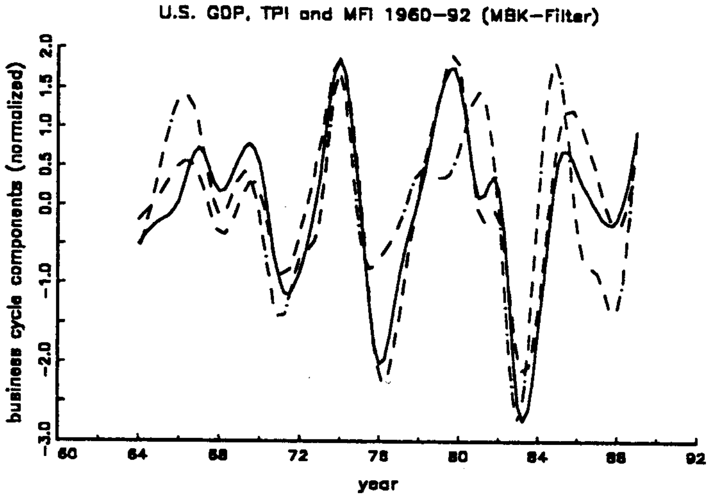
*Source: Hillinger and Reiter 1992

Figure 10*
UK Domestic and International Investment
1870-1913



*Source: Matthews (1959)

Figure 11*

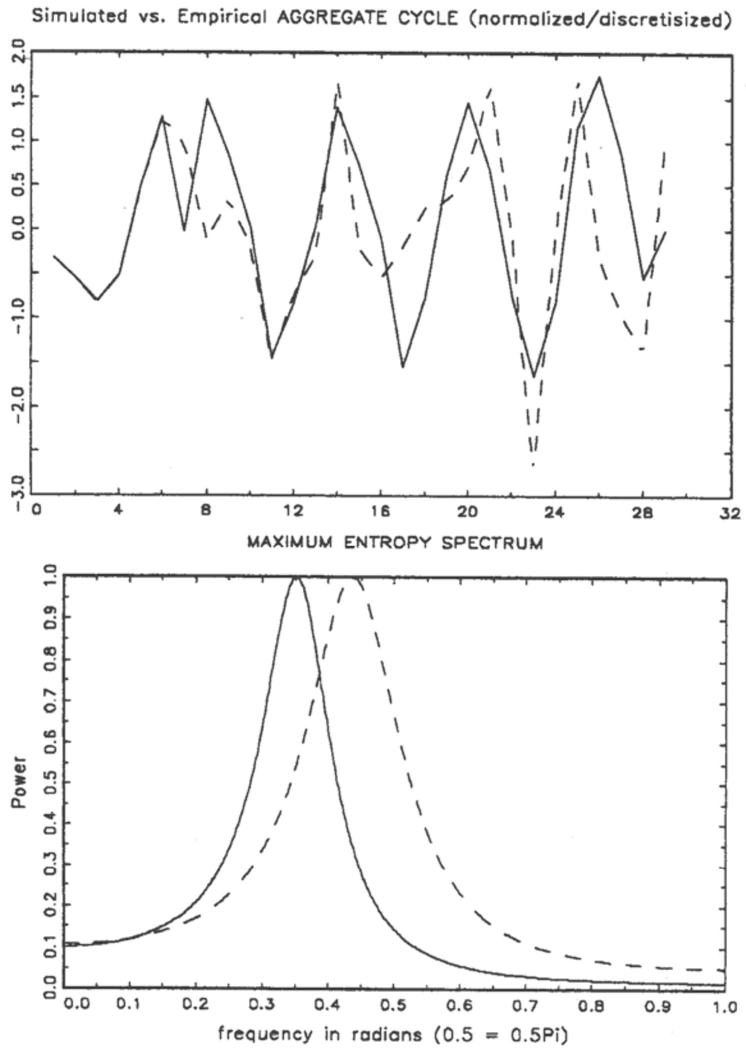


Note: solid: GDP, dashed: TPI, dotted and dashed: MFI

*Source: Süssmuth (2003, Fig. 6.1a)

Figure 12*
Simulation of Aggregate Fixed Investment
Optimized Parameter Values

Aggregate dynamics for exemplary simulation run:
$\gamma = 0.3$, $\vartheta = 1$



Note: Solid line: simulated, dashed line: empirical series/spectrum

Performance measures:	
Period length (years)	5.63 (4.55)[a]
mod	0.81 (0.75)[a]
RMSE	0.40
abs. std. dev. discrepancy	3.56 (0.001%)[b]

Note: Displayed in parantheses:
a) corresponding empirical results, b) share of actual std. dev.

*Source; Süssmuth (2003, Fig. 8.4b)