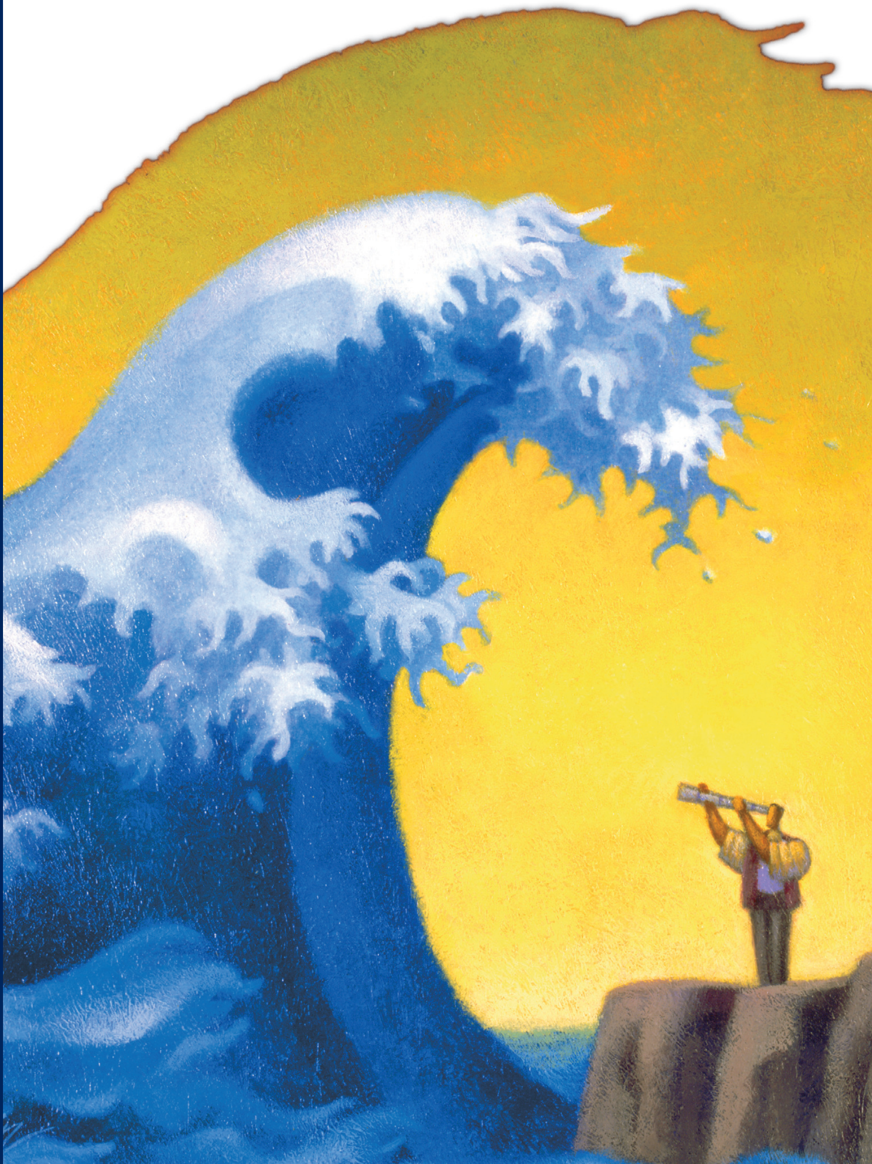
BERT DE GROOT

Essays on Economic Cycles



ESSAYS ON ECONOMIC CYCLES

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Essays over economische cycli

Proefschrift

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To Alexandra, Florian and Edward

Preface

This thesis is about cyclical behavior of economic variables and short and long-term forecasting by using multiple cycles which are found in various business and macro-economic variables. It also is a journey of discovery to the origin of economic waves, a revival of the long wave debate with a remarkable and intriguing finale.

The journey started at Randstad Holding N.V., a world player in staffing services. Years of experience in the staffing industry led to the insight that weekly staffing statistics provided an excellent understanding of the direction of the development of the company. Moreover, a connection between the development of Randstad and the Dutch economy was conjectured.

Dr. F.J.D. Goldschmeding, the founder of Randstad, used his intuitive knowledge of the staffing market to project the growth and decline of the company and to make operational decisions accordingly. In 1997 I joined Randstad as an executive board member and in debating the company's future with Dr. F.J.D. Goldschmeding a simple question was raised: "In what year will the company and the Dutch economy peak and when will the downturn commence". It took a while before I found an answer to this question. We concluded that halfway the year 2000 the growth of the company and the economy would peak and subsequently decline. We thought we had done well in concluding that and went home to find ourselves the next morning telling one another that we missed half of the subject. The question we missed the first time around obviously was: "when will the decline in revenues of the company and the market sector and the downturn of the economy reach its minimum and when will the next upturn start?" This question turned out to be much more difficult to answer. Dr. F.J.D. Goldschmeding's and my own reasoning to come to a projected date differed. Because our dating schemes and final projected date also differed we decided to place a bet just for the fun of it. Dr. F.J.D. Goldschmeding thought that the upturn would start at the beginning of the 3rd quarter of 2004. I thought this would happen at the beginning of the 2nd quarter of 2004. We decided to middle our predictions for our final forecast. We concluded that, so we would not forget, the economy and Randstad would experience an upturn on May 13, 2004 at 12:15 hours. A more detailed description of the whole prediction would be: from 1997 up until June 2000 the growth of the economy continues to a peak, followed by a downturn, which should reach its bottom in May 2004 followed by a new upturn in growth.

We thought these forecasts were simple to remember, practical to work with and, when applied correctly, could be used as a profound steering device for the company. This know-how was shared with the rest of the company in order to stimulate further thinking by management. Outside the company this information was given to the community for raising awareness so that entrepreneurs, firms, institutions and governments could benefit. Fortunately our forecasts eventually turned out to be right on the nose. Indeed the economy and the company experienced a downturn in 2000. The Financieel Dagblad and NRC Handelsblad headlined on May 13 and May 14 2004: "The economy starts growing again thanks to increase of foreign trade".

In 1999 I got into contact with Prof. Dr. H.R. Commandeur, the present (2006) Dean of the Faculty of Economics of Erasmus University Rotterdam, who became highly interested in the matter as well as Prof. Dr. P.H.B.F. Franses, director of the Econometric Institute. They stimulated me to create an academic experience for myself. In 2002 I delivered my first report on the matter. I was invited to write a PHD thesis under their supervision. I gracefully accepted their offer, so that after 25 years leading a business life I found myself back in the university library picking up the original works of Schumpeter.

In 2003 I had the opportunity to publish my first book with my ideas on using staffing data for forecasting purposes and my views on the long wave literature at the Stichting Maatschappij en Onderneming (SMO). SMO is led by Prof. Dr. W.J. de Ridder who was very supportive and had keen interest in this topic. I thank him greatly for his support and valuable comments that improved the book. I would also like to thank my co-authors, Dr. F.J.D. Goldschmeding, Drs. R.C.L. Haasnoot, Prof. Dr. C.W.J.A.M. van Paridon and Prof. Dr. A.J. van Weele for their contributions.

After an investigation of the critical literature, however, it became clear that especially for the longer cycles many research questions remained unanswered. An overview of the controversies surrounding the debate exposed issues which could be investigated further empirically. However, as the classical approach could not provide the answers a new approach was developed in order to attain novel insights. Schumpeter's thoughts on innovation and particularly his notion of multiple cycles seemed to be very interesting. The hypothesis of the simultaneous existence of multiple cycles was then identified as a promising research area. After empirically testing this hypothesis it was found that multiple cycles were indeed present, albeit not in the classical sense. Our research revealed the simultaneous existence of multiple cycles within a single variable. I would like to thank L. Kruithof for providing computational support. A special great thanks to Drs. R.C.L. Haasnoot who kept on challenging my thoughts and for his never-ending support on the many manuscripts that were produced.

An interesting phenomenon appeared when the research results were viewed from a different perspective. The individual cycle lengths are remarkably close to the Fibonacci sequence. A similar phenomenon was observed when all known cycles from the literature were put together in a grand scheme. The lengths of well-known cycles such as the Kitchin, Juglar, Kuznetz, Kondratieff and hegemony cycles as well as several other cycles showed a remarkable gravitation around the domains of the Fibonacci sequence[1]. I greatly thank Dr. R. Paap for his valuable comments and help in finding the normal distributions around the Fibonacci domains. We know that Fibonacci patterns are found in biology, physics, astronomy and mathematics. Fibonacci patterns in economic variables however was a green pasture. I found the findings remarkable and it was building to my enthusiasm. Science started to become fun!

After studying the subject of business cycles extensively, deeper insight was gained in the forecasting abilities of the Randstad data. It became clear that Real Gross Domestic Product (GDP) of the Netherlands and the Randstad staffing data share a common stochastic trend. This underlined the intuitive knowledge. An acceptable forecasting model could be built by using the Randstad staffing data as the single explanatory variable. Scientifically speaking, the use of staffing data as the only explanatory variable is an interesting feature since most current forecasting models

[1] Fibonacci sequence: 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, …

rely on many variables rather than one. The Econometric Institute Current Indicator of the Economy, in short, EICIE, was first introduced in the E.S.B. of January 2005 and published there every quarter since. The EICIE is a real time, nowcast indicator which was later extended to incorporate medium and longer term forecasts as well. Great interest by the business cycle research community[2] and the media was raised. Information on the development of the GDP therefore could be made public well in advance of the official reporting done by the CBS. I greatly thank Dr. D.J.C. van Dijk and Dr. D. Fok for their valuable comments when I was working on the various papers on the EICIE indicator. Their sharp and critical understanding was of great help. I would also like to thank mr. B.J. Noteboom, CEO of Randstad, for kindly making available the staffing data.

What originally started as a bet to forecast a company's future and to gain knowledge on the direction of the development of the Dutch economy turned into a journey of discovery. A journey that led to the origins of the long wave debate and made me explore such concepts as business cycles, constellations of cycles and Fibonacci patterns. It allowed me to develop a GDP indicator based upon a real time single variable which can nowcast and forecast the quarterly, yearly and even longer term values of Dutch GDP.

Again, I would like to express my great thanks towards Philip Hans Franses and Harry Commandeur for letting me have the opportunity to work with them. Philip Hans showed me the fountain of econometrics, he inspired me to travel to the borders of the econometric science and taught me many things through stimulating debates. Harry showed me the various contemporary concepts in economic thinking. Through stimulating debates we refined our thoughts on the applicability of these concepts in the business environment. In sharing their experience and having stimulating debates they enriched my academic journey. They believed this thesis was possible and I greatly thank them for their unconditional support.

I would like to express my great thanks towards Frits Goldschmeding for his inspiration, never ending enthusiasm, stimulating debate, challenging remarks and

[2] CPB, DNB, Rabobank, VNO-NCW, RuG, VU, CBS and EUR

many hours of philosophy. I thank him for giving me the opportunity to learn from his insights and share his experiences.

Frits, Harry, Philip Hans and Rob inspired me to make a difference with my thesis in both the academic and the business world. Although academically based, the message delivered in this thesis should be understandable, practical, ready to implement and serve a purpose for entrepreneurs, firms, institutions and society. I have done my utmost best in trying to achieve that and I could have never succeeded without their support.

I would like to thank Prof. Dr. C.G. de Vries, Dr. D.J.C. van Dijk, Prof. Dr. J. Veenman, Prof. Dr. G.A. van der Knaap and Prof. Dr. W.J. de Ridder and for being a member of the thesis committee.

Finally I would like to express my deepest thanks towards Alexandra, Florian and Edward, my wife and my two sons, because they have been a limitless source of emotional support.

Bert de Groot, May 11, 2006

Econometric Institute, Erasmus Universiteit Rotterdam

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Chapter 1.1 General Motivation

1.1.1 Introduction

Companies and governments always have to deal with uncertainty regarding economic prospects. Entrepreneurs, executive board members and governments are concerned with the current state of their business and the economy and want to have a clear look at the future. Economists recognize short and long cycles in the economy which, according to some researchers, make it easier to foresee economic changes due to their repetitive character. In the area of business cycle fluctuations forecasting and nowcasting models can at least partly reduce uncertainty by providing reliable predictions.

In this thesis a better understanding is developed of the cyclical behavior of economic variables and consequently of the cyclical behavior of a firm and the economy. The scientific findings are used to create understandable and practical nowcasting solutions for decision makers in companies and the government.

Some researchers conjecture that, besides the well-known short-term business cycles, longer cycles also exist. The existence of cycles says a lot about the impact of macroeconomic policy. The presence of a single deterministic cycle such as for instance the classic version of the Kondratieff cycle would imply that the influence of policy makers is only marginal. We, however, think the economy has a multiple cycle rather than a single cycle structure and thus that macroeconomic policy is useful.

In this thesis we investigate whether these multiple cycle structures can be found. The Schumpeterian concept of multiple cycles was identified as an interesting starting point. First we examine an innovation dataset and find evidence for the simultaneous existence of five different cycles. We furthermore inspect 33 macroeconomic series from three countries and 6 classic long wave datasets and again discover multiple cycle structures in all examined variables. We found a total of 90 individual cycles in the macroeconomic datasets.

Remarkable is that the lengths of the individual cycles in our multiple cycle structures seem to follow the Fibonacci sequence. In the innovation dataset we find five cycles with lengths of 5, 13, 24, 34 and 61 years. Again, these lengths are surprisingly close to the Fibonacci sequence. The various macroeconomic variables we examine also reveal structures in which the cycle lengths seem to approach the Fibonacci sequence. In conjunction with this observation we document that the lengths of the classic known single cycles from the literature are also surprisingly close to the Fibonacci sequence.

One of the features of multiple cycle structures with Fibonacci cycle lengths is that there is not a single moment in time in which all cycles simultaneously reach their maximum or their minimum. Thanks to this property it can be argued that the found multiple cycle structures can provide stability in the economy. Because the peaks and the troughs of the cycles are not simultaneous they blunt each others extremes. This implies that macroeconomic policy is useful. By means of policy, cycles can be created which can counterbalance unwanted extreme fluctuations. These findings update the traditional image of the single cycle to that of a multiple cycle economy.

By recognizing the concept of multiple cycles in both business and macro-economic variables, a better understanding and insight in the workings and interactions of such variables can be gained. This knowledge can also be used for scenario planning and for creating an outlook on the future

We further investigate whether staffing data from Randstad can be used for nowcasting purposes. We elaborate on the hypothesis arisen from practice that with staffing data from Randstad forecasts and nowcasts for the development of both Randstad and Dutch GDP can be made. First we examine whether Dutch GDP and the Randstad staffing data share a common stochastic trend. If such a relationship does indeed exist it is possible to create a forecasting and a nowcasting model. Moreover we will test whether multiple cycle structures are also present in Dutch

GDP and Randstad staffing data. This appears to be the case. The cycles found in both Dutch GDP and the Randstad data have lengths of respectively 5 and 11 years. Based on these findings we develop a long-term multiple cycle forecasting model for Dutch GDP. This simple model based on the Schumpeterian concept of multiple cycles offers a more dynamic alternative to the long run static equilibrium outcome of other econometric nowcasting models. Our model can deliver information about the long run dynamic development to the business community and the government. With the help of the model we give a forecast for Dutch GDP for the period 2005-2015.

In this thesis the Randstad staffing data will also be used to develop a new "real time", nowcast indicator of Dutch GDP. This new indicator will be called the Econometric Institute Current Indicator of the Economy, or EICIE for short. The special feature of this new indicator is that, in contrast to the vast majority of other models, it is only based on a single explanatory variable, namely staffing data from Randstad staffing services, and that it has an extremely simple model structure. The model thus is inexpensive and can be applied very easily. Other GDP indicators are complex models based on many variables. It should also be stated that the explanatory variable of the EICIE displays factual behavior and thus is not composed from surveys. The EICIE cannot only serve as a real time indicator but can be extended for medium and longer term nowcasts as well.

Because the information from Randstad becomes available fast, the nowcasts can be published well in advance of the first official estimate of the Netherlands Central Bureau of Statistics (CBS). This indicator is also very interesting on a corporate level. Randstad can use the forecasts and the nowcasts of the indicator for its own policy planning. By using this tool the government and firms can reduce uncertainty and thus act more effectively.

1.1.2 Research Questions

The literature on the topic of economic cycles is extensive. To make a contribution to this field of research the following research questions are:

1. Can a Fibonacci sequence (1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, …) be identified when the cycle lengths of the cycles in the literature, such as Kitchin, Juglar, Kuznets, Kondratieff and Hegemony cycles, are put together in a grand scheme?

2. Is the traditional image of the Kondratieff as the single cycle with a length of approximately 55 years is no longer valid and does it have to be changed? Is the Schumpeterian multiple cycle hypothesis a better alternative?

3. Can corporate and macroeconomic variables be decomposed into multiple cycles?

4. Do basic innovations cluster in time?

5. Can the constellation of cycles in economic variables be associated with a harmonic development of the economy and economic stability?

6. Do innovation series and other macroeconomic data display multiple cycles with lengths that resemble the Fibonacci sequence?

7. When multiple cycles structures are acknowledged in economic variables, is it appropriate to explicitly use them for forecasting purposes?

8. Do Dutch GDP and staffing data share a common stochastic trend?

9. Does Dutch GDP show cycles with length of 5 and 11 years? Could these cycles be used to produce long-term forecasts of Dutch GDP?

10. Can nowcasts for quarterly and yearly Dutch GDP be done reliably with the help of a single explanatory variable from the real economy which displays factual behavior?

1.1.3 Limitations of the Research

This thesis aims at investigating multiple cycle structures in innovation data and in various macroeconomic variables. Furthermore a longer term GDP indicator is developed based on multiple cycles and staffing data. A nowcast indicator solely based on staffing data is also created. Our research is only limited to the topics mentioned above.

The econometric techniques used in this thesis can best be described as "simple". Everyone with a Master degree in econometrics should be able to apply these techniques. All the software used for calculations, testing and evaluations is standard statistical software (Eviews).

1.1.4 Methodology

In this thesis the following econometric techniques are applied:

- Poisson regression model with harmonic regressions
- Linear regression models
- Estimation of parameters using a mixture of three/four normal distributions with the same variance using maximum likelihood
- Error correction model (VECM) and cointegration model
- All calculations are done with Eviews standard statistical software

Chapter 1.2 General Outline

1.2.1 Overview

Classic cycle researchers generally assume single economic cycles. In Chapter 2 a comprehensive overview is given of the long wave (Kondratieff) literature. Other cycles known from the literature such as the Kitchin, Juglar, Kuznets and hegemony cycles will also be discussed in this chapter. The unanswered questions and controversies of the long wave debate will be identified in order to make clear which parts can be investigated further and with which approach this can be done best. The conclusion we derive from this literature study is that the current approach of the long wave researchers does not work, the field is in an impasse and a different perspective is needed. It is remarkable though that the lengths of the known cycles from the literature seem to follow the Fibonacci sequence.

A promising angle to create better understanding and perhaps even to create a solution is the multiple cycle approach. In Chapter 3 we describe Schumpeter's original multiple cycle theory and other contemporary multiple cycle approaches. The most important subject Schumpeter brought into the limelight is the role of innovations in the economy. Therefore it seems useful to investigate whether the supposed multiple cycle structures can by found in an innovation dataset. We will examine various innovation theories and will eventually investigate whether multiple cycle structures are present in an innovation series. This turns out to be the case. We find five cycles with lengths of 5, 13, 24, 34 and 61 years. Again these lengths are remarkably close to the Fibonacci sequence.[3] Furthermore we find evidence for the clustering of basic innovations.

In Chapter 3.4 we will explore whether our results from the innovation series can also be found in other macroeconomic variables. We will investigate 33 series from three countries and 6 classic long wave datasets and discover multiple cycle structures in all

[3] Fibonacci sequence: 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, …

investigated variables with in total 90 individual cycles. Here we also observe that the found cycle lengths seem to approach the Fibonacci sequence.

One of the features of Fibonacci cycle lengths is that there is not a single moment in time in which all cycles simultaneously reach their maximum or their minimum. Thanks to this property the found multiple cycle structures close or equal to the Fibonacci sequence can be associated with stability in the economy. Because the peaks and the troughs of the cycles are not simultaneous they blunt each others extremes. This implies that macroeconomic policy is useful. By means of issuing policy, cycles are attenuated or can be sustained which can counterbalance unwanted extreme fluctuations. These findings update the traditional image of the single cycle to that of a multiple cycle economy.

In Chapter 4 we will elaborate on the hypothesis arisen from practice that with staffing data from Randstad forecasts for the development of Dutch GDP can be made. We will discuss the origins of this hypothesis and will describe the relationship between Dutch GDP and staffing data from Randstad. First we will show that Dutch GDP and Randstad staffing data share a common stochastic trend. This makes it possible to make forecasts based on a model. Moreover we will test whether multiple cycle structures are also present in Dutch GDP and Randstad staffing data. This appears to be the case. The cycles found in both Dutch GDP and the Randstad data have lengths of respectively 5 and 11 years. Based on these findings we will develop a long-term multiple cycle forecasting model for Dutch GDP. With the help of the model we will give a forecast for Dutch GDP for the period 2005-2015.

In Chapter 5 we will delve into the possibility to develop a reliable real time indicator of Dutch GDP based on the weekly available staffing data from Randstad. This real time indicator, named EICIE, is unique because it is based on only a single explanatory real variable and has an extremely simple model structure. Other GDP indicators are complex models based on many variables. It should be remarked that the explanatory variable of the EICIE displays factual behavior and thus is not composed from surveys. Because the Randstad data become available soon after the quarter has ended and the EICIE can be easily calculated it is possible to publish a reliable quarter nowcast within two weeks after the quarter has ended. This is well before the publication of the first official estimate.

In Chapter 6 we will give a summary of Chapter 2 up to and including 5. We will also indicate which cycles were found in which data. The most important conclusion of this thesis is that constellations of cycles were found in innovation and macroeconomic data of which the lengths of the individual cycles remarkably approach the Fibonacci sequence. These multiple cycle structures can provide stability in the economy, therefore macroeconomic policy makes sense. Moreover it has been shown that reliable forecasts and nowcasts for Dutch GDP can be made based on staffing data from Randstad. Subsequently, we give recommendation for policy makers and determine possibilities for future research.

1.2.2 Key Words

Business cycles, forecasting, nowcasting, EICIE, staffing services, long waves, multiple cycles, innovation, Fibonacci, Real GDP, Schumpeter, Kondratieff, harmonic Poisson regression, economic cycles, VECM, cointegration, Granger causes

Contents

Chapter 2. The Long Wave Debate

Chapter 2.1 Introduction

Companies and governments always have to deal with uncertainty regarding economic prospects. Economists recognize short and long cycles in the economy which, according to some researchers, make it easier to foresee economic changes due to their repetitive character. Some researchers conjecture that besides the well-known short-term business cycles longer cycles also exist. Such cycles with supposed lengths of 55 are not uncontroversial. In this thesis it will be investigated whether these long cycles can be found in the data.

The existence of cycles says a lot about the impact of macroeconomic policy. Moreover, the presence of a deterministic cycle implies that the influence of policy makers is only marginal. In such a situation the cycles, and thus the economy, have their own rhythm and ups and downs. It is therefore very interesting to examine if and, when present, in what form these types of longer economic cycles manifest themselves.

Large cyclical economic movements which extend themselves over long periods of time are also called "long waves". This is a somewhat controversial subject amongst economists. The skepticism with which the long wave is approached can largely be attributed to the poor empirical evidence. This in general has led people to reject the long wave hypothesis without any examination of the long wave debate. In this chapter, however, the long wave will be discussed extensively in order to develop a balanced picture of the debate. Both the theoretical and empirical-methodological aspects of the discussion will be examined.

Not only are people searching for the long wave in the economy but the entire social system is regularly involved in the analysis. Therefore it is necessary to search for the underlying laws which underpin economic events. In this chapter an overview is given of the theories and ideas as a result of which insight arises in the development of the debate over the years. Over a hundred authors have occupied themselves with the long wave from different perspectives. This makes it unpractical to discuss everything. In this chapter a most complete as possible overview of the long wave will be given by concentrating on the theories of the most relevant authors.

In this Chapter a comprehensive overview is given of the long wave, Kondratieff, literature. The critical literature review will be divided over three sections because of its size. In Chapter 2.2 the most important theories from the period up to 1950 will be discussed, in Chapter 2.3 the theories after 1950 will be examined and finally in Chapter 2.4 the econometric aspects of the long wave discussion and the critics will be explored. Moreover, the unanswered questions and controversies of the long wave debate will be identified as a result of which a good picture of the agreements and disagreements between the authors can be formed. This will make clear which parts can be investigated further and by which approach this can be done best.

Other cycles known from the literature such as the Kitchin, Juglar, Kuznets and hegemony cycles will be discussed in Chapter 2.5. The conclusion we derive from this literature study is that the current approach of the long wave researchers does not work, the field is in an impasse and a different perspective is needed. Remarkable is that the lengths of the known cycles from the literature seem to follow the Fibonacci sequence.

Chapter 2.2 The Historical Long Wave Debate (pre 1950)

2.2.1 The Origins of the Long Wave Debate

It is remarkable to observe that in times of economic prosperity there is little attention for the long wave whereas in times of economic despair the debate thrives. When Parvus and van Gelderen published their articles in the booming economy of the early 20th century there thus was little resonance. In fact, the long wave debate was really started by Kondratieff during the depression before the Second World War. Schumpeter ensured the further distribution of the long wave principles. After the Second World War had finished and the economy got back on track researchers again lost interest in the long wave until the depression of the seventies revived the debate.

This chapter will start with a short overview of all relevant schools of thought which have occupied themselves with the long wave phenomenon throughout the years. After this overview we will begin our review of the long wave discussion by describing the original thoughts of the pioneering authors.

2.2.2 Schools of Thought

There has been a diffusion of theories and ideas since the beginning of the long wave debate. A historically determined classification gives a good overview of the development of the debate. It is furthermore preferable to classify the theories of the authors according to a certain criterion.

Schouten uses a classification after Delbeke in his book "De Lange Golf" (SMO informatief 1984-1). The theories are classified to shortage and abundance of one determining production factor. In the classification of Delbeke (1981) those production factors and its authors are successively; entrepreneurship and innovation by Schumpeter and Mensch, capital by Forrester and Mandel, labour by Freeman and foodstuffs and raw materials by Rostow.

Delbeke states in his consideration that each of these theories, from different starting points and assumptions, emphasises different aspects of the long wave and does not make it entirely clear how the mechanism of the long wave is constructed. He concludes: "the theories which we have discussed emphasise different aspects of the long wave, has different starting points and underlying assumptions. In reality they are more complementary than has thus far been assumed, multicausality is clearly a better approach for the complex problem of the long wave." Recent authors such as Freeman, Perez, Soete, Gordon, Boyer and Tylecote emphasise that economic changes go hand in hand with socio-institutional changes and hold a similar plead for multicausality.

Gordon (1991) distinguishes the following schools within the long wave framework: bunched investments (Kondratieff and Forrester), traditional Schumpetarian (Schumpeter, Mensch and Kleinknecht), neo-Schumpetarian (Freeman and Perez), modified Trotsky (Mandel), traditional Marxist (Shaikh), world-systems (Wallerstein), economic/warfare interactions (Goldstein), French regulationist (Boyer) en social structures of accumulation (Gordon).

Goldstein uses a different classification is his book “Long Cycles” (1988). He distinguishes three main schools: the liberal innovation school of among others Schumpeter, Mensch and Freeman, the conservative capital investment school to which Kondratieff and Forrester belong and the Marxist capitalist crisis school of Trotsky, Mandel and Gordon. Authors such as Rostow and van Duijn have according to Goldstein hybrid theories in which elements from the innovation school and the capitalist crisis school are combined.

In this chapter the debate will be presented in historical order and the authors will as well be placed in a so-called school of thought. This classification has been based on the determining variable of the different theories and roughly follows Gordon and Goldstein but also deviates on certain points. The discussion will begin with a short overview of the main schools of thought.

The Pioneers: to which belong among others Hyde Clark, Jevons, Juglar, Tugan-Baranowsky, Parvus and van Gelderen.

Investment in Capital Goods: to which belong among others Kondratieff (1928) and Forrester (1978). This theory states that long waves originate from large investments in and depreciation of capital goods and infrastructure, like for example railways, canals, factories and terrains. During the upswing phase of the economy over-investments take place after which there is a decline. Overcapacity is depreciated in this period after which a new wave of investments can take place.

Capitalist Crisis: to which belong, among others, Mandel (1976, 1980, 1995). The teachings of Marx form the basis of this school (Kuczynski, 1987). Capitalism has repeatedly dealt with large crises because the "rate of profit" has a decreasing tendency in the long run. The system will inevitably collapse because it cannot restore itself due to the internal contradictions within capitalism. According to Mandel capitalism can recover temporarily thanks to exogenous, external to the system, factors. These factors facilitate the necessary conditions for recovery of the profitability and a new period of capital accumulation. The period of prosperity will eventually always come to an end and capitalism will yet again become depended on exogenous shocks for survival.

Innovation: to which belong among others Schumpeter (1939), Mensch (1975) and Kleinknecht (1986). This school states that long waves originate from clusters of innovations. These clusters of related innovations, not inventions, create a new fast growing leading sector in the economy which causes an upswing in the long wave. Radical basic innovations are discouraged during the upswing phase because investments in existing technologies generate good margins and income. However, after a while competition will increase whereas the market becomes saturated. As a consequence margins are put under pressure and income will diminish. The economic developments slow down and the long wave bends to a downswing. In Schumpeter's analysis the economy depends on entrepreneurial efforts to get out of the recession. Mensch states that the depressed investment climate will lead investors to radical innovations out of despair after which a new leading sector will develop.

Some authors have developed their own hybrid theories in which elements of several main schools are used. Sometimes the research area of economics is left behind and concepts from other branches of science are applied.

Combination of Investment in Capital Goods and Innovation: Rostow (1975). The influence of the relative prices of raw materials and foodstuffs are the basis of this theory. Rostow distinguishes three factors which are important to the long wave process: changes in the profitability of the production of foodstuffs and raw materials, the influence of a leading sector in the economy after the introduction and diffusion of a technology and population growth due to migration.

Combination of Investment in Capital Goods and Innovation: van Duijn (1983). In his analysis he focuses on the diffusion of innovations. He builds his explanation on three core variables: innovation, innovation lifecycles and investments in infrastructure.

Combination of Innovation and Institutional Development: Freeman, Perez, Louça (1983- 2002) and Tylecote (1992). They emphasize the mutual dependence of technical, economical, scientific, political and cultural factors. Certain types of technological change have a widespread influence on all sectors of the economy. They define these as changes in the techno-economic paradigm. The diffusion of such a paradigm is accompanied by a large crisis of structural adjustment. Social and institutional changes are necessary to achieve a better match between the new technology and the political, social and management system, the socio-institutional framework, of the economy. When a certain match is accomplished a relatively stable pattern of long time investment can emerge which withhold about twenty to thirty years.

Combination of Capitalist Crisis and Institutional Development: to which belong the Social Structures if Accumulation (SSA) school with among others Gordon (1978) and the French Régulation school with among others Boyer (1986). The SSA school distinguishes reproductive and non-reproductive cycles. The endogenous mechanisms of capitalism work correctly during reproductive cycles, the long wave upswing, business cycle fluctuations are recovered automatically. This is because the right institutions, the right SSA, provide a stable environment. Every upswing phase has its own unique SSA built from economic, political and social elements. This does not apply to non-reproductive cycles, the downswing phase of the long wave. The downswing starts when the SSA is exhausted and will end when institutional reforms have taken place and a new SSA has emerged.

The French Régulation school sees the development of capitalism as a consecution of periods of crisis and periods in which a regularity of social and institutional relations and structure can be observed. Economical history is hereby divided in two parts. Each upswing has its unique set of coherent, predictable and analyzable rules, an accumulation regime, which makes a harmonious development of the system possible. During a crisis the economic rules don't function any more and the economy is unable to recover by itself. Whether the recession is controlled depends on the outcome of the class struggle and the political choices which are made.

War and Hegemony: to which belong among others Goldstein (1985). He states that there is a twofold causal relationship between economic growth and large wars. There are only enough resources for a large war during a period of economic prosperity. International competition is thereby intensified in the expansion phase which causes conflicts. The growth period will eventually come to halt because large wars weaken long-term production growth significantly. Wars after all devour raw materials and production resources.

Goldstein also distinguishes a longer hegemony of hundred fifty years which is completely autonomous of the economic wave of half a century. There are three hegemonic schools: Modelski's leadership cycle school, Wallerstein's world system school and the power transition school.

Of course the critics should also be heard:

The critics: to which belong among others the Russian authors collected by Garvey who criticized Kondratieff: Oparin, Eventov, Bogdanov, Granovski, Gubermann and Gerzstein. Furthermore Kuznets, who reviewed Schumpeter's work, Solomou who had a discussion with Kleinknecht and Rosenberg and Frishtak who developed universal criteria which a scientifically solid long wave theory must satisfy.

Finally also the econometric debate must be considered. It is of essential importance that the long wave is also examined empirically. The long wave would be nothing more than an empty shell if the authors limited themselves only to the development of theories. Through the years many different econometric methods have been used which often has led to heavy criticism and fierce discussions.

The Econometric Debate: visual inspection, moving averages, growth rates and linear regressions, trend elimination, identification using shorter business cycles, the binary spilt method, orthogonal polynomials, spectral analysis and other contemporary methods will be discussed. A multitude of waves and the problem of perspectivistic distortion will also be looked into. Furthermore we take into account the research done by Kuczynski, Haustein and Neuwirth, Solomou, van Ewijk, Tylecote, Dupriez, Imbert, Mandel, van Duijn, van der Zwan, Bieshaar and Kleinknecht, Berry, Metz, Gordon, Brill and Reijnders and give some attention will be given to the overview work of Goldstein (1988)

The journey trough the history of the debate can now begin: "Where shall we begin?", the red queen asked. "Begin at the beginning", answered the Dodo (Lewis Carroll).

2.2.3 The Pioneers

The long wave debate did not, as many think, start with Kondratieff but has a long history which can be traced back to the nineteenth century. The theories of the most important forerunners will be discussed here.

Hyde Clark

Hyde Clarke (1847) worked at the British Railways and was convinced he found a long cycle in data tracing back to the year 1004. He investigated periods of famine, good and bad harvests and the price movements which belonged to these variables.

He concluded that a period of 54 years expires between each crisis. Hyde Clarke did not give an explanation for these cycles but observed that there existed great parallels between the characteristics of the different cycles. As a curiosity he mentioned the findings of a certain Mackenzie who made prize predictions for crops based on a surplus or shortage of west wind and a surplus or shortage of east wind. Mackenzie had access to price ranges which went back to the year 1202. The cycle measured in wind fluctuations lasted 54 years.

Jevons

Jevons (1835-1882), an economist who was most famous for his contributions to neoclassical micro-economics, also occupied himself with macroeconomic relations in econometrics. He was especially interested in the discovery of the causes of trade and other economic cycles which cause fluctuations in prices. Because he couldn't find a satisfying explanation within the economic realm he looked for it outside. His hypothesis stated that fluctuations of economic cycles were caused by the weather. He explained these weather cycles by relating rainfall to the fluctuating activity of the sun. Perhaps he was aware of the Hyde Clarke's findings. Eventually he concluded that there was no single cause responsible for the alternating periods of rising and falling prices.

Juglar

Juglar (1819-1905) wrote in 1862 in his book "Des crises commerciales et de leur rétour périodique en France, en Angleterre et aux Etats-Unis" that the wave was not caused by forces from outside the economy but from within, hereby indicating that endogenous explanations could be found. Juglar divided the wave in three phases: a period of progress, crisis and liquidation. He didn't formulate an explicit theory but presented historical and statistical data. The emphasis was put on an economic reasoning in combination with a careful analysis of the historical and institutional events. The waves found by Juglar had a length between 7 and 11 years. Juglar's approach to the problems was used as an example by the later institutional or reasoned statistical approach of economic data.

Marx

Thomas Kuczynski (1987) elaborates on how Marx and Engels looked at long waves. He created a historic reconstruction of their thought and tries to reduce a long wave theory. Marx and Engels thus never explicitly formulated this theory themselves.

Whether or not Marx was really on track of the long wave cannot be said with certainty and is also not completely uncontroversial. Freeman (1996), for instance, doubts the authenticity of Kuczynski's reconstruction: "It must be said however that his (*Kuczynski*) plausible reconstruction of this Marx-Engels theory relies more on his own interpretation of the implicit significance of a series of unconnected statements than on an explicit exposition by Marx or Engels themselves." It is still useful to follow the train of thought Kuczynski attributed to Marx because the basic elements return in the workings of later authors who did explicitly investigate the long wave.

The decreasing tendency of the ' rate of profit ' is according to Kuczynski the basis of the assumed long wave theory of Marx and Engels[4]. The most important instrument of the capitalists to slow down this decreasing tendency is technological progress. However, as more technological improvements are applied the positive economic impact will decrease. Capital will be applied differently when incremental changes are no longer enough to thwart the decrease of the rate of profit.

Because of the disappointing profit possibilities basic innovation become an interesting alternative in adverse economic circumstances, despite the higher risk involved with these kinds of radical projects. A successful basic innovation can after all be very profitable for the original innovator and especially for quick imitators. For a certain period they will be able to realize a higher rate of profit than the average rate

[4] Marxism uses its own terminology. Three core concepts will be briefly commented on below:

- 'Value' is equal to the sum of 'Constant Capital' (all non-labor costs), 'Variable Capital' (costs of labor) and 'Surplus Value'. Increasing the Surplus Value is the goal of the capitalist.
- The 'Rate of Profit' (de profit margin) is the Surplus Value divided by the sum of Constant and Variable Capital.
- The 'Organic Composition of Capital' (the capital composition of a company or industry), is equal to Constant Capital divided by the sum of Constant and Variable Capital. The higher the value of the Organic Composition of Capital, the more capital intensive an industry is, the lower the rate of profit will be.

of profit. Here Kuczynski traces the depression trigger argument which officially was developed much later by Mensch, to Marx.

The higher rate of profit obtained by the followers in the market forces, the lagging entrepreneurs, whose margins are pressured more and more, to also adopt the technology. The diffusion of this new basic technology takes its time because profitability must be proven first and a restructuring of the use of capital must take place. The result of the diffusion process is that the profit surplus decreases slowly and the general profit level reaches a new level. Then the cycle starts again.

Another crucial variable in Marxism is the concept of the reserve army of the unemployed. Classic economic theory states that accumulation of capital leads to a larger demand for labor and therefore to an increase of the real wage costs. This will eventually lead to a decrease of the profit. However, the Malthusian population doctrine states that in practice wages will not continue to rise until the profit is completely reduced to zero. Each increase of the wages leads by means of an improvement in the living standards to an increase in population growth. This increase eventually also leads to an enlargement of the working population. The increased supply of labor will bring the wages back to the subsistence minimum.

Marx broke with classic economic theory and the Malthusian population doctrine. According to him within the capitalist system wages can fluctuate between a psychologically determined minimum value and a historically determined maximum. An increase in capital accumulation leads to an enlargement of the demand for labor in Marx's model. When the wages now rise, however, it is prevented that the accumulated surplus value and profits decrease to the minimum. According to Marx there will always be a labor surplus in the market which has a moderating effect on the wages and keeps the surplus value and profits positive.

This labor supply surplus does not arise from population growth but is permanently present in the capitalist system. The surplus exists from laborers who are replaced by machines and cannot find a new job directly, young people who've just finished their education and housewives who enter the labor market because their responsibilities at home have changed. The reserve army of the unemployed keeps the wages down in a

competitive market. This principle plays a crucial role in Marxism. The size of the reserve army and the profit and wage level vary within the given margins with the business cycle. Wages rise and the reserve army diminish during periods of expansion of business activities and accumulation of capital. This increase in wages leads to a reduction of the profit margins. Labor will be substituted by machines to compensate for the loss. This is how the reserve army is refilled with new unemployed people who will eventually cause a decrease in wages and therefore a recovery of the margins.
Kuczynski makes the following remark about the endogeneity of Marx's long wave theory: "These ten points summarize a purely endogenous theory of long waves, so we have to conclude that if nothing happens on the political scene, i.e., if there are no revolutions, wars, etc., a new upswing will occur." This claim seems contradictory to what the Marxist law of the falling tendency of the rate of profit. After all, Kuczynski states that the falling tendency of the rate of profit is systematically thwarted by an endogenous mechanism. In Kuczynski's view only exogenous forces such as a revolution can lead to the demise of the capitalist system. Marxist economists such as Mandel state that the capitalist system will cave in to the pressures of the internal contradictions and that exogenous impulses such as war can temporarily suppress these laws which enable an upswing.

The question remains whether the Marxist elements and laws described here apply to the long wave, such as Kuczynski claims, or that they take place in shorter period of time.

Some other Marxist principles also play an important part in several theories from later long wave researchers. Marx's ideas about the periodic replacement of capital goods, his so-called echo theory, were used later on by Kondratieff as a possible explanation for the long wave. In this particular theory the long wave arises from the replacement of capital goods with a long life span such as industrial terrains, buildings, bridges, shipyards and railway material. The length of the wave is determined by the life span of the capital good, about 10 years in Marx's age. Waves are endogenous in the echo model after they have been started by an exogenous impulse.

Tugan-Baranowsky

Tugan-Baranowsky (1865-1919) emphasizes various principles in his book "Industrial Crises in England" (1894). The first is that economic fluctuations are inherent to the capitalistic system because they are the result of forces from inside the system. According to him economic prosperity is mainly due to the expansion of international markets. This expansion is caused by an increase in free trade and improvements in the transport system. The second is that the most important causes of the waves can be found in the forces which determine the investment expenditures. He was influenced most by Juglar and specially Marx. These principles which emphasize the inherent stability of capitalism and the role played by investments have influenced many economists in history including modern Keynesian analyses.

Parvus

Parvus is the pseudonym of a Russian Marxist and theoretical socialist named Alexander I. Helphand (1867-1924). In 1901 he wrote about waves as being a continuous motion. These waves are not necessarily regularly and periodic but a period of long economic expansion can possibly be alternated with a periods of economic contraction. After every depression period there will start the next period of expansion. The factors held responsible for the wavelike movements by Parvus are the opening of new markets, an increase in gold production and the development of electricity. Parvus influenced Trotsky and was also acknowledged by van Gelderen. Van Duijn (1983) remarks that Trotsky (1923) in fact borrowed his idea that the long-term capitalist development followed a wavelike movement. Parvus writes: "There are points in time when the situation in all spheres of the capitalist economy – in technology, the world market, in commerce and in the colonies – has matured to the degree that an important extension of the world market becomes inevitable, which places aggregate world production on a new more comprehensive basis." This according to Parvus, is the beginning of the period of *Sturm und Drang* of capital, which wavelike movements can be recognized. The upswing will be stronger than the crisis and will last shorter. This will continue until all the development potential has been used. Then the sharpest crisis will break out and this crisis will alter itself into an economic depression. This period will be characterized by a slowing down of economic development, the expansive waves will become less powerful and the crisis goes on while production has a hard time recovering. This will continue until a new period of *Sturm und Drang* develops. The above is not seen as a theory but more as factors accompanying the *Sturm und Drang* period. Parvus also did not publish the historic turning points and did not give an explanation for their existence.

Van Gelderen

As previously indicated many authors have occupied themselves with the long wave before van Gelderen wrote his article about the long wave phenomenon. They did, however, engage more in making observation than in creating theories. The inspiration which underpinned his first article, originated from the desire to find an explanation for the strongly expanding economy. Maybe typical for the Dutch perception of an economic expansion the Dutch economist J. van Gelderen chose in 1913 "Springtij" as the name for his article which he published under the pseudonym J. Fedder in "De Nieuwe Tijd", the monthly magazine of the Dutch Social Democrats. In this article he attempts to create a theory which describes the long wave phenomenon. Because of this he is considered to be one of the pioneers in the research area which is nowadays known as the long wave, even before Kondratieff.

Van Gelderen (1913) starts his description of the wave movement at the point were production is diminished severely due to the crisis. There is a lack of market demand and product prices stay low during the entire phase. Low profits, low wages and mass unemployment are the consequences. Capital which was saved from the collapse will be pulled back form the industries and entrusted to large banks or used to buy state bonds. The cash supplies of the banks grow and the interest rate stays low.

After a while the hunger for new profit possibilities awakens. Entrepreneurs look for new economic possibilities and technological improvements. Cheap credit comes in handy in this process. Decreasing prices create new demand and markets are being chased with more energy than ever before. New activities begin. New geographical areas and industry sectors are being developed. Companies are established and grow and the stock market has new quotations and issues of shares. Both the gold production and employment rise.

Subsequently, the production of goods rises, unemployment diminishes and wages rise. The demand for raw materials and foodstuffs increases, prices rise and a new confidence arises which stimulates production even more. This process accelerates to an enormous growth with great activity, large profits, high interest rates, high prices for raw materials and it becomes more difficult to arrange credit. The increase of production accelerates faster than the demand for goods and creates scarcity in raw materials which also raises their prices. Then the prices of the final products rise, demand decreases, the margins are pressured, stocks increase, profits diminish and the economy becomess stuck in another downfall.

The demand for raw materials decreases, production diminishes and the prices of final products go down. Profits are low and investments find a low. Unemployment increases. Money is no longer invested in companies but is put away at banks. The interest rate is low. After a while the hunger for profit will yet again reawaken, entrepreneurs will find new economic possibilities and technological improvements and will, aided by cheap credit, search for new markets. Thus starting the whole process again from the start.

Van Gelderen's theory has many ideas which would later be incorporated by other authors. He, for instance, already describes the role of new industries and new technologies which characterize the fast paced and forward moving long wave upswing. Van Gelderen also mentioned the importance of the availability of electricity and the effects this had on the development of industries and demand and price implications this had for the consumers. The role played by the railways in a later phase of industrial development is also indicated. Van Gelderen saw the development of new areas and colonization as a positive impulse for further investments and trade. In light of later discussions it is important to remark that van Gelderen interpreted the explanations for the long wave as being exogenous factors, thus coming from outside the economic process.

Van Gelderen's contribution started the real long wave debate. Because the article which was published in the socialist journal was written in Dutch it remained largely unnoticed in the international debate for a long time. In 1996 van Gelderen is reappreciated when this article is translated by Bart Verspagen and acquires an honorary place in “The Long Wave Theory”, Freeman’s large overview work with original contributions.

2.2.4 The Debate Begins

Kondratieff

The actual long wave debate seems to start with Kondratieff in 1925. Kondratieff stated that the dynamics of economic life in the capitalist system is not linear but has a complex cyclical character. He concluded in his empirical research, in which data from England, France, Germany and the US were used, that long waves with an average length of 50 years exist in prices and other variables such as interest rates, wages, consumption, foreign trade and the production of coals, pig iron and lead. According to him these long waves were inherent to the capitalist system. He also stated that the timing of these long waves is just about synchronized internationally. From 1780 until the 20’s of the twentieth century Kondratieff recognized two and a half long wave cycle.

The long wave was considered by Kondratieff to be an independent phenomenon. Changes in technology, wars and revolutions, the assimilation of new countries into the world economy and fluctuations in gold production were seen as consequences of the wave, thus as endogenous. Kondratieff recognized the following characteristics of the long wave.

- During the long wave upswing the years of expansion form the majority while during the long wave downswing the years of depression dominate
- The agricultural sector is hit by a particularly heavy and long depression during the long wave downswing
- Many important discoveries and inventions concerning the areas of production techniques and communications are made during the long wave downswing, but in general they not applied on a large scale until the beginning of the next upswing phase

- At the beginning of the upswing phase the gold production usually increases and the world market becomes enlarged through the assimilation of new countries, mainly former colonies
- Most great wars and revolutions take place during the long wave upswing phase

Kondratieff indicated that he formulated this theory in the period between 1919 and 1921 and published it in 1922. He writes he was unaware of van Gelderen's work. In 1926 he was first informed about its existence when he read an article by the Dutch Marxist de Wolff which referred to van Gelderen's article.

Only in his later work did Kondratieff attempt to also explanation the long wave theoretically. The need for profitable accumulation was considered by Kondratieff as the engine of capitalism. He used Marx's echo theory in which the replacement of worn out fundamental capital goods and infrastructure is essential in the explanation of the movements of the long wave. Kondratieff also used Tugan-Baranowsky's theory about the availability of credit. The mass replacement of capital goods can only take place when sufficient savings are accumulated during the long wave downswing. The investment boom increases the demand for capital which in turn increases the price of capital. Eventually capital will become so expensive that investments will diminish and the long wave down turn begins. During this period the price of capital will decrease until the circumstances become suitable again for a new wave of mass replacement investments.

Important innovations cannot diffuse in Kondratieff's theory until sufficient capital is accumulated. When this is the case a demand for the new innovation will arise to replace the old capital goods and infrastructure. Kondratieff thus recognized the influence of the commercialization of scientific discoveries on the economy but innovations were also seen as being an effect and not as a cause of the cycle.

Kondratieff used Marshall's theory which states that equilibrium can be reached in different ways to explain the simultaneous existence of different types of cycles.

The Russian Critics

Kondratieff's paper was heavily criticized directly after publication. Garvy, an American who was originally from Russia, published a compilation of the various criticisms in 1943. These early criticisms were made by Kondratieff's own co-workers. The criticisms encompassed both methodological and theoretical aspects; the logic behind the decomposition of the time series, the significance of the results, the regularity of the long waves and Kondratieff's hypothesis which explained the long wave.

Oparin and Eventov argued that statistical methods could only be applied in combination with a theoretical concept. Oparin criticized Kondratieff's statistical methods because a trend decomposition could only be applied when it represented the schematic equilibrium. He also made his own calculations and came up with different curves. Barazov had argued before that Kondratieff's methodology did not lead to a clean separation of the trend and Eventov was convinced the decomposition implied the independence of different movements. Bogdanov added that the long waves were the result of the statistical methods which were used. Oparin, Granovsky and Guberman concluded that long cycles could be observed in price time series from the 19th and 20th century but not in the other time series so that there was no compelling evidence for Kondratieff's claims.

Leon Trotsky was one of Kondratieff's most important critics. He acknowledged the existence of the long wave but did not assign a cyclical character to them. Trotsky emphasized that long waves were unique historical periods which were determined by political factors such as revolutions. The long wave movement has its origin in the super-structural order thus not come about endogenously but exogenously. Consequently long waves are therefore not inherent to capitalism. This implies that the economic progress of the capitalist system would stop if the capitalists lost their political power. Trotsky (1923) was convinced that the concept of long wave was as presented by Kondratieff would lead to nothing: "As for those large phases of the trend of the capitalist evolution (of 50 years) for which professor Kondratieff incautiously suggests use of the term 'cycles', we must stress that their character and duration are determined not by the internal dynamics of the capitalist economy, but by the external conditions which constitute the framework of capitalist evolution." His own long wave theory contained a consecution of long linear downward and upward sloping trends of unequal length and angle.

Kondratieff held the opinion that the replacement of capital (echo theory) was not a continuous process and a periodicity could be recognized in it. This view was also criticized. How could after all different life cycles of different types of capital goods form one life cycle? The monetary aspects were criticized by Gerzstein who wondered why the application of new inventions could only take place when credit was widely available. Kondratieff did not foresee an expansion of credit possibilities and stated that this delayed the application of inventions. This was not thought to be realistic.

This fierce criticism should also be seen in the context of the then present situation in which Soviet leaders were convinced the Western capitalist system would collapse automatically after World War One. Kondratieff had an unpopular message: the capitalist system will recover from the downward development between 1914 and 1920 because eventually there would always be a new upswing. Kondratieff's obstinacy in his viewpoints led to his departure in 1928 with the "Business cycle Institute" which was once founded by him. Later on he was arrested and after a (fake) trial exiled to Siberia where he died.

Garvy concludes: "Thus Kondratieff's entire theoretical construction emerges as, after consideration, as extremely unrealistic." Van Duijn (1983) writes that all of Kondratieff's work is surrounded by a negative image. His statistical methodology was criticized, his theory rejected and the political implications of his work eventually ruined his professional career and even cost him his life. Because of all this criticism for most economists Kondratieff's long wave remained nothing more than a price cycle without any theoretical groundings until at least the early 1970s.

Schumpeter

In 1929 Rolf Wagenfuhr was the first to pay attention to Kondratieff's findings and the vast criticism of his work in German. Simon Kuznets translated Kondratieff in 1930 in English, Jenny Griotti-Kretschmann in 1933 in Italian and Jurgen Kuczinsky in 1934 in German.

It is remarkable considering the criticism on the Russian Kondratieff that Austrian born Harvard professor Joseph Schumpeter after reading the translations picks up the ideas about economic waves and describes them in his 1939 book *Business Cycles: A Theoretical, Historical, and Statistical Analysis of the Capitalistic Process*. After all, until then mostly only Marxists and Socialists tried to explain the workings of capitalist system.

Schumpeter (1939) was the leading figure in the development and promotion of the long wave theory in the period before World War Two. It was him who connected Kondratieff's name with the long wave for good. They did however use a different approach; Schumpeter worked deductive (theory before empirics) while Kondratieff worked inductively (empirics before theory). Furthermore Schumpeter applied Walras's general equilibrium concept while Kondratieff used Marshall's partial equilibrium theory.

Schumpeter distinguished three different waves which he named after their discoverers; the Kitchin cycle[5] with a length between 3 and 5 years which was

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[5] The Kitchin supply cycle was discovered in 1923. Kitchin found a pattern of fluctuations from three to four years. The explanation was as follows. Businesses had to little supplies of raw materials, parts, half fabricates and final products after a recession. In their desire to bring their supplies back on level they created a demand which influenced the entire economy. This demand created more demand hereby increasing the influence on the economy. This lasted until companies found out their expansion was too exuberant and they lowered their supply orders and decreased their output which would pull the economy in a downfall, decrease demand and leave the businesses with to much supplies. The Kitchin cycle was considered to be an endogenous cycle, Tylecote (1992), and was not criticized very much because the relatively short cycle was found abundantly in the period investigated by Kitchin which proved its existence. It is according to Tylecote (1992) unlikely that the cycle stills exists in its original form but it is possible that its character has changed over the years and the cycle can be found in an alternative form. He for instance refers to the four year presidential cycle in the US. The Juglar cycle is also thought to have lost its original form by now. Although van Duijn (1983) indicates it is still active in the US

determined by investment in supplies, the Juglar cycle which has a length between 7 and 11 years and which is determined by investments in machines and finally the Kondratieff long wave of approximately 60 years in length. Schumpeter hypothesized that one Kondratieff contained six Juglars each of which could be decomposed in three Kitchins (see figure 1).[6] These autonomous waves could operate at the same time because every innovation, the engine behind the waves, has a different impact. Schumpeter divided the Kondratieff in four phases[7]: *Prosperity, Recession, Depression and Recovery*. In the schematic representation of the long wave depicted in figure 1 Schumpeter used a Kondratieff with a length of 60 years.

The first phase of the cycle is called *Prosperity* by Schumpeter and runs from the middle value of the cycle, here the horizontal axis, until the peak. The part from the peak back the middle value is called *Recession*. From this point downwards to the minimum is called *Depression* and back up to the middle value again is called *Recovery*. After this a new cycle starts

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[6] Schumpeter's concept of multiple cycles will be discussed more extensively in chapter 3

[7] Fels (1964) states some stylized remarks can be made with regard to the different stages of the long wave in Schumpeter's analysis. It should moreover not be forgotten that external factors will always be of influence.

-*Output of consumer goods* increases the most during the recession and the recovery phases

-*Output of producer goods* increases the most during the recovery and prosperity phases and decreases (of increases less) during the recession and depression phases

-*Output* always increases except during deep depression

-*Prices* (consumer goods) rise during the prosperity phase, go down during the recession phase (with more than the previous increase) and finally a partial (not full) rise during the recovery phase

-*The interest rate* undergoes a delayed rise during the prosperity phase, a comparable fall during the recession phase, a further decline during the depression phase and finally a rise towards the equilibrium value during the recovery phase

-*Employment* increases with diminishing speed during the prosperity phase, decreases with increasing speed during the recession phase, the maximum speed of decrease is reached during the depression phase and there will be an increase to the equilibrium value during the recovery phase

-*Expenditures* increase during the recovery phase, increase with more than total output during the prosperity phase, decrease during the depression phase and decrease slower than total output during the recession phase

-*Trade (when all other countries are considered static)* there will be a decrease of exports and an increase of imports during the prosperity and recovery phases and a increase of exports and a decrease of imports during the recession and depression phases

-*The stock market* reacts faster than the business world, has an upward trend during the last part of the recovery phase and during the prosperity phase, the downward trend starts at the last part of the prosperity phase which will continue during the recession and the depression phases

-*Total employee wages* has the strongest increase during the prosperity phase (this will however not always be recognized). The *individual wage* has a delayed during the prosperity phase and a delayed decrease during the entire downswing but there does not always have to be a decrease during the recession phase or even during the depression phase. The *real wage* increases more during the recession, depression and recovery phases than during the prosperity phase.

Figure 1, taken from: Schumpeter, J. (1939), Business Cycles: A theoretical, historical and statistical analysis of the Capitalist process

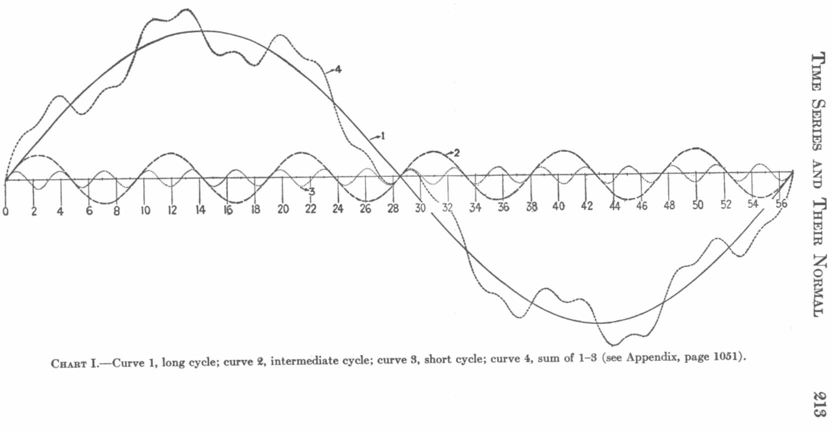

CHART I.—Curve 1, long cycle; curve 2, intermediate cycle; curve 3, short cycle; curve 4, sum of 1–3 (see Appendix, page 1051).

In his analysis Schumpeter focused himself on the economic life. In spite of this he did realize that the social process, of which the economy is only a part, is actually one inextricable linked whole. He distinguishes between factors of change which can be seen as being inherent to the capitalist system and some exogenous factors such as wars, revolutions, social unrest, government policies, natural disasters and the production of crops. The external events make, in combination with a variety of endogenous technological innovations (the engine of the long wave), every cycle unique. Equilibrium thus can never be reached because the economic life is subject to constant changes, both small and revolutionary.

Radical basic innovations were considered by Schumpeter to be the engine of the long wave upswing. These important innovations were distributed discontinuously in time, thus not via a random walk. He saw innovations as the “durchsetsung neuer Kombinationen.” Innovations should not be confused with inventions. An invention is the successful economic application of an invention. Schumpeter recognized five types of innovation; the introduction of a new product, the introduction of a new production method, recognizing and opening a new market, using a new raw material of half fabricate and finally introduction of a new form of organization.

In Schumpeter's view big important innovations are done by skilled entrepreneurs who do not shy away taking risks. These entrepreneurs are driven by good profit prospects. The availability of credit is a necessary condition for success. Important innovations appear in clusters during the prosperity phase. The grouping of innovations arises because after the successful introduction of one innovation it becomes easier for other entrepreneurs to also succeed via imitation and by means of making small improvements. This way a leading sector arises which will spread the innovation throughout society is able to push the whole economy forward.

The inevitable downturn of a period of prosperity sets in when the profit possibilities deteriorate and eventually exhaust because of market saturation. This happens because of the increase in the number of suppliers of the "new" innovation. The increased demand for means of production and raw materials will lead to a price increase whereas the price of the innovation itself will decrease due to the increased competition. Costs rise while revenue decreases. A pessimistic mood arises and the recession becomes a depression. According to Schumpeter there is, however, also a positive side to depression, after all, in this phase only the most efficient companies will survive. Eventually an entrepreneur with a new innovation will lead in the new upswing.

Kuznets

Schumpeter also had to face some criticism. Simon Kuznets's critique, which is accepted by long wave researchers as being justified criticism, can be summarized in the following points:

- Schumpeter did succeed in proving that 40 to 60 year fluctuations repeat themselves with a reasonable extent of simultaneousness in the movements of the various important aspects of economic life. Kuznets stated that Schumpeter did not sufficiently answer the question why the heroic entrepreneurs introduce an innovation exactly every half a century.
- Schumpeter's explanation of the long wave states that clustering of important innovations takes place in certain periods, which is not proven empirically.

- Schumpeter does not give a convincing explanation why the supposed grouping of radical innovations takes place.
- Another criticism by Kuznets was that everyday many innovations are created but that none of them have an impact which is far reaching enough to carry a whole cycle of economic development. He considered the railways to be the only possible exception to this rule.

Kuznets did not entirely reject Schumpeter's theory, despite his criticism. He simply determined that Schumpeter's argumentation was faulty or incomplete on certain points. The questions he raised remained unanswered for a long time until the (neo) Schumpeterian economists picked up the points of criticism. Fels (1964) tries to indicate that Schumpeter's model is not dependent on heroic entrepreneurs who introduce new radical innovations every 50 years. Mensch (1975/1979) investigated the clustering hypothesis which led to a new discussion within the innovation school. Freeman, Soete and Perez (1983-2002) tried, among others, to prove that carrying radical innovations actually did have far reaching economical and social consequences. Meanwhile several authors have attributed and agree that the Kuznets[8],[9] critique has now, at least partly, been refuted.

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[8] Kuznets himself was also on track of long waves. In his early work Kuznets found long-term trends in output and prices of some important industries, the life cycles of technological innovations or the use of new land followed fast but slowing down increases in output and fast slowing down decreases in prices. Comparable developments in time were also found in agricultural and raw material sectors. Kuznets furthermore discovered that movements in prices round their long-term trend preceded movements in output, which supposes a role for price movements in moving productive resources between sectors and in the time.

[9] Kuznets became famous, however, with his later work in which he found the so-called Kuznets cycle. This cycle was accepted by economists because there was sufficient data material present, just like the Kitchin cycle. The Kuznets cycle is related to investments in construction and has a length of 15 to 25 years. His empirical research led Kuznets to the conclusion that American population growth, with as most important exogenous factor the immigration ratio between the 1870s and the 1920s, determined fluctuations in the construction of houses and investments in the railways. There was moreover a debate about the exogenous explanation of the cycle concerning the heavy emigration from Europe to the US. Did emigration cause the upswing or was the upswing already taking place and did it trigger the immigration boom because of the good economic outlook?

2.2.5 Conclusion

The discussion concerning wavelike movements in the economy can be traced to the work of 19th century researchers such as Hyde-Clarke, Jevons, Juglar and Parvus. The Dutchman van Gelderen is considered as being the godfather of long wave research. The subject of the long wave however was really put on the research agenda when in 1925 in the USSR Kondratieff published his article "the Long Waves in Economic Life". Schumpeter was inspired by the ideas of the Russian, despite the fact that the research was heavily criticized. He created his own theoretical argumentation in which entrepreneurs play a central role. Kuznets formulated some points of criticism in his otherwise mainly positive review of Schumpeter's "Business Cycles".

With this overview of the origins of the long wave debate we have a solid basis for the contemporary discussion which will be presented in section 2.3

Chapter 2.3 The Contemporary Long Wave Debate (post 1950)

2.3.1 Introduction

The long wave discussion regains momentum in the 1970s and 1980s after a stalemate in the 1950s and 1960s. The theories which have been developed during this period will be discussed in the following section. After a short overview of the events in the 1950s and 1960s Mandel's thoughts on long waves, the most important Marxist author, will be discussed. The ideas of the Schumpeterians and Neo-Schumpeterians will also been taken into consideration. Mensch, Kleinknecht, van Duijn, Freeman, Tylecote and Perez have dominated these schools of thought. Furthermore Rostow, Forrester, Goldstein, Gordon and Boyer each made a contribution from a different perspective. As the discussion progresses the differences between the schools of thought become smaller and more hybrid theories which integrate principles from all schools arise.

2.3.2 The 1950s and 1960s

In the 1950s and 1960s the interest for the long wave faded. The development of the economy went well, the Second World War was over and people were looking ahead. During this period the prices for raw materials rose. This was not seen as objectionable because the increase in the final good prices made the consumers pay. The interest rate also went up, first slowly later on faster. Were we dealing with the "frohes zukunft glauben" about which van Gelderen already wrote in 1913? Anyway, for the long wave debate it was a relatively quiet period. The economists who were in the spotlight in those years were for instance Milton Friedman, Paul Samuelson, Kenneth Arrow, John Kenneth Galbraith, Robert Solow and Ronald Coase.

Some authors like Belgians Imbert and Dupriez nevertheless did occupy themselves with the problem of the long wave. Dupriez observed that time series based on prices gave better results then time series based on other data. He meant that price developments caused the course of the other waves. Dupriez developed a monetary explanation.

Imbert investigated long waves from the year 1300 onwards. His theory stated that the combined influence of war and innovation caused the long wave. Innovations cause an increase in production and with some delay a rise in prices. Dynamic industries play a leading role in the economy. This economic expansion will, however, inevitably lead, via an increase in international competition and colonization, to war. Money which was originally going to the entrepreneurs is now spend on the tax raise the government needs in order to support the war. This is how the economy becomes dependent on war expenditures. In the short run this will have a stimulating effect but eventually the war will destroy so much physical and human capital that the economy will stagnate and the long wave decline will set in. Then people have to wait until the climate is sufficiently stabilized so that a new innovation wave can push the economy back up. It should be noticed that Imbert claims to opposite of Trotsky. Wars cause the decline of the long wave and not, like Russian claims, the upswing. Although they originally were supported by historical data these claims don't apply to modern times very well.

2.3.3 The Debate from the 1970s onwards

Mandel and Mensch took the initiative to revive the debate in the 1970s. Mandel suggests that the next depression is at hand and Mensch wants to close the holes in Schumpeter's theory. This completely brings back the attention for the debate. In the 1970s the debate becomes more intensive because of the increased number of participants, because of the number of different approaches, the introduction of factors from outside the domain of economic science and the introduction of new models, methods and techniques. The debate becomes fierce when new attempts at theory building are criticized because others refute the evidence. Findings and argumentations which reject the existence of the long wave lead to new examinations and theories.

The character of the debate changed during the course of time. In a paper by van Duijn it can be read that in the 1930s six publications focused on gold and monetary variables, four on war, two on innovations and one on raw materials and agriculture. At the 1985 conference in Weimar (Vasko, 1987) eight publications on the topic of technological revolutions were presented, three were about the role of financial and monetary variables and one about investment behavior and innovation.

The debate keeps on moving for 30 years and meanwhile according to some authors the next, according to most the fifth Kondratieff will emerge somewhere around the turn of the millennium.

The following authors will be discussed: Mandel, Mensch, Kleinknecht, van Duijn, Rostow, Forrester, Goldstein, Gordon, Boyer, Freeman, Tylecote and Perez.

Mandel

Trotskyian Marxist Ernest Mandel uses an asymmetric approach in his long wave theory. He explains the upswing phase exogenous whereas the downswing is givens an endogenous explanation. This deviates from orthodox Marxism. According to Marx capitalism will eventually inevitably collapse due to the internal contradiction of the system. In his analysis he thus only uses factors which are endogenous to capitalism. Mandel, however, states that according to Marxism the inherent laws of capitalism, such as the falling rate of profit can temporarily be opposed by exogenous factors. This can postpone the collapse. The other elements in Mandel's analysis can directly be reduced to Marx. He is, for example, in agreement with other Marxist schools of thought, emphasizes the interaction between, political, social and economic factors in a continuously changing society.

According to Mandel a capitalist economy can get out of a depression when a combination of exogenous factors interrupts the falling tendency of the rate of profit and temporarily makes it rise. This rise in the rate of profit leads to an increase in production and thus to an acceleration of capital accumulation. A capitalist after all will never invest until the rate of profit is sufficiently high and is expected to stay on the desired level. Thus there will only be invested in radical innovations when the profit expectations are favorable enough. Technological change, in Mandel's analysis not the cause of the long wave upswing but a consequence, enables the rise of the rate of profit and thus the long wave expansion to persist. The new technology also temporarily enables the possibility to earn monopolistic profits. An increase in demand is furthermore needed to create a favorable growth climate.

The large numbers of immigrants which are attracted by the positive development of the economy also contribute to the force of the upswing. They complete the reserve army of the unemployed, which enables the capitalists to keep the wages down. The organic composition of capital increases during this phase of the long wave because the capitalists will invest in more capital intensive technologies. The rate of surplus value also rises because the productivity increase surpasses the increase in real wages. The growth of the rate of surplus value is initially larger than the increase in the organic composition of capital which enables the rate of profit to keep increasing.

The reserve army of the unemployed will eventually dry out due to the increase in the demand for labor. The low unemployment increases the negotiation power of the laborers which will rapidly increase the real wages. There will also be an end to the revenue generated by the new technology. The rise of the rate of surplus value will decrease or even stagnate. When this is the case the effect of the increasing organic composition of capital will dominate. The rate of profit will decrease, capital accumulation will diminish and a new depression will begin. According to Mandel the process which leads to the depression is inherent to the internal contradictions of the capitalist system.

It is important to realize that the exogenous factors in Mandel's long wave theory which cause the increase in the rate of profit, which in turn eventually will help a capitalist economy out of a depression, are non-economic forces. With this he means changes in the social environment such as wars, imperialism, losses of the labor movement with respect to the capitalists (supported by technological developments) and sharp increases in gold production. Mandel furthermore states that the class struggle does not have a cyclical character but is relatively independent from the economic circumstances. The class struggle should reach its peak during the end of the long wave upswing phase.

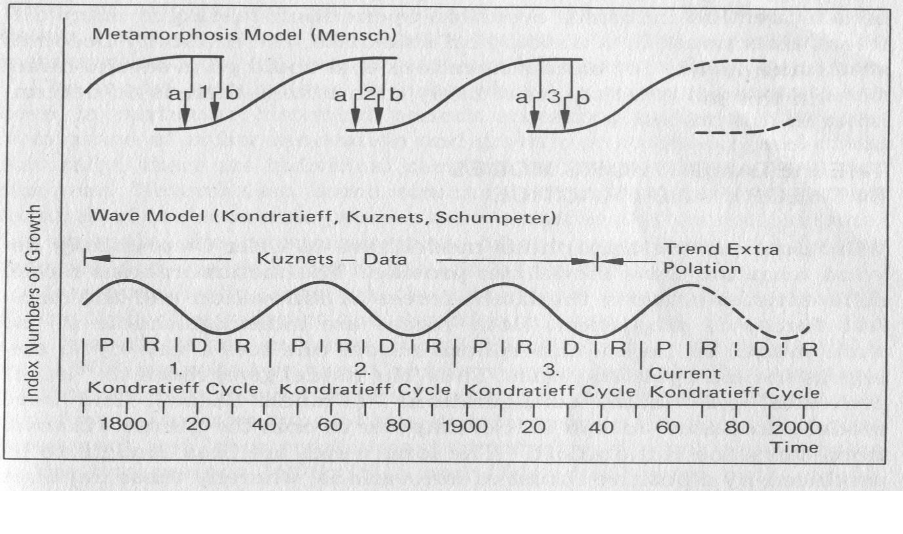
Mensch

Gerhard Mensch gave an adaptation of Schumpeter's theory. He provided an explanation regarding when and why basic innovations cluster. Mensch stated that basic innovations appear in groups during the depression phase just before the beginning of the upswing phase because in this period entrepreneurs are more inclined to undertake radical projects.

Just like in Schumpeter's theory basic innovations cause the long wave upswing. Inventions are considered to be exogenous in Mensch's theory, they happen randomly as a result of scientific progress. The economic implementations of inventions, innovations, reach in a stalemate during the expansionary period of the long wave. Innovations, which thus are endogenous, will only break through in the market at the end of the depression phase. The innovation process thus is not smooth and continuous. The diffusion, the breakthrough of the cluster of innovations happens during a very short period in the depression phase.

Figure 2, taken from: Mensch, G. (1979) [1975]: Stalemate in Technology

Figure 2–8. The Metamorphosis Model of Industrial Evolution.



Mensch distinguished three types of innovations; basic-, improvement- and pseudo innovations. Basic innovations lead to the creation of new industries. Improvement innovations enable the further development of existing sectors. Pseudo innovations are actually fake innovations which are only meant to maintain the conquered market shares. In his metamorphosis model Mensch uses an S-shaped representation of the long wave (see figure 2) instead of a wavelike pattern. Basic innovations cause the beginning of a new “S”. These appear, thanks to a bandwagon effect, in groups during a short period of time in the depression phase. They restore profitability at increasing demand. The economy will form itself after the new innovation cluster and gets in a lock-in this way. By now companies only want to protect their market shares and they will limit themselves to improvement innovations, at decreasing demand. On a certain moment the profit possibilities of the technology will become exhausted, saturation sets in and businesses will try to prevent total stagnation with pseudo innovations. This, off course, will not work. The market is saturated, suppliers are expensive because they are in a good negotiation position and investments in the “old” technology don’t yield anything anymore. The lack of profitability of the old innovations causes investors to turn themselves to new radical projects, despite the present higher risk and pessimism in the depression phase. This is the only way a society can conquer a period of technological stalemate.

Kleinknecht

Schumpeterian Alfred Kleinknecht subscribed Mensch’s theory. In his own research with Bieshaar, Kleinknecht found evidence for the existence of long waves in growth rates in the period from 1893 onwards to the present. He thought the existence of long waves in the period before 1893 to be liable to doubt. Kleinknecht furthermore concludes that technological innovations followed a random walk until first half of the 19th century. Important innovation would later on concentrate themselves discontinuously around the depression phase and the beginning of the upswing.

Kleinknecht also holds the opinion that in long wave research there must always be corrected for the influence of great wars. If the long wave exists, only endogenous theoretical explanations will be relevant according to him.

Clark, Freeman, Soete and Perez utter points of criticism on Mensch's and Kleinknecht's findings. Freeman and Perez state that Mensch's theory concerning the timing of the clusters of radical innovations is incorrect in a number of areas. They first of all hold the opinion that the diffusion of a group of revolutionary innovations does not take place directly after their introduction but that it can take many years before a cluster breaks through. The diffusion process also does not consist of blindly copying an innovation but contains a whole series of further innovations. Mensch deals with the grouping of a set of individual basic innovations whereas Freeman and Perez talk about the clustering of technologically related families of inventions and innovations. Furthermore, according to Freeman and Perez the diffusion does not only take place during the depression phase but throughout the whole cycle and predominantly in the upswing phase.

Diffusion remains also the most important factor for van Duijn. He states that the long wave upswing is not caused by the dire situation in the depression, such as is the case with Mensch, but is triggered by innovations based on radical scientific breakthroughs and a strong increase in demand. Clark (1981), among others, do not think the empirical evidence for the stimulating effect of depressions on the speed of (R&D) development has been provided. In their view both technological and economical factors lead to the formation of clusters and the development of new technology systems. The economic connection lies predominantly with material components, machines and final products.

Kleinknecht provided more proof for his position concerning the clustering process in a reaction to the criticism summarized above but he also realized clustering could take place during the recovery phase. The Mensch-Kleinknecht debate expanded the insight in the relationship between innovation, diffusion and the different phases of the long wave.

Van Duijn

Van Duijn combines the innovation theory and the investment theory. He emphasizes the moment of diffusion and the large-scale diffusion and application of innovations, which he saw as the driving force behind the wave. The original moments of introduction of the innovations themselves are of lesser importance, according to van Duijn. He renounces Mensch's hypothesis that the diffusion of innovations takes place during the depression.

Three core concepts are central in van Duijn's theory: innovation, innovation life cycles and investments in infrastructure. Innovations and innovation life cycles are seen as the boosters of the growth process. The investments in the infrastructure cause a further reinforcement. Van Duijn does not see a clear connection between the long wave phase and the innovation life cycle, innovations are everywhere throughout the cycle. He also distinguishes between four different types of innovations: important product innovations which create new industries, important product innovations in existing industries, process innovations in existing industries and process innovations in basic sectors such as oil refineries and the steel industry.

Van Duijn sees the long wave as a prices as different from the long wave which explains production fluctuations. These waves are caused by other mechanisms and have a different chronology. According to van Duijn there is a synchronicity between production and price before World War One, afterwards he does no longer find a connection. He focuses more on the long waves which explain production growth.

Van Duijn sees the direct cause for a turnaround in the economy in the investment behavior driven by the expectations of the entrepreneurs. When expectations change, justified or not, it is difficult to reverse them. A stock market or oil crisis is seen as a reason for the beginning of a downward movement but not as the ultimate cause. A certain event functions more as a collective moment of realization. Whereas a decline in investments can be seen as the cause of the downward movement, an increase will stimulate the upswing after a period of depression. When the excess capacity is eliminated in the old industries new growth industries will emerge and because of this the existing infrastructure must be renewed.

Van Duijn (1983) moreover gives an alternative division of the Kondratieff in five phases: *Prosperity I, Prosperity II, War, Recession, Depression and Recovery*. He places five Juglar cycles in a Kondratieff. With this he puts Schumpeter's classification in Prosperity, Recession, Depression and Recovery and which encompassed six Juglar cycles, in a new perspective

According to van Duijn basic innovations will lead to the formation of new industrial sectors which need their own infrastructure and will develop following the S-shaped life cycle pattern. Eventually these sectors will build up a surplus of physical supplies. Demand in the sectors which use the innovation will decline which will accentuate the fact that the capital sector has become to big. The combination of both forces will start the long wave decline. Investments will be low during this phase. Recovery will start when the replacement investments will increase again. The demand for investments will change the economic prospects for the better, which prepares the economy to facilitate a new outburst of innovations.

Different kinds of innovation take place during different phases of the long wave according to van Duijn. Process innovations are done more during the downswing phase while product innovations mainly happen throughout the upswing period.

Rostow

Rostow has his own perspective and sees temporary periods of scarcity and abundance in foodstuffs and raw materials as the most important cause of the long wave. He combines in his approach influences from the innovation and investment school. In his model there is delayed reaction in the creation of new capacity or in the opening of new agricultural areas. Wars extend and worsen the situation of scarcity. Rostow especially emphasizes the long wave as being a price cycle. He also prefers to use terms as “trend periods” in stead over more deterministic terms such as cycles and waves. Controversial remains Rostow’s claim that the period between 1951 and 1972 was the downswing of the fourth Kondratieff wave and the period after 1972 the upswing of the fifth.

Rostow’s long wave theory is built on three elements. The first is the influence of the leading sector in the economy. This process originates in the introduction and the gradual diffusion of a new important technology. The second, most important, factor is the influence of the changes in the profitability of the production of food stuffs and raw materials. The degree of profitability is influenced by the price level, by the technology and by the effects on new investments in new areas and mines, on capital movements, interest rates, exchange rates and on both the national and international income distribution. Rostow finally uses the influence of migration waves (similar as Kuznets), the demand for houses and the size of the working population.

Rostow's reasoning is as follows; the combination of a growing population and a rising real income in the industrialized countries creates an increasing demand for food stuffs. The demand for raw materials also rises in these countries. Given the structure of the world economy only a limited increase in the production of primary products is possible. This induces a sharp rise in the prices of these goods in comparison to the prices of industrial products. The relative price increase will induce an improvement in the terms of trade of the LDCs[10], considering the fact that food stuffs and raw materials are mainly produced in LDCs. This implies that LDCs will have more industrial products for the same amount of food stuffs and raw materials.

This improvement in the terms of trade creates the possibility of an industrial take off. The arisen profit possibilities enable the food stuff and raw material sectors to attract large quantities of labor (via immigration) and, predominantly foreign, capital. The increase in immigration causes a substantial rise in the construction, transport and infrastructure sectors. Leading sectors develop in the search for a solution for the relative scarcity. Their influence stretches out to other sectors in the economy. This induces an increase in the production of the scarce primary products. Then the prices decrease again because of overproduction and a new downswing phase starts. In short Rostow's theory is based on the discontinuous built up of production capacity in the food stuff and raw material sector, which has the tendency to defect alternating with a surplus or a shortage from the dynamic optimal capacity level.

In a study into the development of the Australian economy, Pope (1984) concludes that he can find no proof of the correctness of Rostow's theory in this setting. Pope, however, does not deny the existence of the long wave. He reverses Rostow's

[10] Low Developed Countries

argument and states that not the export prices but the import prices are of interest by the terms of trade effect.

Volland's (1987) theory is very similar to Rostow's. He, however, focuses on primary energy sources not so much on foodstuffs and raw materials. Volland studies technological revolutions and the eventual limits to the mineral supplies, fossil fuels and other natural resources. He states that the limitations of future economic growth are not determined by the supply of food but in the supply of energy and raw materials. Volland utters his concern about his conclusion that new economic growth will be severely limited because the natural resources are becoming exhausted.

Forrester

Jay W. Forrester suddenly joined the long wave discussion when he created a national economic model for the club of Rome. In his "System Dynamics National Model" he observed, completely unexpected, that the capital sector peaked every 50 years. He consciously chose to use real variables instead of monetary and price variables in his simulation model. His theory gives an endogenous explanation.

Forrester divided the long wave cycle in periods of successively 30 years of investment, 10 years of market saturation and finally 10 years of depression. Except the Kondratieff wave he also distinguished short run business cycles from 3 to 7 years and the Kuznets wave with length between 15 and 25 years.

The fluctuations in the capital sector according to Forrester cause the long wave. Forrester's theory is built around the tendency of the capital sector to grow beyond the long-term equilibrium optimal size. There arises a surplus of capital goods. The excess capacity is financially and physically depreciated during the depression phase. In principle this cycle has a length of 20 years. Three delay mechanisms, namely bootstrap structures, psychological delays and echo replacement, however, extend the duration of the cycle up to 50 years.

A bootstrap structure arises when a sector uses part of its own sales as a production factor. The signal to increase the supply of the factor leads to actions which, at least in the sort run, actually cause a reduction in the supply. This process also takes place in the capital sector. When the capital sector has to increase its supply to be able to satisfy an increase in demand both labor and capital are needed. The only possibility to acquire this is by withdrawing investments from the consumption sector. This is regardless of the fact that the consumption sector was responsible for the increase in demand in the first place. This is how a delay arises which instigates a considerable extension of the periods of fluctuations.

The second element that is important is the delays, which arise by taking decisions and the implementation of decisions in businesses and politics. Policy makers hesitate when they have to make a decision when they do not have all the relevant information or are uncertain over the correctness of the available information. People will also resist all change which entails a certain degree of uncertainty.

The third delay factor is the echo effect. These waves of replacement of capital goods play a central role in Kondratieff's analysis. Forrester states that these waves do not have to have a narrowly defined life span and that the periodicity of the replacement wave does not have to be equal to those of the long wave in order to be of influence.

Forrester acknowledges that innovations play a part in the process. Every long wave upswing phase develops itself around a very integrated mutually supportive combination of technologies from which a leading sector develops. The economy gets locked in a certain technology system. Non-fitting and new innovations will be deterred. The rejected innovations remain "stored" until a leading sector develops in which they do fit.

The phases from the long wave have a strong influence on the innovation climate. Technological innovation will diffuse during the upswing period. Radical innovations will be rejected more and more as the lock-in becomes stronger, only small innovations in already established industries will take place. Political and management innovations will be done during the downswing phase of the long wave.

These can eventually clear the path for a new wave of radical technologies at the beginning of the next long wave upswing.

Reijnders (1990) has serious objections to the National Model. This is because the model is based on parameters of which the values can vary strongly, so strong that Reijnders questions whether this is tolerable. Because of this it is possible that the long wave found in the model is an effect of the model itself. Forrester's long wave could thus be disconnected from reality.

Goldstein

The war school was especially popular in the period before World War Two. Researchers then concluded that war cycles were independent of economic cycles. Goldstein, however, states that even though there is a certain degree of autonomy between both, there also is some mutual influencing. He does disconnect the Kondratieff wave from a longer hegemony cycle[11].
Goldstein finds a long wave of approximately 50 years in wars, prices, and wages and, to a lesser extent, in production. The long wave arises from the mutual influencing between war and economical growth. The long wave is also synchronized in the whole core of the world system and can be found in several economic variables. Goldstein recognizes nine long waves between 1495 and 1945. Social cycles must, according to Goldstein, not be defined to strictly in time. They have to be seen as a pattern of alternating historical periods of which the length is only equal by approximation.

The character of the long wave in war has in his perception changed over the last five centuries, the period between great wars is become longer and the wars themselves shorter but much more intensive. The timing, however, has remained the same at least up until the Second World War. Nine consecutive great wars, up to and including

[11] The hegemony cycle has an average length of 150 years and encompasses wars between world powers from the core of the world system for the world wide dominance on military, political and economical level. Goldstein distinguishes three hegemony wars; the thirty year war (1618-48), the French revolution together with the Napoleonistic wars (1793-1815) and the First– and Second World War (1914-45).

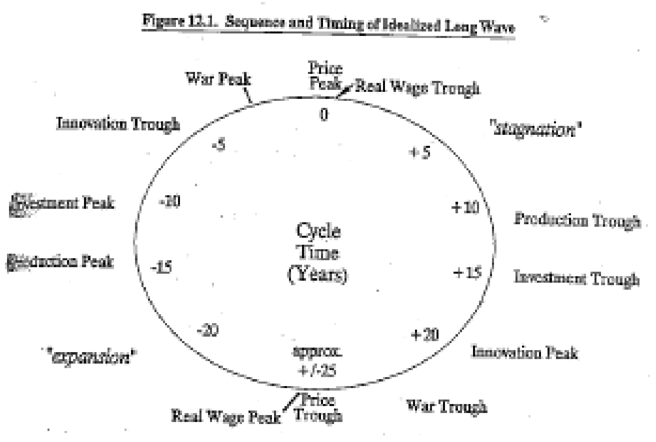
World War One, on average took place between one and five years before the end of the long wave upswing period. Only the last Great War, World War Two, does not fit in this pattern. It took place at the beginning of the long wave upswing. Because the deviating observation is the most recent great war it according to Goldstein cannot yet be determined whether this is an exception or a change in the pattern. Other authors also experience difficulty in determining the economic effects of the Second World War as these are expressed in time series.

The “greatness” of a war is determined by Goldstein by counting the number of combat victims. This criterion corresponds more with the long wave than with the duration of wars. He states that both the duration as the number of wars is equal during the long wave upswing and downswing. The number of combat victims, however, is ten times larger during to long wave upswing.

Goldstein states there is a two-sided causal relationship between economic growth and war. The long wave upswing phase leads to an increase in the “greatness” of wars. This is because the economical situation only then is conducive enough for supporting very expensive “great” wars. During the expansion phase it is furthermore the case that the important countries grow fast and tensions arise because of the increased competition for raw materials and markets.

“Great” wars slow down long-term growth because they devour raw materials and production resources. Allocation does not longer take place to the economically most efficient criterion and resources are literally destroyed in combat. There often also arise large war debts which have to be paid off. The demand explosion which arises because of the increase in state expenditures only has a stimulating effect in the short run. Only by exception can a country obtain an economic advantage from a “great” war. This is only possible when a country experiences very little physical damage to its own territory and though the victory heavily weakened the competition.

Figure 3, taken from: Goldstein, J.S. (1988): Long Cycles: Prosperity and War in the Modern Age



Concerning the timing (see figure 3) he states that some 5 years before the end of the upswing phase "great" world wars take place. Prices follow the long wave movement, internationally synchronized, throughout the whole cycle without any delay. During the end of the expansion period prices reach their maximum whereas the real wages arrive at their minimum. The real wages thus run opposite proportional to "great" wars. This is because in war time direct and indirect taxes reduce the part of the economic surplus which is available for employees. Innovational activity peaks 5 years before prices hit their minimum. The investments reach their high point about ten years before the price maximum. Goldstein finally remarks that it is probable that changes in production reach their maximum about 10 to 15 years earlier then the long wave in prices. Van Duijn also acknowledges that prices and production have a different chronology. The delay between prices and production can provide an explanation for periods of stagflation.

Next to Goldstein other recent authors have also occupied themselves with the long wave in war. Three different schools can be distinguished: the leadership cycle school, the world transition school and the power transition school. Modelski's leadership cycle school actually doesn't describe war- but political cycles in which the institutions and regulations arise from the basis of which international contacts take place. They eventually distinguish twenty long waves. Wallerstein's world system school has a neo-Marxist background and occupies itself with the relationship between core and periphery, this in contrast to the other schools which mostly focus on conflicts within the core of the world system. The power transition school follows Organski's work and states that an international hierarchy is necessary to prevent wars. A superpower must intimidate potential challengers in such a manner that war is no longer a real option for them.

Gordon

David Gordon was the most important person behind the Social Structures of Accumulation, or SSA, school. This school within the long wave context emphasizes the role the social superstructure has in the regulation of the accumulation process. It contains elements from both Marxism and the innovation school.

Gordon looks at the role of the social environment in the growth process and recognizes the interaction between economical, political and social factors within the most important institutions of capitalism. The most important hypothesis of the SSA school is that the profit expectations of companies in the long run fundamentally depend on the degree of structuralized stability of the institutional environment[12].

A second hypothesis is that capitalism evolves via consecutive waves of development and that the downswing of each wave is characterized by fundamental, every time rebuilt and qualitatively different set of economical, political and social institutions which collectively is known as the social structure of accumulation (SSA)[13]. Every

[12] Gordon recognizes the following institutions needed for stable accumulation: the internal corporate structure, management systems, a moderate competition structure, de institutionalization of the class struggle, an orderly government, a well working monetary and credit system, a continuous supply of high quality natural resources, intermediary goods, good transport structures, a reliable labor market and finally an effective system of labor management and effective demand

[13] The institutions responsible for the long wave upswing are different in every timeframe and wave. An example: the long wave upswing after the Second World War of the Americans economy is based on the SSA from the period 1950-1960. That SSA is built from three important institutional structures. These are: the Pax Americana which was based was on the hegemonistic dominance of the US via the Bretton Woods system of fixed exchange rates, Wall Street's role as the financial centre of thee world, the Marshall plan which to the recovery of Europe, the Vietnam war in the battle against communism and finally the central position of American multinationals in technology and production. The second pillar of this SSA was the Capital-Labor accord in which was agreed that union leaders would stay in the background en let the supervision of the companies to the management in exchange for better labor

wave has five phases of change: reinstatement of an SSA, expanding reproduction, diminishing accumulation, institutional instability and institutional crisis. The first four phases form the long wave upswing while the institutional crisis belongs to the long wave downswing. The crisis phase is characterized by large socio-institutional problems such as deep recession, large unemployment and poverty.

Gordon makes a distinction between reproductive and non-reproductive cycles. The reproductive cycle has a well functioning SSA which ensures that business cycle problems are solved endogenously. The arisen instability sets in the downswing, or non reproductive cycle, when an established SSA ends. Profitability will only be restored when the necessary forms have taken place and a new SSA has been formed. Only in the then arisen stable environment can capital accumulation recover and can the long wave upswing start.

The balance of power determines the degree of profitability and thus also the degree of capital accumulation. The social, political and economical environments thus influence the possibilities for capital accumulation of the individual capitalist.

In his theoretical reasoning of upward and downward moving waves Gordon, especially in his early work, largely follows Marx and Mandel's thoughts. He does doubt the separation Marx makes between the economical and social sphere and states that the interaction between them should be studied. He adds to this that this should happen at a lower level of abstraction as Marx's.

French Régulation School

Robert Boyer is the most important author of the Régulation school. This school is the French counterpart of Gordon's American SSA school. The Régulation school is built on criticism on Marx. They denounce his catastrophic interpretations because according to them capitalist economies only need a relatively small crisis to restore economic growth.

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conditions for the employees. The third institution, the State Citizen accord, (the Keynesian welfare state) was based on the one hand the payment of taxes by civilians and on the other hand more government interference in the economy.

According to Boyer long waves of regular growth and crisis are characterized by successive accumulation regimes. No accumulation regime has the same shape and content, they differ in both time and between countries. During the long wave upswing the success of the accumulation regime ensures that the structural parameters only change slowly. The long wave downswing sets in when the accumulation regime eventually becomes unstable. A crisis arises in the institutional system.

Boyer distinguishes two types of crisis, the ordinary business cycle crisis and the structural crisis. The former solves itself and doesn't need any large institutional changes. An institutional crisis, however, can only be solved after serious institutional reforms. A new long wave upswing begins when a new accumulation regime emerges. This depends on innovations, social and political conflicts, a process of trial and error and chance.

An accumulation regime is defined by a set of regularities, Gordon calls these SSA's, which facilitate the more or less constant evolution of capital formation. Some institutional entities, which can have a different configuration every accumulation regime, form the basis of this framework of social regularities. These institutions are the monetary and credit relations (the financial markets), the wage-labor nexus (the relationship between capital and labor), the form and content of competition, the relation to the international regime (the international relations, hegemony and the rules and customs in international trade and investment) and finally the nature of government intervention.

Technological developments are not explicitly mentioned but do form an important part of the various institutions. In long wave analysis, Boyer states, people must not lose themselves Schumpeterian technological determinism. Economic growth is not purely the product of the technology system. The interaction with the economic and social system is of great importance. The institutions play a decisive role. No technology system can be analyzed independently of the accumulation regime. Boyer holds the opinion that economists should not only focus on their abstract models but stay grounded in reality.

Freeman and Perez

Christopher Freeman and Carlota Perez often work together and have a similar long wave theory. They call themselves neo-Schumpeterians and state that technological and institutional changes are intertwined. A good match and dynamic between both forms the basis of the long wave upswing. Both emphasize that theories which only use one explaining factor are per definition incorrect. Freeman and Perez also emphasize the importance of having a multidisciplinary approach. Scientific, technological, political and cultural factors are also important next to economical factors. Their interaction has a great impact on the process of economic growth although historically speaking they have been relatively autonomous in their development. Freeman and Perez recognize that each long wave in principle is characterized by a unique combination of factors but also that some regularities can be acknowledged.

In Freeman and Perez's theory, a great surge in development which starts the long wave upswing is defined as being the process through which a technological revolution and the accompanying techno-economic paradigm spread throughout the economy and cause structural changes in production, distribution, communication and consumption, as well as changes in society. Each consecutive wave the economy reaches a higher level of productivity.

Each technological revolution has a certain technological style. The technologies, innovations and products that belong to a certain style often already exist much longer; it is the unique combination of factors which causes a technological revolution. A technological revolution can be defined as a powerful, visible cluster of new and dynamic technologies, products and industries which are able to cause a revolution in every aspect of the economy just as a long-term surge in economic development. The diffusion of such a cluster takes place at the beginning of the long wave upswing phase. Freeman and Perez explicitly state that, in contradiction to Mensch's claims, depression do not stimulate the diffusion process but hold it back. In the beginning a wave of infrastructural investment brings about the full exploitation of the growth potential of the technological revolution by accelerating the diffusion. Furthermore it must also be taken into consideration that the profit expectations play a propelling role with the diffusion of a group of innovations. Ultimately both the infrastructural investments and the profit expectations are determined by the innovations.

The cluster is a strongly mutually dependent constellation of technological innovations which encompass a cheap input factor, the so-called key factor and new products, processes and infrastructure. Each technological style has certain inputs or a set of inputs called key factors whose excessive supply against diminishing relative costs and many applications make possible other related innovations which also use the key factor. Key factors such as cotton, iron ore, cokes, transport, steel, oil, chips and micro-electronics each have, according to Freeman and Perez, made it possible for new industries from the first to the fifth Kondratieff to grow fast and for old industries to adapt as much as possible.

Each technological revolution leads to the massive replacement of one certain set of technologies by another. This happens via direct substitution or by modernizing existing equipment, processes and the techno-economic paradigm. The techno-economic paradigm[14] is a set of unique best practice principles which indicate the most efficient way of using a technological revolution. The paradigm breaks through the existing organization customs in the areas of technology, economy, management and social institutions and accompanies the diffusion of each consecutive revolution.

[14] Elements of a techno-economic paradigm. When a techno-economic paradigm has finally been fully developed, the following changes have been carried through:

- A new best practice organization form for companies and factories
- A new Skill profile within the working population concerning both quality and quantity and a corresponding income division
- A new product mix, which means that the products which intensively use the cheap key factor are preferred by investors and because of this will encompass an increasing share of the GNP
- New trends in both radical and marginal innovations are directed at the replacement of the relatively expensive cost price elements for the cheap key factor
- A new pattern in national and international investments arises because the changes in the relative cost structure has shifted the comparative advantage
- A wave of investment in infrastructure aims to provide the whole system with a structure which facilitates the use of the new products and processes
- New small companies of the entrepreneur-innovator type have the tendency to enter the new rapidly expanding sectors of the economy, or, in some cases even to initiate whole new production sectors
- Large corporations have the tendency to concentrate themselves, by means of growth or diversification, on those parts of the economy in which the key factor is produced and is most intensively used. This creates clearly separate sectors which act as the engines of growth during each consecutive Kondratieff wave

Besides economic and technological factors political, social and cultural variables are also important in Freeman and Perez's analysis. A techno-economic paradigm cannot function when society does not know how to use it. It is thus of the utmost importance that the so-called socio-institutional framework forms itself after the techno-economic paradigm. The adaptations of the socio-institutional framework come about slowly because new skills must be learned and new rules must be designed.

The long wave upswing thus only starts after a harmonic complementarity has arisen between the technological revolution, the accompanying techno-economic paradigm and the adapted socio-institutional climate. Once a certain good match has become fact a relatively stable pattern of long-term investment can arise which can withhold for about twenty to thirty years.

After a certain time the growth possibilities of a technological style become exhausted. A new technological revolution then already announces itself but because the socio-institutional framework is still adjusted to the old techno-economic paradigm a mismatch arises. During periods of recession and depression there will be experimented with multiple configurations of the socio-institutional framework and via a process of trial and error a new match will be found between the new technological style and the techno-economic paradigm. This will happen after the right reforms have been carried through, only then the long wave expansion will start again. Perez elaborates on this line of thinking in her 2002 book "Technological Revolutions and Financial Capital". This book will be discussed extensively later on.

Tylecote

Tylecote's, in origin Schumpeterian, long wave theory has an interdisciplinary and evolutionary nature. Perez and the French Regulation school also have been very influential on his views.

- New consumption goods and services and new types of distribution and consumer behavior

His theory is as follows. The diffusion of a cluster of innovations, of a new technology system, lies at the basis of the long wave upswing. These clusters arise via the interaction between political, social and economical factors. Tylecote distinguishes a Regime of Accumulation (ROA) and a Mode of Regulation (MOR). The ROA can be compared to Perez's techno-economic paradigm and the MOR to the socio-institutional framework. A long wave upswing is based on a good match between a ROA with a MOR, the downswing arises from a mismatch between both. The changes which are needed for the next long wave upswing can be accelerated by political actions.

Tylecote (1992) holds the opinion that although Perez's analysis is correct in principle, it falls short on some points: "I have argued that this model, though elegant (…) needs a great deal of modification". The most important difference is that Tylecote distinguishes three types of mismatch. First of all there is the depression crisis, also called micro-economic crisis, this is a blockage on the level of the individual companies which arises because the old framework blocks the diffusion of the new technological style this will lead to both an economic and a socio-political crisis. In her analysis Perez only acknowledges crisis of this type. The second kind of crisis the upswing crisis, also called the socio-political crisis. This type of crisis does not block the entire system because sufficient reforms have already taken place, the upswing is able to go on even though the diffusion is obstructed in such a way that although there is no economic crisis there will be a socio-political crisis. The third type crisis is the mixed crisis, also called the macroeconomic crisis, is a mix between the depression and the upswing crisis. The diffusion of the new style does take place but problems on the macro level, for example too much income inequality which prohibits further development, do arise.

The three types of mismatch provide, in combination with difference in the interaction between the technology and the framework, the specific historical characteristics of each consecutive technological style. Each long wave differs from the previous and future waves, each ROA and MOR consist of different specific parts. The succession of technological styles every fifty years has been the only relatively constant factor in the past two hundred years.

Other factors which influence the long wave are the feedback loops in money, population and inequality, the long wave cycle in international relations and the influence of the environment. These feedback processes are needed to generate the long wave fully endogenously. The feedback process in money causes high prices and a large demand for money during the upswing phase because of the limited supply of money will lead to a high interest rate. On a certain moment during the upswing phase this process thus becomes anti-cyclical. During the downswing phase prices and interest rates are low.

The population feedback process once was anti-cyclical but nowadays works pro-cyclical. When this loop was still working pro-cyclically a period of growth caused a baby boom. Once the kids became adults they enlarged the supply of labor and the demand for goods. This ensured that just before the end of the upswing or downswing phase the long wave had a new impulse which delayed the beginning of the next upswing or downswing. Until the end of the 19th century migration fortified the anti-cyclical effect even further. Early 20th century this process changed, however, and the feedback loop became pro-cyclical because the speed with which people could migrate increased and new laws ensured that only during the upswing phase migration was allowed.

The feedback process in inequality between rich and poor countries is characterized by increasing inequality while the inequality between poor countries is diminishing. The inequality between rich countries also decreases. Increasing inequality causes a diminishing demand and at the same time also a decrease in supply because of the low investments in human capital for the poorer part of the population. The three feedback processes in money, population and inequality have changed markedly over the years.

Tylecote also uses Modelski's principle that the Kondratieff long wave which lasts about half a century is in a certain way intertwined with the even longer hegemony cycle of 100 to 120 years. This hegemony cycle does not cause the long wave according to Tylecote (1992): "the timing and length of global wars, and the character of the peace settlements, have a strong influence in long economic fluctuations, but they can scarcely account for them". The Kondratieff is also connected with the

Kuznets cycle. Kuznets cycles, according to Tylecote, work completely endogenous whereas the Kondratieff need reforms in order to function.

Perez

Perez in her book “Technological Revolutions and Financial Capital” (2002) focuses on the relation between technological revolutions and capital. She combines the technological cycle with the availability of capital and the necessary, sometimes painful, adjustments to the socio-economic framework.

In her analysis about every half a century these is a cycle with the following phases: technological revolution, financial bubble, collapse, golden age and political unrest. This repeating movement according to Perez is based on causal mechanisms embedded in the nature of capitalism. These mechanisms find their origin in three, mutually influential, characteristics of the system:

- Technological changes break through in clusters of radical innovations which cause consecutive, unique revolutions which modernize the entire production structure
- The functional separation between financial and production capital, each of which looks for profit in its own way
- The much greater slowness in reaction and resistance against changes within the socio-institutional framework than in the techno-economic paradigm, which is propelled by the pressure of competition

Perez furthermore reaches the conclusion that three elements in long wave research must be discarded: She holds the opinion that:

- The long wave does not only stretch out over the economic system and is not caused by endogenous factors
- There are no regular upswing and downswing periods in GNP and other aggregate variables
- Long waves do not take place simultaneously worldwide

Using the life cycle of the technological revolutions as a guideline Perez describes the different periods and phases of development.

Each great surge in development can be divided in two periods which each last about 20 to 30 years. The first is called the installation period, the second the deployment period. The transition between both periods is called the turning point. The installation period of each techno-economic paradigm can also be divided in two phases. The phase following the big bang is called the irruption phase. The second phase is called the frenzy phase. The deployment period can also be divided in two phases, the synergy phase and the maturity phase.

During the installation period the new techno-economic paradigm wins the battle of the old. The installation phase is one of polarization[15] between the old and the new. This is reflected in the division of income. The rich will become richer and the poor poorer. This unequal division will cause various protests.

The irruption phase begins with the breakthrough, big bang, of a technological revolution. This offers possibilities for companies to cost competitively adopt this new technological style. Venture capitalists are impressed by the possibilities of the new technology and are attracted by the very high profit expectations to invest in new activities and companies. The rise of new industries and companies takes place in an environment which is still dominated by the old institutions.

During the frenzy phase the new techno-economic paradigm wins the battle from the old. Relatively many mergers take place in the frenzy phase in order to avoid the fierce price competition. During the end of the frenzy phase a lot is invested in the new industries and infrastructure. Because of financial speculation, technological euphoria and irrational expectations a bubble arises in the stock market.

[15]Between new and mature industries, modern and old fashioned companies, new and old regions, people with old skills and people with new skills, people working in old industries and people working in old industries and finally on the international level between countries which use the new technology and they who stay behind.

When the bubble bursts a recession or even a depression follows in which the financial markets return back into reality. This period is called the turning point. The recession and social protests put the pressure on which enables the institutional reforms to finish. On this crossroads the length of the recession primarily depends on politics, ideologies and the relative influence of both. Politicians must introduce the right rules and changes to the socio-institutional framework.

In the deployment period the entire society forms itself after the new techno-economic paradigm and the potential of the technological revolution is fully reached.

During the synergy phase a catch up takes place. The low unemployment and more equal division of wealth ensures that, even though the frenzy phase possibly experienced higher growth, the synergy phase is seen as a golden age. The wealth is based on a good match between the technological style and the institutional framework.

Slowly but unavoidably new industries mature and markets becomes saturated. The profit possibilities become exhausted. The economy has now reached the maturity phase. During this period also lots of mergers take place. The main reasons this time are to ensure a sufficient market share in a diminishing market and to enable economies of scale. The signs of deterioration in the apparently still wealthy society cause unrest by the laborers, politicians and in society in general.

Capital plays an important part, as Schumpeter already determined. Perez distinguishes two types of capital: financial capital and production capital. Both have their own way of making profit. The former consists purely of paper means, is mobile and has as objective to make money out of money via various intermediaries. The latter, on the contrary, is solid, encompasses physical investments and creates value by producing goods and services.

The relationship between both determines the rhythm and direction of the growth in an economy. When production capital has become conservative at the end of the maturity phase, rusted in the old technology, financial capital, looking for alternative profit possibilities, is willing to finance the new technological revolution, hereby starting a new irruption phase. Because of the high expectations and risky speculations of the financial capital a bubble arises at the end of the frenzy phase. The financial capital becomes detached from the production capital. This is straightened during the turning point thanks to changes in the financial regulations. The renewed production capital then facilitates stable and now real growth during the synergy phase which enables the technological revolution to reach its full potential.

In her book Perez (2002) also considers the current situation. This will be treated in chapter 7.3.

Hirooka (2003) for the most agrees with Perez's analysis but also notices some distinctions with his own ideas. He remarks that Perez spreads an S-curve over the entire innovation surge whereas he holds the opinion that the actual S-curve only manifests itself in the deployment period because the commercial production of innovative products during the installation periods is negligible.

2.3.4 Conclusion

In this section all relevant schools of thought and authors who have occupied themselves with long wave research in the post World War II era have been discussed. After the relative lull of the 1950s and 1960s the long wave debate regained momentum in the 1970s and 1980s. The basic ideas from authors such as Marx, Kondratieff and Schumpeter were expanded upon and combined. Marxist Mandel emphasizes the "falling rate of profit" in his long wave theory. Mensch, later supported by Kleinknecht, elaborates on the ideas of Schumpeter and formulates the "depression trigger" hypothesis. Van Duijn combines principles from the innovation theory and investment theory. Rostow has a unique approach in which temporary periods of scarcity and excess in foodstuffs raw materials are seen as the propeller of the long wave. Forrester unexpectedly finds long waves in his "National Model" which he, in the vein of Kondratieff, attributes to fluctuations in the capital sector. Goldstein states that long waves are influenced by "great" wars. Gordon's SSA school emphasizes the role of the social superstructure in the process of the long wave. The French counterpart of the SSA school is the Régulation school of which Boyer is the most important representative. Freemen criticizes Mensch's depression trigger hypothesizes and supposes that the clustering of basic innovations takes place at the beginning of the long wave upswing. Together with Perez Freeman develops the notion that the diffusion of innovations depends on adaptations in the political, social and corporate institutions and structure. Tylecote follows Freeman and Perez and combines their ideas with concepts from the hegemony school.

The differences and agreements between the various schools of thought and authors will be discussed in Chapter 2.4. The econometric aspects of the long wave discussion will also be brought under the attention in that Chapter. Also an overview will be given of the most important critics. Finally the controversies and unanswered questions will be identified and discussed.

Chapter 2.4 Status of the Long Wave Debate

2.4.1 Introduction

The long wave critical literature review of section 2.2 and 2.3 will be brought to an end in this chapter. First there will be taken a look at the econometric side of the long wave discussion. Subsequently, the most important critics will be discussed. Finally the unanswered questions and controversies of the long wave debate will be summarized and discussed.

2.4.2 The Econometric and Statistical Debate

The search for the long wave remains in vogue in the 1980s and the 1990s. Freeman (1996) and Louça and Reijnders (1999) summarize the history of the debate with original contributions of many authors who each researched the long wave in a different way. The overview is given in Table 1. Some choose the (i) *historical approach*, others the (ii) *statistical and econometric approach* or the (iii) *model simulation and non-linear approach*. This thesis fits best in the third category: a combination of the SEA and HA approach.

Table 1: Freeman, C. and Louça, F. (2001): As Time goes by: From Industrial Revolutions to the Information Revolution

Model Analysis	**Statistical and Econometric Analysis (SEA)**	**Combination of the SEA and HA Approach**	**Historical Analysis (HA)**
	Kondratieff		Trotsky
	Oparin		
	Kuznets		
	Imbert		
	Dupriez		
	Van Duijn	Mandel	Madisson
Forrester	Kleinknecht	SSA	
Sterman	Menshikov	Gordon	Regulation Schools
Mosekilde	Hartman	Aglietta	
	Metz	Boyer	Freeman
Mensch	Reijnders		Perez
	Ewijk	Reati	Tylecote
	Zwan	Kuczynski	Fayolle
Silverberg		Shaikh	Bosserelle
		Entov	
		Poletayev	
		Moseley	
	Others: Sipos, Chizov, Craig /Watt. Glismann, Taylor, Nakicenovic, Marchetti		Others: Braudel, Wallerstein, Modelski

In the debate elaborated below it must especially be seen that the authors are looking for the right and consistent methodology which is reproducible and explainable. It is also important that the results can be generated automatically or to it put differently no subjective element of the authors may be present. The development of the scientific work cannot escape advancing insight. Some authors mentioned before will also make an appearance here, both researchers who claim to have found Kondratieff waves as well as those who claim the opposite. Both Kuczynski (1978) and Haustein and Neuwirth (1982), for instance, have found a whole range of waves of different lengths. They have similar findings as Kitchin, Juglar, Kuznets and Kondratieff. The debate about the applied methods, techniques and data can be traced back to Kondratieff who, according to his critics, could not convincingly quantify his theory. The Kuznets cycle does not face comparable criticism. That cycle is also shorter and the historical data more convincing. Solomou, van Ewijk, Tylecote, Berry and others conclude that the evidence is convincing. They, however, also hold the opinion that the evidence for the Kondratieff wave is not strong enough or even completely absent. Berry even sees inflationary and deflationary cycles in the Kondratieff wave.

Other participants to the debate go to work to find the evidence but encounter difficulties. It has been chosen to keep the descriptions of the methods and techniques as simple as possible. The amount of specific econometric, statistical and mathematical terminology is kept to a minimum. Because of this omission of some specific details it is possible that not all nuances will be discussed.

What is a wave? A wave is characterized by a combination of a trend, multiple types of wave movements and a series of random disturbances. The trend and the wave movements each have their own domain. Different approaches can be distinguished. The most important methods of analysis will be discussed briefly below.

1. Visual Inspection of maximums and minimums

This method assigns maximums and minimums based on visual inspection of a graphical representation of a time series. The question remains which maximums and minimums of erratic patterns now actually may be connected with each other. The subjective character of this method makes it only suitable for illustration purposes. Van Gelderen, Sirol and Kondratieff have used this method in the past.

2. Moving averages

This technique tries to exclude short run cycles by taking more year averages. In the literature 9-year averages have often been used. Kondratieff was the first to use this technique by copying Warren Person's methodology. This method has some drawbacks. The use of the implicit assumption that wave movements can be distinguished in the data can be mentioned first. Second it can also be determined that it is possible that there are more short waves in the data between the 50-60 year wave and the 9-year moving average. These other waves will not be filtered out. Nine years in itself is also arbitrary and can also be an average of the waves with an average length of around nine years.

One of the most important econometric problems in the long wave debate is the Slutsky effect. In 1926 Slutsky indicated in an article that the application of the moving average method could artificially produce waves and also that the method produces a longer cycle where shorter cycles exist. Slutsky also applied the argument and methodology on random disturbances. The method of moving averages which was used by de Wolff, Kondratieff, Von Ciracy-Wantrup and Sirol thus already faced serious criticism early on.

3. Growth rates and linear regression in different periods

This method assumes that a wave is present in the data. Beforehand defined historical periods of up- and downswing are estimated by using linear functions of time. This is how periods of growth and shrink are compared. The problem which applies to visual inspection also applies here. The question remains which maximums and minimums should be selected and to what extent the regression results are actually discriminating.

4. Trend elimination from the data

This technique is also called the decomposition or the long run method. The decomposition method eliminates the trend and tries to find the long wave in the remaining cyclical elements and random disturbances.

5. The long wave is analyzed from shorter business cycles

This method leaves the trend intact. Subsequently, one by one a layer of shorter cycles and random disturbances is removed consequently letting only the long wave remains. Cyclical averages thus are used.

The methodological problem of the methods discussed in bullet 4 and 5 is that every step in trying to separate trend and cycles can lead to a disturbance in one of the domains of the remaining movements. In modern methods all elements are simultaneously approached. Schumpeter used the peal method, he did not want to eliminate the trend because it has its own right to existence. The trend plays a part in determining the equilibrium level. When this, for instance, was disturbed by the diffusion of innovations the economic forces would find a new equilibrium level. These equilibrium levels are the points in a graph where the line passes the horizontal axis such as is represented in figure 1 in Chapter 2.4. For a correct interpretation of what is argued above, the figure must be rotated to the above right, which reveals a rising trend. The normal point method which was used by Schumpeter tries to find these equilibrium points. Schumpeter found them for various cycles. Subsequently, he eliminated them to finally only remain the trend. The problem with this technique is that there cannot be made a distinction between the different components.

6. The binary split method

Another method is the binary split method. This technique has been used extensively in the past 50 years for simple and more complex applications. Dupriez (1947), Imbert (1959), Mandel (1975, 1980, 1995), Van Duijn (1979, 1980, 1983), Bieshaar and Kleinknecht (1980), van der Zwan (1980) and Solomou (1987), for instance, have applied this method. This technique uses time series of prices to determine the periodicity of the supposedly present long waves. Subsequently, it is used on the accompanying volumes. The assumption is that both time series move in the same way. Correspondingly the hypothesis is tested that the growth rates of upswing periods are significantly higher then those of the downswing. It is important to determine that the application of the binary split method can lead to notable differences with comparable empirical material. According to Reijnders (1990) this has nothing to do with the different complexity levels but with the method in itself. He shows that the problem of the trend is not avoided. The hypothesis tests are not powerful enough. Reijnders furthermore states that the method does not automatically generate the same answers. There is a subjective element that will be interpreted differently by different researchers. Certain authors thus indicate that they found confirming evidence whereas others found nothing.

7. Fit by using orthogonal polynomials

Taylor (1988) proposes a different technique, orthogonal polynomials, to purely mathematically achieve a fit between model and data. Brill (1988) does not agree to the use of this technique and shows by means of a simulation that biased estimations are made and that the cyclical elements cannot be identified correctly. Metz (1987) suggests a filtering technique which, because every element can be defined in specific frequencies, is able to distinguish between all cyclical elements. He shows that in volume series long waves exist exactly as Kondratieff found. The outcomes differ, however, when he applies this technique to prices and monetary time series.

8. Spectral analysis

Another class of methods is spectral analysis. This method is developed to classify time series as an infinite sum of cycles, some of which are more relevant than others. The existence of a certain cycle can be shown when the accompanying frequency set has a high explaining value. This is as elegant as it is attractive. The problem of stationarity of the data however is applicable. This implies that it is not allowed to have a trend in the average and the variance.

9. Perspectivistic distortion; unfinished waves

Reijnders (1990) addresses the general problem of perspectivistic distortion. Perspectivistic distortion in fact is self-created confusion with trend elimination. This problem arises when a researcher does not recognize that a wave is not yet finished and his estimations only apply to a part of the wave. The problem can be avoided by using a standardized set of intervals. Although both use spectral analysis, Reijnders and van Ewijk results differ. According to Reijnders this can be blamed on the fact that van Ewijk uses growth rates which makes it difficult to separate the domain of the trend and the domain of the cycle. Van Ewijk furthermore transforms the data which unintentionally eliminates the entire wave characteristic which obviously makes it impossible to find.

10. Other contemporary methods

One of the latest developments is the use and further development of non linear systems and chaos theory. A further discussion of this complex matter can be found in the original articles.

11. Multitude of waves versus the Kondratieff wave, an interim conclusion?

Up to now besides the Kondratieff long wave other waves have also been discussed. Reijnders (1990) writes about this: "(…) which makes the systematic long-run movements of all items that relate to the economic process fit together like pieces in a giant jigsaw puzzle." He endorses the existence of the long wave and states: "if one decides to accept the Kondratieff wave on the basis of the present results, one will also have to accept that this particular movement is embedded in a rather complicated structure which contains a multitude of wavelike movements, not only of shorter but also of considerably longer duration than the Kondratieff wave itself. Therefore one cannot claim a separate raison d'être for the Kondratieff wave because it is an integral part of this multiple cycle structure and does not have a life of its own." Goodwin (1985) writes: "In economics we commonly have models in search of facts – by contrast, long waves appear to be facts in search of a model."

Reijnders and Louça (1999) conclude that despite all the good scientific work and advanced models the empirical part of the long wave research remains controversial. This is because an arbitrary element is always used which makes the results somewhat questionable. They ask themselves whether the assumption that time series consist of a deterministic trend and on top of that cyclical elements is not to restrictive for the research. Changing some implicit assumptions could lead to innovative thoughts and directions, or so they claim.

2.4.3 Proponents and Opponents

The history of the discussion and research concerning the Kondratieff wave gives an image of continuous debate. The subject remains fascinating. This explains the fierceness of the proponents and the opponents. Long wave adepts come up with empirical evidence and theoretical explanations whereas opponents refute the long wave theory partially or even completely.

In order to keep things interesting the proponents are also internally divided. Some are convinced waves are in origin cyclical and endlessly self-repeating. Others hold the opinion that the long wave is an alteration of historical periods of growth and stagnation or depression. The controversies which play internally in the long wave debate will be discussed at large in Chapter 4.4. In this chapter an overview of the most important external critics will be given.

The Critics

For criticism two different areas of application can be distinguished. The type of criticism to which is based on a fundamental difference with regard to the assumptions and conclusions of a certain theory and the kind of criticism which occupies itself with the choice and application of methods and datasets.

Various cycles have been discussed[16] in the literature overview of Chapter 2 and 3 and the methodological overview of Chapter 4. Some critics represent a school of thought with a different angle but are long wave proponents themselves while others take a more skeptic or even denouncing stand concerning the long wave. The importance of these critics must not be underestimated. For the scientific correctness of the debate it is absolutely necessary that requirements are formulated which the argumentation must meet. But what are the criteria a long wave theory should meet?

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[16] See the discussions between Kondratieff and the Russian critics collected by Garvey and the debates between Schumpeter and Kuznets, Mensch and Freeman et al. and Kleinknecht and Solomou.

Rosenberg and Frischtak (1983) are very skeptical towards the long wave. According to them it can only possibly be found in price series. They state that so far no convincing evidence supporting the existence of the long wave in real variables such as output of employment has yet been brought forward. Rosenberg and Frishtak give four criteria which a meaningful long wave theory should meet: (i) the first condition is causality: "(…) a clear specification of causality among the factors associated with long wave phenomena", (ii) the second is timing: "The process of technological innovation involves extremely complex relations among a set of key variables – inventions, innovations, diffusion paths, and investment activity. A technological theory of long cycles needs to demonstrate that the variables interact in a manner that is compatible with the peculiar timing requirements of such cycles", (iii) the third criterion is economy wide repercussions: "An essential step in a technological theory of long cycles is the demonstration of the mechanisms through which particular changes in technology exercise *sizable* changes in the performance of the macro economy", (iv) the fourth and final condition is recurrence: "The final requirement for a theory of long waves based upon technological innovations involves demonstrating their cyclical or recurrent character."

Different authors have since indicated that Rosenberg's and Frishtak's criteria could be met. Forrester (1981) already answered the fourth criterion by stating: "People often question the idea that a long-wave economic model could persist for nearly 200 years, despite the major changes that have occurred in society and technology. But the policies and structures that generate the long wave have changed very little. The long wave depends on production methods that use capital equipment, on the life of capital equipment and buildings, and on the sluggish pace with which people move between sectors of an economy. The long wave is accentuated by how far ahead people plan and the length of their memories of past economic disasters – both of which are substantially determined by the length of a human lifetime. None of these factors that give rise to the long wave depends significantly on faster communications or details of technological change. The policies and industrial structure that generate the long-wave capital-construction cycle have changed very little since 1800."

Influence

From a historical viewpoint it is interesting to observe how economists react to evidence, thesis and conditions of colleagues. The thought pattern of whole generations of economists can be influenced by certain view points, which is not necessarily always positive for the development of the profession. As an example Landreth and Colander (2002) could be cited who quote Nobel prize winner Paul Samuelson who wrote about Alfred Marshall that his multi explainable interpretations "paralyzed the best brains in the Anglo-Saxon branch of our profession for three decades."

Goodwin (1991), within the context of the endogeneity-exogeneity issue in the long wave debate, uses words of the same tenor as Samuelson for Nobel prize winner Ragnar Frisch: "We have explored here not a solution of a given system subject to exogenous shocks but a non-linear system which generates irregular or erratic behavior endogenously. Of course, the importance of exogenous shocks cannot be denied but I think that Ragnar Frisch really misled a generation of economists by saying that you must have a stable system dynamically disturbed by exogenous shocks. We now know that that is only half the story. If you have the right kind of non-linear theory you get irregular behavior of the kind that he thought only exogenous."

Schumpeter, for instance, did not let the comprehensive criticism on Kondratieff influence him to such an extent that he did not develop any initiative to further elaborate on Kondratieff's way of thought. Kuznets criticism on Schumpeter similarly did not hold back the many authors who have expanded his ideas.

The scientific debate should eventually lead to the development of the right theory and the right methods which are able to provide the definitive proof for or against the existence of the long wave. The discussion between the long wave proponents and opponents will continue until this is not the case.

2.4.4 Unanswered Questions and Controversies

Overseeing the long wave debate many methodological and theoretical questions remain unanswered. The schools of thought emphasize different mechanisms, variables and methods. Internally plenty discussion also takes place. Mandel (1992) and Goldstein (1988) each in their own manner indicate what they see as the most important unanswered questions and controversies

In the years after 1992 relatively little has happened in the long wave debate. Only recently has there been somewhat of a revival in the interest for the long wave. Freeman and Louça (2001) place their ideas in a historical perspective, Perez (2002) further elaborates her theories and Silverberg and Verspagen (1998-2004) give the econometric research concerning the role of innovations a new impulse. The discussion points indicated by Mandel and Goldstein remain relevant despite these developments.

In 1989 an informal seminar between the participants of the long wave debate takes place in Brussels. In a reaction to the articles and ideas presented there Mandel (1992) gives an overview of the unanswered questions and controversies. According to him there are seven subjects around which the debate revolves in essence[17].

[17] 1. A temporal / spatial framework problem: can long waves be statistically verified and in what time frame, regarding what geographically significant areas, and with what key indices?
2. What is the basic dynamic of capitalist growth? Is it inherent in the capitalist system itself, or does it in the last analysis depends upon the ups and downs of innovative individuals (the Marxist versus the Schumpeterians controversy)? Closely related is the debate about the prime movers of long waves. Are oscillations in the average rate of profit the basic causes of variations in the rate of growth (of capital accumulation), or are they rather the result of these variations?
3. What is the precise correlation between the ups and downs of scientific technological innovation, and the long-term movements of capitalist growth?
4. What is the extent of regularity, verifiable in long-term capitalist development? (the “long cycles versus “long waves”, or Kondratieff versus Trotsky controversy)
5. The controversy about the “exogenous” versus the “endogenous” determination of long waves of capitalist development (the Mandel versus the “regulation school” controversy)
6. The correlated controversy about the mono-causal or pluri-causal nature of capital’s control over wage labor
7. The controversy about forces determining basic changes in general conditions of capital accumulation, and the correlated questions about the ups and downs of hegemonic states in the world market

In Long Cycles (1988) Goldstein also indicates which questions he thinks are of central importance to the long wave discussion[18].

Taking into consideration the points mentioned by the authors the following list of discussion points can be formed:

1. Methods and Data: can the long wave be found with the assistance of econometric methods? Which methods are most suitable for this, for which variables should be looked and what are the limitations?
2. Theory formation: which mechanism underlies the long wave movement?
3. Regularity and Dating: does the long wave have a fixed periodicity? From when is the long wave active? How does the long fit a chronology, which historical periods belong to which phase of the long wave?
4. International Synchronization: is the long wave internationally synchronized?
5. Innovations: what is the relationship between technological inventions, innovations, the diffusion process and the long wave?
6. Endogenous or Exogenous: can the long wave upswing and downswing be explained endogenously of exogenously? The question whether the long wave can be explained mono-causal or pluri-causal relates to this.
7. War and Hegemony: what influence do wars and the international relations have on the long wave?

1. Methods and Data

Many different variables have been analyzed in the search for the long wave. The seven most important categories according to Goldstein (1988) are prices, production, innovations and inventions, capital investments, trade, real wages and working class behavior and war. Considering that they have to be investigated for a long time period the data differ in quality and availability. The most important question is whether long waves besides price and other monetary variables can also be found in real variables.

[18] 1. Can long waves be identified in a variety of economic time series?
2. In which time periods, countries, and types of economic variables can long waves be found?
3. Is there a connection between the ups and downs of wars and the phases of the long wave?
4. From the above, what relationships among various economic and political elements can be adduced and what causal theories of the long wave do these relationships suggest?

Freeman (1996) states that the debate covers a very long period, over two centuries and that especially for the first half of the period statistical data are difficult to find. The data which are available are predominantly price and interest data. The amount of reliable output, investment, profit and employment data is considerable less.

Goldstein (1988) also indicates that the available data is not of the desired quality: ”The search for historical empirical evidence of long waves is greatly constrained by data limitations. Quantitative data regarding economic history are spotty (especially for pre-industrial times). Most quantitative data are estimates of particular quantities at particular (occasional) years (or for such longer periods as decades).”

Kleinknecht (1986) goes even further and states that data from before 1890 are unreliable per definition: ”It is obvious that the series for the 19th century are less reliable than those for the 20th century and therefore any positive or negative result on long waves for the pre-1890’s period has to be interpreted with the utmost caution.”

Thompson (1990) remarks that long wave researchers might have been using the wrong data: “Perhaps there is a problem with the nature of the evidence being examined. If analysts are looking in not quite the right places for traces of a fifty-year production wave, it could be that the misplaced foci are partially responsible for a debate that has persisted throughout the twentieth century.” Furthermore he states that because of the lack of consensus in the methodological area contradictory outcomes will always remain: “Whatever the relative contribution of each of these potential sources of disagreement to the empirical debate, one conclusion seems fairly safe: as long as these analytic characteristics continue to prevail, there is no reason to expect the debate to end. Some authors will continue to find supporting evidence, and others will continue to reject the very existence of long production waves.”

2. Theory

Every theoretical school has its own vision concerning the workings of the long wave mechanism. Every school emphasizes a different explaining variable.

In “Long Cycles” (1988) Goldstein distinguishes three main theoretical schools within the long wave research area: the innovation school, the capital investment school and the capitalist crisis school. Other authors have a hybrid theory in which elements from the different schools are combined. Many recent hybrid theories recognize the influence of institutions on the long wave. They form a separate sub school which is not acknowledged by Goldstein. Goldstein himself belongs to a niche school within the context of the long wave research.

Gordon (1991) recognizes the following schools: bunched investments, traditional Schumpetarian, neo-Schumpeterian, modified Trotsky, traditional Marxist, world-systems, economic/warfare interactions, French regulationist and social structures of accumulation.

Delbeke furthermore gives (1981) a division after scarcity and abundance in the production factors entrepreneurship and innovation, foodstuffs and raw materials and finally capital and labor.

Thompson (1990) states that by dividing the various authors in demarcated schools of thought to much emphasis is put on the differences between them. He states this is al the more regrettable because the differences really aren’t that great and it is even possible to create a consensus core model: “As it happens, the differences between these schools have begun to blur more than a bit, and it is even possible to argue that a core model centered on technological innovation is emerging. The theoretical disputes that exist are not focused so much on widely different interpretations of reality. Rather, different groups are apt to emphasize one corner of the core model over another. They may also disagree over which way the causal arrow should be pointed. Nevertheless, the various groups increasingly seem to be discussing the interconnections between may of the same variables.”

3. Regularity and Dating

Only few authors presume a strict regularity. Most researchers hold the opinion that the length of the upswing and downswing phase of the long wave can vary in time.

The concept of "cycles" is regarded as being to deterministic and mechanistic. They prefer to use the notion of "waves."

Not all long wave authors are in agreement concerning the starting point of the long wave. Most researchers let the long wave start at the beginning of the industrial revolution in the UK. Goldstein (1988), however, traces the long wave back to the end of the 15th century. The availability and quality of the data plays an important part in this specific controversy.

Goldstein (1988) states there is a consensus among the majority of the long wave researchers concerning the long wave dating: "I will compare the dating schemes arrived at by thirty-three long wave scholars and demonstrate a strong consensus around a single basic dating of long wave phases." In "Long Cycles" (1988) he creates a base dating scheme by combining the dating schemes of other researchers: "I will use a base dating scheme that I developed by splicing together fours scholars' datings[19]." Each wave goes from trough to peak and from peak to trough. The scheme is as follows:

Table 2: Goldstein's (1988) Long Wave Dating Scheme

	Upswing	Downswing
		1495-1509
(1)	1509-1529	1529-1539
(2)	1539-1559	1559-1575
(3)	1575-1595	1595-1621
(4)	1621-1650	1650-1689
(5)	1689-1720	1720-1747
(6)	1747-1762	1762-1790
(7)	1790-1814	1814-1848
(8)	1848-1872	1872-1893
(9)	1893-1917	1917-1940
(10)	1940-1980	1980-…

[19] For the period from 1495 to 1650 Goldstein uses Braudel's data (1972), for the period from 1659 to 1790 he uses Frank (1978), for the period from 1790 to 1917 Kondratieff (1926) and for the period from 1927 to 1980 Mandel (1980).

In the placement of his tenth wave Goldstein deviates from the majority of the authors by following Mandel and not letting the wave end between 1968 and 1974 but in 1980.

Freeman and Louça (2001) discern five long waves. Because they hold the opinion that long waves can only be recognized as such with some certainty in course of time, they only give the dating of the first four waves (see Table 3). The first three waves in Freeman and Louça's scheme run almost parallel to Goldstein's base dating scheme. Only the starting point of the upswing of the fourth wave differs.

Table 3: Freeman and Louça's (2001) Long Wave Dating Scheme

	Upswing	Downswing
(1)	1780s-1815	1815-1848
(2)	1848-1873	1873-1895
(3)	1895-1918	1918-1940
(4)	1941-1973	1973-…

Hirooka (2003) recognizes that exogenous disturbances make it difficult to identify the long wave. He tries to get round this problem by using the much more recognizable diffusion curves of basic innovations for his long wave dating scheme. Hirooka's fourth Kondratieff wave has two peaks:

Table 4: Hirooka's (2003) Long Wave Dating Scheme

	Upswing	Downswing
(1)	1789-1825	1825-1846
(2)	1846-1872	1872-1897
(3)	1897-1929	1929-1950
(4)	1950-1973	1990-…

Not everybody agrees with these almost consensus dating schemes. Rostow for instance sees the period from 1951 to 1972 as a downswing phase and the period after 1972 as the beginning of an upswing.

In her book "Technological Revolutions and Financial Capital" (2002) Perez also gives a deviating scheme. She does not choose for the traditional separation of the long wave in an upswing and a downswing period but uses an alternative division. The division successively concerns the installation period which is divided in the irruption phase and the frenzy phase, the turning point and the deployment period which is divided in the synergy phase and the maturity phase:

Table 6: Perez's (2002) Long Wave Dating Scheme

Installation Period		Turning Point	Deployment Period	
Irruption Phase	Frenzy Phase		Synergy Phase	Maturity Phase
(1) 1771-early 1880s	late 1780s-early 1790s	1793-1797	1798-1812	1813-1829
(2) 1829-1830s	1840s	1848-1850	1850-1857	1857-1873
(3) 1875-1884	1884-1893	1893-1895	1895-1907	1908-1918
(4) 1908-1920	1920-1929	1929-1933 (eur) 1929-1943 (us)	1943-1959	1960-1974
(5) 1971-1987	1987-2001	2001-…		

Hirooka (2003) remarks that Perez's deployment period corresponds with the upswing periods of the other researchers: "We, however, suggest that the Deployment Period perfectly coincides with our diffusion period of innovations, which strictly corresponds to the upswing of the Kondratieff wave." Furthermore there is an interpretation difference with regard to the placement of the crashes. Hirooka places all crashes at the end of the upswing periods whereas Perez places the crashes at the end of the installation period, which corresponds to the downswing phase. The crashes described by Perez are not strong enough to lead to a great depression and the 1929 crash should be placed somewhere else, according to Hirooka: "Crashes as identified by Perez seem to be only a shake-off process of venture business after a bandwagon effect, not enough to bring about a pervasive recession. The crash in 1929 should be located at the end of the third wave, not at the middle of the fourth."

There is considerable more discord among the authors about the existence of the long wave in the pre-industrial era before 1780 than about the existence of the long wave in the industrial era. This can predominantly be blamed on the bad quality of the data form before the industrial revolution and on the fact that most authors consider the long wave to be an explicitly capitalist wave.

4. International Synchronization

The authors do not agree on whether or not the long waves are internationally synchronized.

Kondratieff (1926/1935) considered the long wave to be a world wide almost simultaneous phenomenon: "The long waves that we have established above relative to the series most important in economic life are international; and the timing of these cycles corresponds fairly well for European capitalistic countries. On the basis of data that we have adduced, we can venture the statement that the same thing holds also for the United States (…) however (…) the latter country may have peculiarities."

Van Ewijk (1982) transforms the original data in growth rates and after two different decompositions claims to have found evidence for the international synchronicity of long waves in time series for prices from England, France and the US. He could not discover a long wave in volume time series.

Van Duijn (1983) means that the long wave can be found better in aggregate data than in data for individual countries: "(…) the national peculiarities of the four core countries are precisely that: national peculiarities. Great Britain, the USA, Germany and France each have their own histories, in which the S-shaped life cycle of development may be more conspicuous than long wave fluctuations. The industrialized world as a whole, or even the four core countries taken together, moves forward along a long wave path."

Hirooka (2003) also endorses that long waves are internationally synchronized. According to him the long wave is an innovation wave of which the technological leadership goes from country to country: "(…) business cycles have been synchronized all over the world (…) with latecomers industrializing at the upswing of later cycles." The first two waves were guided by England and the last two by the US. It is possible for lagging countries to make a catch up at the beginning of a wave by learning from the knowledge and experience of forerunners and develop different technologies simultaneously and skip steps where possible.

Goldstein (1988) states that the long wave only operates simultaneously in countries which belong to the core of the world system: "The long-term ups and downs of national economies are not autonomous but synchronous throughout the core. Synchrony spreads to larger and larger regions of the world over the centuries as the core expands."

Perez (2002) is sharper in her wording than Goldstein and denounces synchronization completely: "On the whole, long-wave interpretations have been bogged down by three conceptual shortcomings involving expectations that cannot be fulfilled (…) 3. the conviction that such cycles must be a simultaneous worldwide phenomena." Every techno-economic paradigm according to her spreads in a "ripple like fashion." According to Perez crashes do take place simultaneously world wide, this is because of the strong connections between markets.

Thompson (1990) also does not see anything in internationally synchronized long waves: “Any chronology of long waves that is expected to describe economic fluctuations in the industrialized world cannot be expected to fit each industrialized economy’s fluctuations equally well. Some deviations from the world norm are anticipated. Consequently, some writers argue that long waves should be viewed strictly as systemic phenomena that national patterns approximate only crudely.” Basic innovations create a similar picture: “Major technological innovations are not only discontinuous in time and space, but the lead in innovational development, as suggested earlier, tends to be confined to a single national economy.” Technological leadership according to Thompson shifts with increasing speed from country to country.

5. Innovations

Innovations play a central part in all long wave theories. The exact relationship between the innovation process and the long wave is not completely clear. Some state that innovation propels the long wave movement whereas others suppose a more supportive role.

The moment of diffusion also creates plenty discussion. The innovation school is also divided internally. Mensch, Kleinknecht and Gordon place the diffusion during the end of the downswing phase. Mensch (1975/1979) for instance states: “The evolutionary alternation between stagnation and innovation allows us to surmise that surges of basic innovations will come during the periods when stagnation is most pressing, that is in times of depression.”

Goldstein (1988) investigates the clustering hypothesis by re-analyzing the data sets of his predecessors. He endorses the original conclusion form Mensch that basic innovations cluster during the downswing phase of the long wave: “The inverted five-year lead in growth means that innovations cluster at the end of the nominal downswing phase.”

Freeman, Clarke and Soete and van Duijn however don’t agree and state that the diffusion predominantly takes place during the beginning of the upswing period.

Clark, Freeman and Soete (1981) express their criticism on Mensch's depression trigger as follows: "In our view, the 'swarming' of innovative behavior, which gives rise to economic fluctuations in Schumpeter's model, arises from the imitation and diffusion process and from the bunching of technically related families of innovations and inventions, rather than from a depression-induced bunching of a set of individual basic innovations." Clark, Freeman and Soete (1981) prefer a combination of the influence of scientific progress and an increasing demand: "But we think it is rather more likely that any such bunching is related to breakthroughs in fundamental science and technology, to bursts of invention, and to periods of very strong demand (including booms and wars)."

Hirooka (2003) agrees with the criticism on Mensch's depression trigger hypothesis. He also thinks that basic innovations cluster at the beginning of the long wave upswing: "These results clearly indicate that the diffusion timing of various innovations always gathered at the upswings of the Kondratieff business cycles."

Some authors think that the clustering of innovations does not take place at all

The relationship between basic innovations and the long wave will be further studied in depth in Chapter 3.

6. Endogenous or Exogenous

The endogeneity-exogeneity debate finds its origin in the discussion between Kondratieff and Trotsky. In Kondratieff's analysis (1926/1935) the long wave is endogenous: "In asserting the existence of long waves and in denying that they arise out of random causes, we are also of the opinion that the long waves arise out of causes which are inherent in the essence of the capitalist economy." Trotsky (quoted by Mandel, 1975) does not agree and states that long run economic fluctuations wave an exogenous cause: "The acquisition by capitalism of new countries and continents, the discovery of new natural resources, and, in the wake of these, such major facts of a "super structural" order as wars and revolutions, determine the character and the replacement of ascending, stagnating or declining epoch[s] of capitalist development."

Two fundamental positions arise from this discussion. Louça and Reijnders (1999) give a description: “The first is that the mechanism is located outside the economy itself and can accordingly be considered an exogenous force that sets the economy in motion. The second is that the movements of the economy are interpreted as the pulsations of a living organism, in which case the mechanism is conceived as an integral part of the economy itself and accordingly forms an endogenous force that accounts for its pulsations. The nature of such a mechanism might be either exogenous or endogenous.”

Recent authors still take opposite positions in the endogeneity-exogeneity debate. Kleinknecht (1986) holds the opinion that every long wave theory should be endogenous: ”The question of whether or not we can speak of true cycles depends decisively on whether convincing *endogenous* explanations of the upper and lower turning points of the waves can be given.”

Perez (2002) has an entirely different opinion: “On the whole, long-wave interpretations have been bogged down by three conceptual shortcomings involving expectations that cannot be fulfilled (…) 1. The attempt to confine the analysis of the long wave within a narrowly defined economic system and to search for endogenous causes.”

Gordon (1991) tries to bring both points of view together: “(…) the distinction between endogenous and exogenous sources of long swings is relatively arbitrary and difficult to draw.” He states that it depends on the definition of the investigated research area whether it is appropriate to speak about an endogenous or an exogenous explanation of the long wave. When certain authors draw in factors from outside of the traditional research area of the economic science, such as the influence of institutions, in their analysis it can be that what is endogenous to them is exogenous to other researchers.

Gordon is supported by Freeman and Louça (2001) in his view point that endogeneity is a relative concept: “Clearly, the very definition of endogeneity depends on the scope of the operational model that is used.” Freeman and Louça (2001) furthermore agree with Perez that a fully endogenous explanation for the long wave is not possible: ”(…) a complete endogenous explanation whose scope is the universe itself is either a literary device and an aesthetic vindication leading to resignation, or a meaningless methodological criterion, since causality is not self-sufficient except in theology.”

7. War and Hegemony

The effects of wars and civil wars on the long wave are also unclear. Although many agree that the four large and five smaller wars since 1495 (Goldstein, 1988) have had a substantial impact on both prices and interest rates as well as on real variables such as output, investments, trade, and employment, there is no consensus on how to deal with these effects. Certain authors hold the opinion that that the influence of war should be removed from whereas others mean that these effects should be maintained.

Kondratieff (1926/1935) made the following observation: “It is during the period of the rise of the long waves, i.e., during the period of high tension in the expansion of economic forces, that, as a rule, the most disastrous and extensive wars and revolutions occur.” Economic expansion leads to war in his analysis. According to Kondratieff the causality runs from the long wave to the economy: “Wars and revolutions, therefore, can also be fitted into the rhythm of the long waves and do not prove to be the forces from which these movements originate, but rather to be one of their symptoms.” Wars thus don’t have a place in the long wave mechanism.

Following Kondratieff Mandel (1992) also states that the chance for conflicts is increased during the depression phase of the long wave: “Rivalry, whether in the form of trade wars or military conflict, tends to grow in long depressions, and it tends to be less explosive in long expansions.”

Mensch (1975/1979) comes to the conclusion that the chance for war is especially great during depressions: “Our metamorphosis model delineates the historical periods in which – due to stagnation in the economy – there is a particularly high probability of war.” This rule however, according to Mensch (1975/1979), does only apply to economic wars and not to political ones: “Our model considers only some economic factors and does not include the political determinants of war. Thus World War II does not fit in our propensity schema (…).”

Goldstein (1988) also incorporates wars in his long wave analysis. His theory assumes the existence of a two-way causal relationship between economic growth and war: “The heart of the theory (…) is the two-way causality between war and production – a dialectical movement in which economic growth generates war and is disrupted by it.” Goldstein (1988) states that World War Two does not fit in this theory: “World War II is anomalous, coming at the beginning rather than the end of a long wave upswing.” Despite the difference in the placement of wars in their long wave schedules he does agree with Mensch that World War Two deviates from the normal pattern.

Tylecote (1992) integrates wars and Modelski’s long hegemony cycle into the long wave: “I have deployed five main explanatory factors in explaining the ups and downs of the world economy over the last two centuries (…) 5 The ‘long Cycle’ in international relations, with the rise and decline of ‘world powers’ and the ‘global wars’ which end with the appearance of a new world power.”

Freeman and Louça (2001) agree with the authors discussed above and state that wars should always be taken up in a long wave analysis: “Finally, in order to preserve the method, some supplementary assumptions were made, such as the declaration of irrelevance of the inconvenient part of history (wars and major economic crisis) which should not be considered in order to make possible the study of the relevant part. But this amounts to a confession of failure, since structural changes in economic history cannot be explained in ignorance of the concrete historic ruptures.”

Some authors hold the opinion that wars should be left out the long wave analysis. Kleinknecht (1993) states that there should always be made a correction for the influence of great wars: ”In my view, it is doubtful whether results derived from series without correction for the World War outliers are reliable.”

Van Duijn (1983) also means that in certain cases there should be made corrections for the influence of wars: “World War I has to be omitted in order to save the pattern of alternating acceleration and deceleration." He continues: "Although less conspicuously, and only by excluding the World War I impasse, most countries for which we have long time series available have grown according to a long wave pattern."

2.4.5 Conclusion

In Chapters 2.2 and 2.3 all relevant schools and authors of the long wave research area have been discussed and the most important controversies have been identified in Chapter 2.4.4. However, overseeing everything in light of all the controversies the question can be put to what extent there can still be spoken of "long waves." The outcome of the long wave debate thus far has been unsatisfactory on certain points. The main conclusion we derive from this literature study is that the current approach of the long wave researchers does not work, the field is in an impasse and a different perspective is needed.

Chapter 2.5 Other Waves

2.5.1 Introduction

Not only do long wave researchers view economic development as being cyclical. Over the years many different types of cycles have been hypothesised. Some well-known examples, besides the somewhat controversial 48 to 60 year Kondratieff (1928) cycle which mainly concerns itself with structural economic development, are the 3 to 4 year Kitchin (1923) inventory investment cycle, the 7 to 11 year Juglar (1860) cycle which focuses on investment in machines and the 15 to 25 year Kuznets (1930) cycle in migration and investment in construction. Some researchers, such as Modelski and Thompson (1987), claim that even longer 110 to 150 year cycles of hegemony exist. These cycles all have their own empirical and theoretical background. In the following section a concise overview is given of these cycles.

2.5.2 The Kitchin Cycle

The Kitchin cycle was discovered in 1923. Kitchin found a pattern of fluctuations in bank clearings and prices that lasted for about 3 to 4 years. He attributed these fluctuations to adjustments to inventory shocks. After a recession firms do not have enough raw materials, parts, half fabricates and final products in stock. When they refill their stocks, businesses create a demand shock that influences the entire economy. Demand remains high for longer period than strictly necessary. Companies have expanded too exuberantly and have acquired too much stock. In order to diminish the excess stock, firms will cut back on their orders and lower their output. This can drag the economy into a recession. According to Tylecote (1992) the Kitchin cycle is viewed as an endogenous cycle. The strong empirical support for the existence of this particular cycle has stopped it from being criticized very much.

Van Duijn (1983) links the Kitchin inventory cycle to the business cycle: “The short 3-5 year cycle which we have come to call ‘business cycle’ is in fact the inventory investment cycle. This is to say, turning points of the business cycle are in the first instance caused by turning points in inventory investment.” He furthermore recognizes three motives for firms keeping inventories: transactions, speculation and buffer. Differences between supply and demand for products lead to under- and overshooting of stock kept for transactions which in turn causes the fluctuations. Stock accumulation for speculative or buffer purposes amplifies the effect.

Tylecote (1992) conjectures that it is unlikely that the cycle still exists in its original form. Furthermore, Tylecote refers to the 4-year U.S. presidential cycle[20], which matches well with the length of the original Kitchin cycle, as a possible modern day replacement.

2.5.3 The Juglar Cycle

Juglar (1862) discovered cycles with length varying between 7 and 11 years. This cycle is now commonly known as the ”ordinary medium term business cycle”. In his 1862 book ”Des crises commerciales et de leur retour periodique en France, en Angleterre et aux Etats-Unis”, he wrote that the cycles were not the consequence of forces from outside of the economy but from the inside, hereby indicating that there must be an endogenous explanation. Juglar discerned three stages in his cycle, that is, a period of progress, of crisis, and of liquidation. He mostly investigated monetary phenomena and also gathered some anecdotal business data. Maddison (1991) mentions: “expansions or contractions in central bank activity, rates of interest, prices of key commodities, etc., plus narrative business material.” According to him these cycles were more or less synchronous in the UK, France and the US. Juglar did not formulate an explicit theoretical explanation for his cycles, he presented historical and statistical data. His methods formed the basis for later statistics-based approaches. Van Duijn (1983) states the Juglar cycle is caused by investments in fixed assets, mostly machines and equipment.

Maddison (1991) argues that the length of the Juglar cycle is more volatile than often is assumed in the literature: “Although it is frequently asserted that Juglar found cycles of a characteristic length of nine years, this is not in fact true. His cycles for

[20] Before the elections the sitting government will take all kind of measures to stimulate or reflate the economy to make the electorate feel prosperous and win their vote. After the election the next

France average seven years with a range from three to eighteen years, and for the UK six years with a range from two to ten years.”

2.5.4 The Kuznets Cycle

The third relevant cycle is the Kuznets cycle. It is widely accepted by economists, at least for the period between the 1870s and the 1920s, as there is sufficient data material. The cycle is related to investments in construction and it lasts for about 15 to 25 years. Kuznets suggested that US population growth, with its large immigration ratio between the 1870s and the 1920s, caused fluctuations in the construction of houses and investments in the railways.

Kuznets (1930) investigated “secondary secular movements” in fifty-nine time series which encompassed both output and price components for particular commodities[21]. He concluded that the secondary secular variations in prices are similar to those in production. The duration of the cycle was, according to Kuznets, around 22 years for production and 23 years for prices. He furthermore argued that the term “cycle” was too strict and preferred to refer to them as historic incidences.

Abramovitz (1959, 1968) is the most important follower of Kuznets. He continued the empirical research and elaborated the theoretical framework of the long swings. After years of research he finally concluded that Kuznets swings existed but only in the period between 1840 and 1914. Abramovitz (1959) found the mean length of the Kuznets swing to be around 14 years.

Kuznets (1958) related the so-called “long swings” he found to population growth and investment in building and railway construction. The theoretical reasoning indicates that the process starts with an increase in GDP growth. This increase leads to a rise in the demand for labor. A migration influx satisfies this demand. The migrants and their families need housing and thus investment in the construction sector is stimulated.

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government is paying the price in facing inflation and/or balance of payments deficits, it deflates, causing a recession.

[21] Kuznets (1930) must have raised the idea when reading the contribution of the Dutch economist de Wolff in Karls Kautsky’s (1924) “Der Lebendige Marximus, Festgabe zum 70 Geburtstage”. On page 262 he mentions de Wolff’s findings of a 25, 23, 21 and 19 year cycle.

A historical explanation of the existence of the Kuznets long swings in the US between 1870 and 1913 can be found when examining the economical developments in Europe. During that particular era Europe experienced periods of labour strikes and strong unemployment. It is very likely that these phenomena caused the emigration towards the US (push factor). The influx of labour stimulated the already booming economy of the US even more. Thus creating a virtuous spiral in which yet more immigrants were attracted (pull factor). This lead to inverse synchronisation of Kuznets swings between the US and Europe, during depressions in Europe the US boomed and vice versa.

According to Solomou (1998) policy regimes play an important role in creating an institutional structure which enables cycles to arise. When this structure collapses the cycles cease to exist as well. The creation of similar institutions in the future may allow the rebirth of cycles which have died out in the past. Solomou also applies this type of reasoning to the Kuznets swing. He states that Kuznets swings existed between 1870 and 1914 because: "A fixed exchange rate regime imposed a rules-driven policy framework on participants, constraining the response to national-specific shocks. Such a policy stance created the need for deflation as a means of adjusting to shocks. High levels of international labor and capital mobility helped the adjustment path by reducing the required level of deflation."

Solomou (1998) gives a summation of the variables, in addition to migration, in which Kuznets swings have been detected over the years: "GDP, balance of payments, productivity, money supply, investment, sectoral terms of trade, and agricultural output (…)" He also provides an overview of the countries in which Kuznets swings have been found between 1870 and 1913 by various researchers: "Germany, France, Canada, Brazil, Argentina, Australia and Japan." Hereby he indicates that Kuznets swings are not exclusively an Anglo-American phenomenon.

2.5.5 The Hegemony Cycle

The concept of hegemony can be described by the ability of a nation to dictate, or at least dominate, the rules and arrangements by which international relations, political and economic, are conducted. Goldstein (1988) describes economic hegemony as the ability of one country to center the world economy around itself. Political hegemony means being able to dominate the world militarily.

The debate concerning the very long hegemony cycles can be organized into three different schools of thought: the leadership cycle school, the world transition school and the power transition school. Modelski's leadership cycle school actually doesn't describe war- but political cycles in which the institutions and regulations arise. International contacts take place in line with them. They eventually distinguish twenty long waves. Wallerstein's world system school has a neo-Marxist background and occupies itself with the relationship between core and periphery. This is in contrast to the other schools which primarily focus on conflicts within the core of the world system. The power transition school follows Organski's pioneering work and states that an international hierarchy is necessary to prevent war. A superpower must intimidate potential challengers in such a manner that war no longer becomes a real option for them.

Goldstein (1985) states that there is a twofold causal relationship between economic growth and large wars. There are only enough resources for a large war during a period of economic prosperity. International competition is thereby intensified in the expansion phase which causes conflicts. The growth period will eventually come to halt because large wars weaken long-term production growth significantly. Wars after all devour raw materials and production resources. Goldstein also distinguishes a longer hegemony of hundred fifty years which is completely autonomous of the economic Kondratieff long wave of half a century. Other authors, such as Modelski and Thompson (1984) and Mandel (1995), also consider the hegemony cycle to be independent of the Kondratieff.

2.5.6 Auxiliary Cycles

In order to complete the overview of the cycles in the literature we will concisely examine some other cycles.

Forrester's (1977) long cycle originates from a model simulation (the National Model), which he associates with the Kondratieff cycle. His model also implies a so-called bootstrap. A bootstrap structure arises when a sector uses part of its own sales as a production factor. The signal to increase the supply of the factor leads to operations which, at least in the short-term, cause a reduction in the supply. This process also takes place in the capital sector. When the capital sector has to increase its supply in order to satisfy an increase in demand, both labor and capital equipment are needed. The only way to facilitate this is by withdrawing investments from the consumption sector, which was responsible for the increase in demand in the first place. Thus a delay arises which ensures a considerable extension of the periods of fluctuations. Haustein and Neuwirth (1982) consider bootstraps to be a well known economic phenomenon. They give an example in the shipbuilding industry with a cycle length of approximately 17 years. According to these authors, Tinbergen proved that the entire cycle length is four times the lag (ibid, p. 68).

Thio (1991) puts forward a model of labour supply and deduces a 32 year cycle. Howe and Strauss (1991) started from the concept of historical generations, which would show a repetition through the centuries. They identify a cohort generation as everyone born within a particular 20-25 year time span. People in a cohort generation have a similar world view. Howe and Strauss delineate 17 different generations over the course of American history between 1584 and 1981 with number 18 starting in 1982. The so-called four-phase four-generation cohort cycle, where recessive and dominant generations alternate, thus has a length of around 90 years. Berry en Kim (1994) connected the age cohort analysis with the Kondratieff cycle. They combine the four consequent waves of types of generations to the four phases of the Kondratieff wave.

Finally, Namenwirth (1973) used political themes to express the dominant ideology which he then related to the economic situation. He analyzed themes from the political campaigns of the American presidential elections between 1844 and the 1960s and he found cycles of political themes of 48 and even 152 years.

2.5.7 Overview of Cycles

In the table below an overview will be given of various cycles from the literature. Looking at the cycle lengths of the various tabulated cycles an interesting observation can be made. Remarkably the cycle lengths seem to cluster around the numbers from the Fibonacci sequence.

Table 6: Grand Scheme of Cycles

Authors	Length (yrs)	Driving Forces	Fibonacci
			1
			1
Kuczynski (1978)	2	Industrial production lag	2
Kitchin (1923)	3 to 4	Inventories	3
			5
Juglar (1860)	7 to 11	Investments in machines	8
Kuczynski (1978)	8	Production and export	
Kuczynski (1978)	9	Innovative activities	
Haustein and Neuwirth (1982)	7	Not supported by theory	
Kuczynski (1978)	13	Unknown	13
Forrester (1977)	14	Bootstrap (in model)	
Haustein and Neuwirth (1982)	13	Not supported by theory	
Haustein and Neuwirth (1982)	17	Bootstrap	
Kuznets (1930)	15 to 25	Construction investment	21
Kuczynski (1978)	23	Inventive activities.	
Haustein and Neuwirth (1982)	20	Innovation	
Solomou (1998)	20 to 23	Not supported by theory	
Thio (1991)	32	Employment	34
Haustein and Neuwirth (1982)	32	Innovation	
Haustein and Neuwirth (1982)	40	Innovation	
Kondratieff (1928)	48 to 60	Industrial complexes	55
Forrester (1977)	50	Capital section	
Kuczynski (1978)	60	Industrial production	
Goldstein (1988)	50 to 60	War	
Marchetti (1983)	54	Innovation	
Namenwirth (1973)	48	Culture and politics	
Berry and Kim (1994)	48 to 60	Generation types	
Rainer Metz (1992)	54 to 56	GDP series	
Howe and Strauss (1991)	90	Generations concept	89
Namenwirth (1973)	152	Culture and politics	144
Modelski (1978)	140	War	
Goldstein (1988)	150	Hegemony	

2.5.8 Conclusion

In the long wave literature, five different economic cycles have been discussed at length. In this chapter the so-called Kitchin, Juglar, Kuznets, Kondratieff and the Hegemony cycles have been described. All these cycles have their own original theoretical and empirical foundations. Some long wave researchers have tried to interlink these cycles. We will touch on these attempts in Chapter 3.

It also can be observed that the longer these cycles are the more controversies surround them. However, the fact that the evidence for the existence of the long wave has not yet been delivered does not automatically mean that it cannot be produced at all. In accordance it cannot be said with absolute certainty that a long wave has not been active for at least a certain period in the industrial era. A comparison to other scientific disciplines is in place here. Certain problems, for example Fermat's theorem, seemed unsolvable until after hundreds of years a solution was found.

It is doubtful whether the current approaches can unravel the unresolved issues. A different approach is therefore felt necessary. Such an approach certainly should lead to different results that would be a differentiator in the economic cycle debate. In Chapter 3 we will develop such a new approach. This approach is based upon multiple cycles. Multiple cycles which in aggregation can be associated with stability in the economy.

Contents

Chapter 3. Multiple Cycles

Chapter 3.1 Introduction

Over the past hundred years the economic development of countries and the behaviour of relevant economic variables have been widely studied. Intense search after the enigma of the rise and decline of economic growth stemmed from the desire to forecast the economic future. Since the erratic movement of the economic waves made them somewhat unpredictable, researchers have tried to come up with theories and empirical evidence that this movement had a cyclical nature at the background.

The idea of decomposition goes all the way back to Marx. In his letter on 31 may 1873 Marx wrote to Engels: "I told Moore about a matter which I have been privately wrestling with for some time. He believes it is insoluble or at least insoluble for the time being because of all the large numbers of factors involved, which for the most part still have to be ascertained. This is it: you know the charts plotting the rising and falling zigzag movements of prices, discount rates etc. over the year etc. To analyse the crisis, I have tried several times to calculate these ups and downs as irregular curves and believed (and still believe given sufficient sifted material) that it is possible *to derive the main laws of crises mathematically from this*."

From the long wave debate, as discussed in Chapter 2, it has become clear that a new approach is needed. In search of such an approach we hold the opinion that Schumpeter's multiple cycle approach has not been sufficiently explored. In Chapter 3 we describe Schumpeter's original multiple cycle theory and other contemporary multiple cycle approaches. The most important subject Schumpeter brought into the limelight is the role of innovations in the economy. Therefore it seems useful to investigate whether the supposed multiple cycle structures can by found in an innovation dataset. We will examine various innovation theories and will eventually investigate whether multiple cycle structures are present in an innovation series. This proves to be the case. We find five cycles with lengths of 5, 13, 24, 34 and 61 years.

These lengths are remarkably close to the Fibonacci sequence. Furthermore we find evidence for the clustering of basic innovations.

In Chapter 3.4 we will explore whether our results from the innovation series can also be found in other macroeconomic variables. We will investigate 33 series from three countries and 6 classic long wave datasets and discover multiple cycle structures in all investigated variables with in total 90 individual cycles. Here we also observe that the observed cycle lengths seem to approach the Fibonacci sequence.

One of the features of Fibonacci cycle lengths is that there is not a single moment in time in which all cycles simultaneously reach their maximum of their minimum. Thanks to this property the multiple cycle structures can be associated with stability in the economy. Because the peaks and the troughs of the cycles are not simultaneous they blunt each others extremes. This implies that macroeconomic policy is useful. By means of policy cycles can be created which can counterbalance unwanted extreme fluctuations. These findings update the traditional image of the single cycle to that of a multiple cycle economy.

Within the context of the longer cycles Schumpeter's multiple cycle hypothesis especially stands out. It is extraordinary interesting to investigate whether and when found, how this premise holds up in practice. This is especially useful since the multiple cycle principle can offer a compromise for the question concerning the existence of cycles and the influence of the decisions of policy makers. Within this concept both cycles and useful macroeconomic policy can coexist via the creation of new cycles with a decelerating or stimulating impact.

Chapter 3.2 Multiple Cycle Theories

3.2.1 Introduction

The main idea on multiple cycles goes as far back as Schumpeter. In his seminal work Business Cycles (1939) he elaborates on the cyclical development theories and proposes the concept of a multiple cycle economy in which innovation is a driving force. A few long wave researchers have picked up on Schumpeter's multiple cycle perspective. Their results will be discussed in Chapter 3.2.3.

3.2.2 Schumpeter's Multiple Cycle Approach

The concept of multiple cycles can be attributed to Schumpeter (1939). He expects the number of active cycles to be indifferent. The famous three cycle schema in which he combines a Kitchin, a Juglar and a Kondratieff is a simplification and is strictly for illustrative purposes only: "Strictly speaking, we should expect an indefinite number of cycles."

For the sake of simplicity Schumpeter only analyses the three-cycle case, disregards the effects of external disturbances, and assumes successful correction for Seasonals and Growth. In reality he does not expect the cycles to have a strict sine form or exact internal regularity.

According to Schumpeter all cycles are generated by innovations: "Innovations their immediate and ulterior effects and the response to them by the system are the common 'cause' of all of them [the cycles, red], although different types of innovations and different types kinds of effects may play different roles in each."

Schumpeter gives three reasons for the existence of multiple cycles. The first reason is that different innovations take varying lengths of time to be absorbed into the economy. Secondly he states that major driving innovations do not emerge in their final form or diffuse synchronously over the whole economy. Some innovations are thus carried out in steps. Finally Schumpeter recognizes that major innovations can have a far reaching influence on the economy. In order to reap the benefits enabled by these types of innovations businesses and even society as whole have to adapt step by step. Schumpeter does not hint at cycles with a strict periodicity and regularity but at unique epochs which each have their own unique driving major innovations, exogenous disturbances and constellation of cycles.

The following captures the essence of Schumpeter's theory: there is no single wave but there are multiple waves present in the economy which interfere with each other. Moreover the cycle lengths tend to be different. As an example he discusses the Industrial Revolution (p. 168): "Another example is the process known as the Industrial Revolution. It consisted of a cluster of cycles of various span that were superimposed on each other. But these together wrought a fundamental change in the economic and social structure of society which in itself also had some obviously cyclical characteristics. It came about in phases in which, prices, interest rates, employment, incomes, credit, and output behaved much as they did in the fluctuations universally recognized as cycles."

Schumpeter concludes: "(…) we conclude, as stated in the first paragraph of this section, that there is a theoretically indefinite number of fluctuations *present* in our material at any time, the word present meaning that there are real factors at work to produce them and *not merely that the material may be decomposed into them by formal methods*, a distinction which will become much clearer in the next chapter. Their duration (period) varies greatly – for we know that some of them are associated with effects of processes which run their course in a year or two, others with effects of processes which are secular by nature – but might in a limiting case vary continuously. As a matter of fact, we shall not expect this, but rather that periods, will display finite differences clustering around certain averages. Some of the periods will be so close together as to be indistinguishable, or undiscoverable by formal methods such as the periodogram analysis, which then may show other than the true periods, *e.g.*, an intermediate one. Others will be so wide apart as to satisfy the one of the requirements of the periodogram analysis almost ideally."

3.2.3 Contemporary Multiple Cycle Approaches

Even though most researchers were empirically trying to proof or disproof the existence of the Kondratieff wave, some researchers kept the multiple cycle approach alive in the years after Schumpeter introduced the phenomenon. The findings and ideas of some of the most important of these researchers will be concisely discussed in this section.

Kuczynski (1978) discerned cycles of 2, 8, 9, 13, 23 and 60 years, see also van Duijn (1983, pp 170-171). Kuczynski focussed on real economic growth of production and also used inventions and innovation data. Using spectral analysis he found a variety of waves with different lengths. He could not explain the theoretical background of his findings.

Haustein and Neuwirth (1982) have found a whole range of waves of different lengths which they all described towards innovations. They have similar findings as Kitchin, Juglar, Kuznets and Kondratieff. Haustein and Neuwirth group their cycles around certain averages, their spectral analysis reveals cycles of: 53 (53.3), 40, 32 (26.7, 32 and 33.3), 20 (16, 16.7, 20 and 22.6), 13 (10.7, 11.4, 12.3, 12.5, 13, 13.3, 14.3 and 14.5) and around 7 (5.9, 6.1, 6.3, 6.7, 6.9, 7, 7.3, 7.6, 8.0, 8.4 and 8.9) years. According to Haustein and Neuwirth these cycles are not strictly regular and periodic and prefer to call them 'historical periods' and 'quasi-cycles'. They connect the cycles which have a corresponding length to the four well-known cycles from the literature and although they find more than one cycle they do not explicitly comment on the existence of a multiple cycle structure in innovations or the economy.

In his research van Duijn (1983) elaborates on Schumpeter's multiple cycle idea. He uses Schumpeter's three-cycle schema concept to develop a schema of his own. In addition to the three cycles used by Schumpeter he also incorporates the 15-25 year Kuznets cycle in his theory. Van Duijn acknowledges that: "All four cycles exist simultaneously." His schema is as follows (p 6): "1 Kondratieff = 3 Kuznets = 6 Juglars = 12 Kitchins." He recognizes that Schumpeter's three-cycle schema is a simplification, but states that it is a valuable depiction of reality nonetheless: "It is very tempting but also very simplistic to see economic development as the result of four thus interwoven cycles. Yet, simplistic as it may seem, there is some truth to this representation." Van Duijn mentions that the cycles most likely operate in an interlinked manner and that they are essentially driven by fluctuations in investment, even though basic innovations are needed to fuel this investment process.

Reijnders (1990) also acknowledges Schumpeter's multiple cycle hypotheses, albeit in a manner which is less mechanical than van Duijn and thus stays truer to the original concept. He writes (p 3): "If it is conceivable that the business cycle is the effect of the economy's reaction to external disturbances it is also conceivable that distinct parts of it react differently. Several sub-systems may generate different adaptation processes of which every single one has a characteristic time path of its own. Consequently, macroeconomic motion can only be interpreted in terms of a multiple cycle concept."

Reijnders furthermore states that the erratic patterns of economic development can at least partially be explained by the interplay between cycles of different lengths, he continues (p 3): "Movements in the economy are then interpreted as the aggregative impact of cycles of different durations. The complexity of the patterns of reality is explained by 'interference'. Different cycles 'ride on each other's backs' and successive phases of one may accentuate the shape of the other to a degree that even what is strictly regular manifests itself in such a great variety of patterns that it appears to be irregular."

He declares that the well-known 'uni-cycles' exist, but not in the traditional way. According to him they are a part of the multiple cycle structure. Reijnders states (p 242): "If one decides to accept the Kondratieff wave on the basis of the present results, one will also have to accept that this particular movement is embedded in a rather complicated structure which contains a multitude of wavelike movements, not only shorter but also of considerably longer duration than the Kondratieff wave itself. Therefore one cannot claim a separate *raison d'etre* for the Kondratieff wave because it is an integral part of this multiple cycle structure and does not have a life on its own." Each cycle, both known and unknown, can be grouped into a domain which corresponds with their average duration.

Solomou (1998) reports the following. British GDP seems to have two stochastic cycles of 8.6 and 24.6 years. When a single cycle is imposed, a cycle length of 12.3 years is found. The US economy displays cycles of 5 years, of 10.8 and of 19.2 years. The German economy displays cycles of 10.8 years as well, and also one of 23.8 years. Finally, the French GDP has cycles of length 4.5, 7.7 and about 20 years. According to Solomou, each era has its own unique and not internationally synchronized constellation of cycles.

Reijnders (1990) writes on p. 425 of Vol 1: ”(…) which makes the systematic long-run movements of all items that relate to the economic process fit together like pieces in a giant jigsaw puzzle”. Herewith Reijnders summarizes the enigma of the multiple cycle approach.

3.2.4 Conclusion

In “Business Cycles” (1939) Schumpeter clearly articulates the concept of real world multiple economic cycles. Other authors have elaborated on this notion. Common elements in the various multiple cycle perspectives are: an indefinite number of independent cycles, varying cycle lengths and the possible interlinkage of cycles. Schumpeter’s hypothesis that the cycle lengths concentrated around certain averages was supported by Haustein and Neuwirth (1982) and Reijnders (1990).

This concept of real world multiple economic cycles seems very appealing and could be worthwhile to apply towards an empirical investigation.

Chapter 3.3 Cycles in Innovation

3.3.1 Introduction

Basic innovations are often believed to be the drivers of economic growth. It has been widely documented that economic growth follows cyclical patterns of varying length. In this section, we examine if such patterns are also present in basic innovations. For an annual time series of count data covering 1764-1976, we fit a harmonic Poisson regression model. The results suggest the presence of multiple cycles of length 5, 13, 24, 34 and 61. We compare these cycles and their joint effect with widely documented economic cycles and find important resemblances and differences.

Radical innovations play a central role in almost all long wave theories. Protagonists of the view that economic development is explicitly driven by radical innovations are for example Schumpeter, Mensch and van Duijn, where Schumpeter was the first to conjecture that economies are driven by entrepreneurial innovation.[22] Economic development is assumed to depend on the ability of heroic entrepreneurs who combine exogenously produced scientific inventions and original ideas to create ”new combinations”, which then lead to a cluster of basic innovations which in turn will propel new leading sectors.

Mensch elaborated on this notion and added the idea that the clusters of radical innovations develop during depression periods because only then, companies would be desperate enough to try to rekindle profitability through investing in radical new technologies. Clark, Freeman and Soete refuted Mensch’s depression trigger hypothesis and argued amongst other things that basic innovations cluster mostly in the beginning of the long wave upswing. Van Duijn combines principles from the innovation literature with investment theory and focuses on innovation life cycles. He states that new radical innovations with the help of a conducive investment climate create new industries which are able to take the economy to a higher level of development. Supporters of the investment school and the Marxists thought innovations only to be supportive in their respective theories.

Here we also focus on innovations, and we examine the link between bursts of radical innovations and economic cycles. Indeed, there is ample evidence of such cycles in economic data. Since the debate on long waves really took off after Kondratieff's somewhat controversial publications (1925), many authors have devoted time and energy to question and examine ”the long wave”. This line of research resulted not only in findings on the long wave with a duration in between 40 to 60 years, but also other waves with different lengths and also different drivers were found. The well-known cycles of Kitchin (1923), Juglar (1862) and Kuznetz (1930) are just a few examples. The length of the various cycles found in terms of the critical literature of ”the long wave” seems to cluster around certain averages. In the present section we give a condensed historical overview of the findings of authors who have studied innovations and long wave related theories.

The main focus in this paragraph is to examine the link between innovations and economic cycles by studying cyclical patterns in innovations. For that purpose, we first start in section 3.3.2 with a review of the literature on the link between innovations and long economic cycles. Next, in section 3.3.3, we concisely summarize the literature on economic cycles by providing a table with the main landmark results. In Section 4, we analyze a time series with count data concerning basic innovations. We propose a harmonic Poisson regression model for this purpose and test for the presence of multiple cycles. We find compelling evidence of such cycles of length 5, 13, 24, 34 and 61 years. In Section 5, we conclude our section by formulating a few conjectures that provide interesting areas for further research.

3.3.2 Innovations and Long Cycles

In this section we summarize the main arguments for the presence of a relation between economic cycles and basic innovations.

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[22] Full reference to the relevant publications will be given in later sections, where we concisely review the literature

Schumpeter and Kuznets

In his book Business Cycles (1939), Joseph Schumpeter developed the entrepreneurial model of innovation in which skilled individuals use exogenously produced inventions and original ideas to create ”neuer Kombinationen”. These radical innovations are distributed randomly over time. A cluster of basic innovations is assumed to create a new and fast growing leading sector in the economy, which facilitates an upswing in the long wave. Innovators who have successful applications are considered able to exploit a temporary monopoly. In contrast, radical innovations are discouraged *during* the upswing because existing technologies already generate ample earnings. Next, after some period of time, a swarm of imitators saturates the market, and consequently, margins will erode and earnings will diminish. By then, economic development will slow down and the long wave will enter the down swing phase. In Schumpeter’s view, the economy is dependent on heroic entrepreneurs to get out of the depression periods.[23]

Schumpeter’s ideas have been criticized along various lines. Kleinknecht (1990) summarizes the most important critiques that appeared in Kuznets (1940) in his, otherwise predominantly positive, review of Schumpeter’s book on business cycles. First, Schumpeter was considered to have failed to give evidence that long waves are not merely a price phenomenon, but also exist in real indicators of general economic activity. Second, Schumpeter’s explanation of the long waves required a clustering of radical innovations, and this had not been substantiated with empirical data. And, third, Schumpeter had failed to give a convincing explanation of why such clusters would occur. Freeman and Louça (2001) respond that, due to additions and adaptations to the original ideas of Schumpeter in various articles and books, the original critiques can now be refuted and that the notion of the clustering of innovations is now well established.

[23] Later in his prolific scientific career, Schumpeter abandoned the idea that innovation is *solely* depending on the creative efforts of individual entrepreneurs. He observed that the bulk of innovations did no longer stem from small entrepreneurial firms but that they were produced by large corporations who relied on the efforts of their R&D departments.

More on the clustering of innovations

Mensch (1975) concluded that clusters of radical innovations develop during the end of the long wave down swing. He formulated a theoretical explanation for this phenomenon, the so-called ”depression trigger” hypothesis. Mensch distinguishes basic innovations, improvement innovations and pseudo-innovations. Instead of the idealized sinus wave pattern, Mensch uses an S-shaped representation of the long wave in his metamorphosis model. A cluster of basic innovations, which arises at the end of the downswing phase, facilitates the development of a new ”S”. Clustering is caused by fast imitation, the so-called bandwagon effect. The economy will form itself after the new leading sector and gets into lock-in. Firms, by then, only want to protect their market shares and will limit themselves to the improvement of innovations. Firms will desperately try to prevent complete stagnation with pseudo-innovations when market saturation kicks in and the possibilities for new applications of the technology are exhausted. The lack of profitability assures that, despite the higher risk and pessimism associated with the depression phase, investors will change to new radical projects. According to Mensch this is the only way a society can defeat a period of technological stalemate.

A little later, Clark, Freeman and Soete (1981) find much weaker support for the clustering hypothesis than Mensch did. They conjecture that clustering of basic innovations occurs throughout an entire long wave cycle and most predominantly at the beginning of the upswing phase. Furthermore, they also indicate that the timing of the emergence appearance of basic innovations is of no direct importance but it is the moment of diffusion that is essential. Clark, et al. (1981) point out that the diffusion of a group of revolutionary innovations does not proceed directly after they have been introduced but that it can take many years before a cluster breaks through. Moreover, they indicate that the diffusion process is not just copying an innovation, but merely that it consists of a series of further improvements.

Van Duijn (1983) analyzes diffusion, that is, the large-scale distribution of innovations, which he believes is the dominant force behind the long waves. His theory is based on three basic principles, which are innovation, innovation life cycles and investments in infrastructure. Innovations and innovation life cycles are the boosters of the growth process, which additionally is strengthened by investments in the infrastructure. Van Duijn does not assume a univocal link between the long wave phases and the innovation life cycles, and therefore innovations occur continuously. He distinguishes four different types of innovations, that is, important product innovations which create new industries, important product innovations in existing industries, process innovations in existing industries and, finally, process innovations in basic sectors (such as oil refineries and the steel industry).

Finally, in Freeman (1996) and Perez (1983, 2002), the authors take a further step by making the allegation that clusters of basic innovations play a far-reaching part in society. It is emphasized that this is due to the mutual dependency of technical, economic, political and cultural factors. Certain types of technological change influence all sectors of the economy. The diffusion of their so-called techno-economical paradigm is accompanied by a large crisis of structural adjustment. Social and institutional change is necessary to bring about a better match between the new technology and the old political, social and management system of the economy, the so-called socio-institutional framework. When such a match is achieved, a relatively stable pattern of long-term investment behavior can emerge that can hold out for about 20 to 30 years, as it is claimed.

Summary

Long wave researchers such as Schumpeter, Mensch, van Duijn, Freeman and Perez have, each in their own way, provided arguments how basic innovations could correlate with economic development. Schumpeter has been the first to point out the dominant role of the individual entrepreneur in the innovation process, but later he was known to switch to the idea that large corporate R&D departments were responsible for the development of new technologies. Mensch further developed the early ideas of the Schumpeter. He created his depression trigger hypothesis, which was later supported by Kleinknecht but criticized by Clark, Freeman and Soete. The latter authors argued that innovational clustering predominantly takes place during the recovery period. Van Duijn elaborated on the role of investment in the innovation process. Finally, Freeman and Perez enlarged the focus of the innovation school and incorporated the institutional environment in their analysis.

The basic notion in all these theories is the same. Innovations are important drivers of economic growth and of economic cycles. The nature of such cycles is already described in Chapter 2 and Chapter 3.2.

In sum, there seem to be many causes and drivers for economic cycles of varying lengths. Innovations, certainly, are viewed as of the key drivers, but also other factors exist. In Table 6, we summarized the various cycles from the literature.

A final issue concerns the notion that two or more cycles can exist at the same time. Schumpeter was one of the first to think in terms of such a multiple cycle concept. He considered the 'Kitchin' cycle, the 'Juglar' cycle and the Kondratieff cycle. Schumpeter believed that one Kondratieff cycle comprised six Juglars. In turn, the Juglars were composed out of three Kitchin's. He argued that these different waves would operate in parallel because each innovation, the driving forces of the waves had different impact.

The question however is whether any cycle should incorporate an integer number of other cycles. It may well be that various cycles exist at the same time, but that their peaks and troughs rarely, if ever, occur at the same time. For example, if there are two cycles of length 8 and length 13, only once in the 8 x 13 = 104 years they share an extremum value. In the next section we therefore examine the properties of an innovation count series and look for the presence of cycles. As innovations appear by and large to drive economic cycles, it is of interest to see how innovation cycles look like.

3.3.3 Cycles in Innovations

In this section we analyze a lengthy series concerning basic innovations for its cyclical properties. We first put forward three hypotheses, which we derive from the literature review in the previous two sections. Next, we discuss the data, and then the econometric modeling method. We conclude with a description of the results.

Hypotheses

We have seen that there is a link between innovations and economic cycles. Next, we have seen that there is a variety of long economic cycles. Our first hypothesis (*H*1) is then that there are various cycles in innovation data. Following various authors, we next hypothesize (*H*2) that there is a clustering of basic innovations. These two hypotheses can be examined using parameter estimates in the regression model to be discussed below. Our next hypothesis concerns the link between the cycles in innovations, if there were any, and the economic cycles. Again following the earlier discussion, we propose (*H*3) that basic innovations peak where the long wave is at its low point and the number of basic innovations is small where the long wave peaks. Hence, in recession periods at the end of the down swing there are clusters of innovations. Herewith we test again the hypothesis as it was also tested by well-known long wave innovation authors.

Data

Before the three hypotheses can be tested, the question should be addressed which data set is the most suitable for our analysis.

We decide to rely on the data set created by Silverberg and Verspagen. Silverberg and Verspagen (2000) create a basic innovation super sample by combining the datasets of Haustein and Neuwirth and of van Duijn. Kleinknecht's dataset is not used as it is too short in comparison to the other two. Silverberg and Verspagen do not apply a weighting procedure because this is not consistent with the use of the Poisson distribution. Innovations which exist in both data sets are counted only once in the super sample, just as innovations which appear in only one of the data sets. All innovations are thus treated equal. When there was a difference in the date of appearance of the basic innovation between the sets of Haustein and Neuwirth and Van Duijn there has consequently been chosen for the earliest date.[24]

[24] By focusing on basic innovations and using this data set we are aware that we choose to investigate basic innovations rather than diffusions. All data sets reflect the moment of introduction of basic innovations. It might be that the moment of diffusion is more important for long wave take-off. This has been indicated before by Freeman, Clark and Soete (1982) in their criticism of Mensch (1975) and has later been further developed by Perez (2002) who explicitly based her long wave scheme on the

Silverberg and Verspagen's (2002) innovation super sample involves historically recognized general data set problems such as the end effect error, personal bias of the creator and the fact that in certain cases it is arbitrary whether an innovation is basic or not. Moreover, an important shortcoming of the used data could be that the basic innovations incorporated in all the data set are assumed to be equal whereas in practice the impact on the economy will be different. This is all the more relevant because the long wave theories which have assigned a central role to basic innovations explicitly point out that that certain innovations, whether or not in cooperation with related innovations, have such a large impact they can influence the entire economy. However, the mentioned shortcomings have been widely discussed among the various authors, the data is the best data available for the research as is to be conducted.

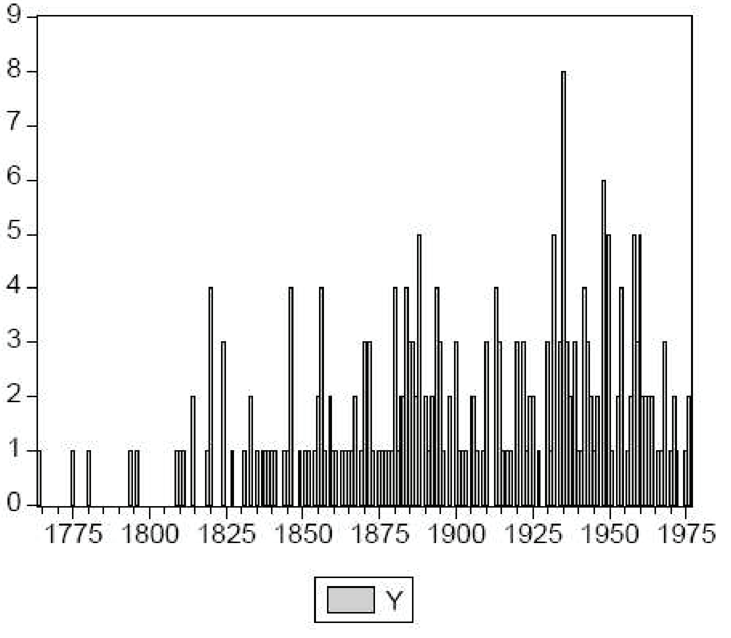
The count data we analyze are depicted in Figure 1. It concerns an annual time series of the number of basic innovations per year, and it runs from 1764 to and including 1976, thereby covering 213 years.

The model

We now say a few words about the Poisson regression model that we use for describing the data in Figure 4.

diffusion of the successive technological revolutions. Recently, Hirooka (2003) follows the same approach.

Figure 4: Time series of amount of basic innovations per year, 1764-1976



Consider the variable Y_i, $i = 1,...,N$ which can take only the discrete values $0,1,2,3,...$. If the variable Y_i has many different values relatively far away from zero, the Linear Regression model is often used as a good approximation. However, if the number of different realizations in Y_i is small as in our case with values ranging from 0 to 8 (which is the maximum amount of innovations in a year in our sample), and the values of Y_i are close to zero, this model does not seem to be appropriate as it is unlikely that a possibly continuous variable x_i is mapped on the discrete variable Y_i.

Therefore, we assume that Y_i is Poisson distributed, that is, $Y_i \sim \text{POI}(\mu)$

$$\Pr[Y_i = j] = \frac{\exp(-\mu)\mu^j}{j!}$$

for $j = 0,1,2,...$ with $\mu > 0$. The mean and variance of Y_i are given by

$$\text{E}[Y_i] = \mu \text{ and } \text{V}[Y_i] = \mu.$$

To translate this unconditional model to a conditional model that is useful for our purposes, we assume that

$$\mu = \exp(\alpha_0 + \alpha_1 t + \sum_{i=1}^{C} [\beta_{1,i} \sin(\frac{2\pi t}{C_i}) + \beta_{2,i} \cos(\frac{2\pi t}{C_i})]) \qquad (1)$$

which is a harmonic Poisson regression model. In words, this model says that basic innovations show a trend and cycles of length *C*1, *C*2 and so on. The amount of cycles is *C*.

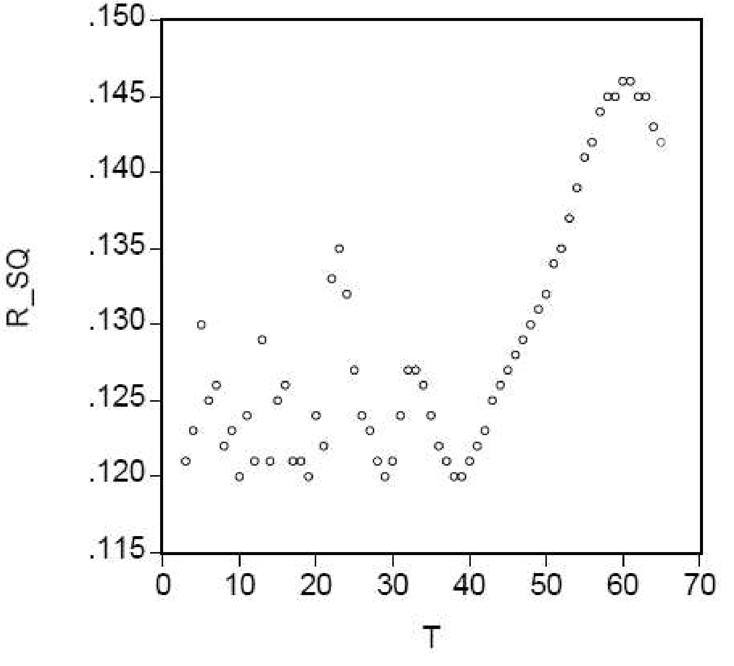
Empirical method

An important empirical decision to be made is the amount of cycles that can be discovered in the data. We decide to take the following strategy. In a test regression we set μ at

$$\mu = \exp(\alpha_0 + \alpha_1 t + [\beta_1 \sin(\frac{2\pi t}{C_i}) + \beta_2 \cos(\frac{2\pi t}{C_i})])$$

where i runs from 1 to 66. Hence, we have 66 regressions. For each of these regressions, we compute a pseudo R^2. In Figure 5, we depict these measures of fit against the value of C_i. We observe that the highest R^2 values are taken around C_i equal to 5, 13, 24, 34 and 61.

Figure 5: Partial R-squared versus cycle length in test regression



In a next step, we fit the harmonic regression model with these $i = 5$ cycles. The $p-$value for the joint significance of $\beta_{1,5}$ and $\beta_{2,5}$ is 0.0082, that of $\beta_{1,13}$ and $\beta_{2,13}$ is 0.112, of $\beta_{1,24}$ and $\beta_{2,24}$ is 0.0046, that of $\beta_{1,34}$ and $\beta_{2,34}$ is 0.341 and finally, that of $\beta_{1,61}$ and $\beta_{2,61}$ is 0.0001. The parameter α_0 parameter is estimated as -1.222 with $p-$value 0.000, and α_1 is estimated as 0.0105 with $p-$value 0.0000. Hence, the data show a marked upward trend. The pseudo- R^2 of this model is 0.184. To see if these estimation outcomes are robust, we re-estimate the model by each time changing the length of one cycle, while keeping the others fixed. We observe that no improvement in fit can be obtained, so we conclude that there is evidence that the innovations data have cycles of length 5, 13, 24, 34, and 61.

3.3.4 Interpretation of the Results

In Figure 6 we depict the cycles of length 61 and 34, while in Figure 7 we present the cycles of length 24 and 13. Next, in Tables 7 to 9 we give the peaks and troughs for the three most lengthy cycles. In Table 10 and in Figure 8 we present the characteristics of the multiple cycle.

Figure 6: Estimated cycles in basic innovations data, length 61 and 34

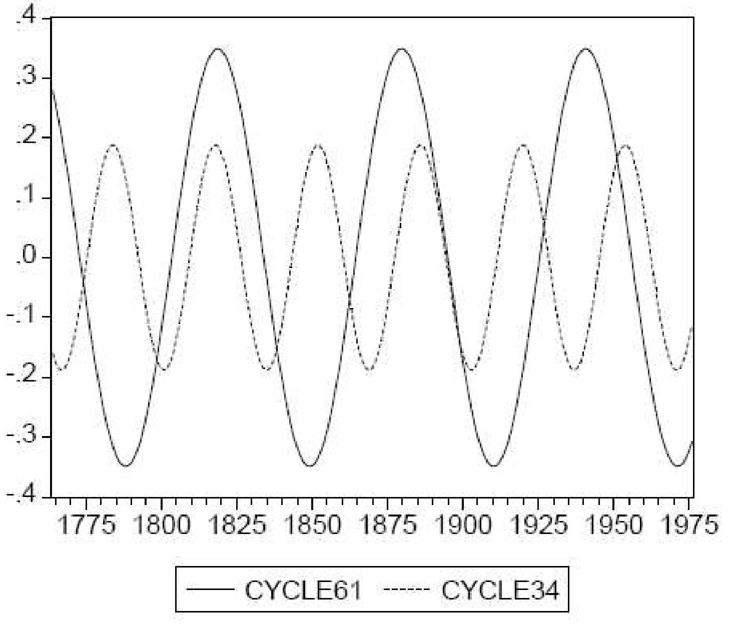


Figure 7: Estimated cycles in basic innovations data, length 24 and 13

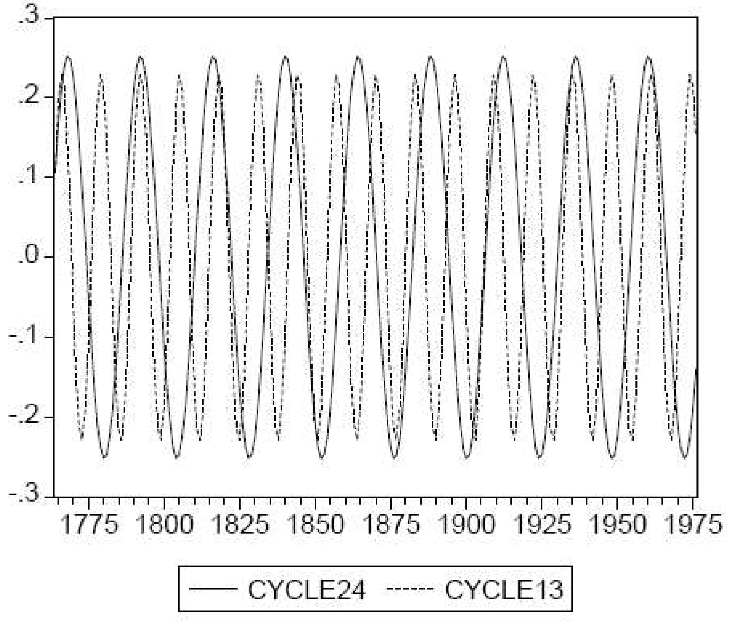


Table 7: Peaks and troughs in 61-year cycle

Peak	Trough
	1788
1819	1849
1880	1910
1941	1971

Table 8: Peaks and troughs in 34-year cycle

Peak	Trough
1784	1801
1818	1835
1852	1869
1886	1903
1920	1937
1954	1971

Table 9: Peaks and troughs in 24-year cycle

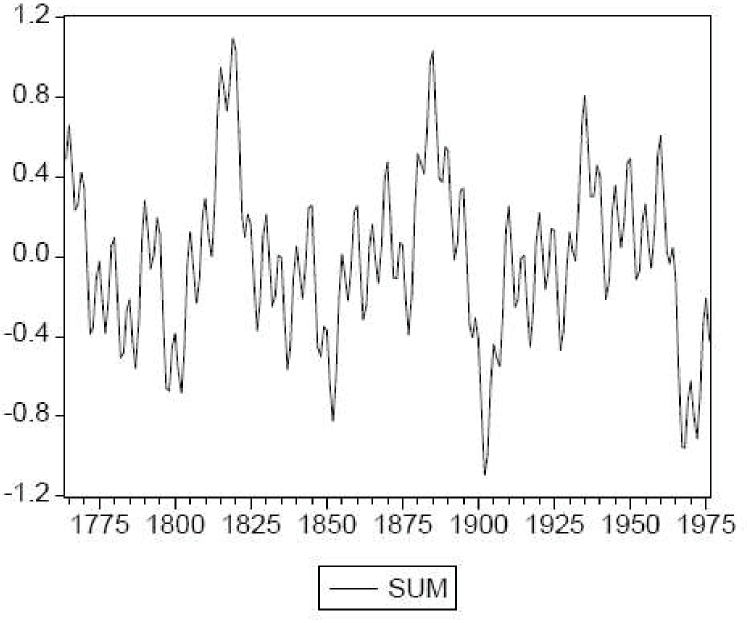
Peak	Trough
1768	1780
1792	1804
1816	1828
1840	1852
1864	1876
1888	1900
1912	1924
1936	1948
1961	1972

A first and obvious conclusion is that we can confirm the first hypothesis. We see that there are five cycles in the innovations series. Note that the length of these cycles also matches with the commonly found economic cycles in the literature.

Table 10: Peaks and troughs in the sum of the cycles, as compared to the Kondratieff cycle (according to Goldstein, 1988)

Peak	Trough	Kondratieff peak	Kondratieff trough
	1779-1802	1762	1790
1814-1821	1851-1853	1814	1848
1883-1886	1901-1904	1872	1893
1934-1936	1967-1973	1917	1940

Figure 8: All cycles in basic innovations data



The second hypothesis, which said that there is a clustering of basic innovations, seems to be confirmed by the results in Figure 8. The joint presence of five cycles in the innovations series shows that there are sequences of years in which more (or fewer) innovations occurred.

The research questions formulated earlier appear to be important in the context of the critical literature review. The hypothesis that basic innovations can be decomposed in cycles has been accepted. It has also been demonstrated that clustering of basic innovations takes place. From 1917 on the clustering manifests itself around the long wave minimum and moreover it is probable that this is more at the end of the downswing than at the beginning of the upswing. To be more specific, during the 1750-1850 period the troughs in innovations match with those in the Kondratieff wave. Interestingly, from 1883 to 1970 it is the peaks that match these troughs. Given the size of the overall sample, and the fact that there are just two cycles per 100 years, we have insufficient evidence which of the patterns will prevail in the future. The notion of the reversal of cycles seems an interesting topic for further research.

In light of the confrontation of this result with other research results it is surprising that a reverse pattern can be observed.

3.3.5 Conclusion

In this section we documented the presence of a multiplicity of cycles in innovations series, a similar multiplicity as for long economic cycles. Next, we found a clustering of basic innovations. Finally, we found that in the early years the troughs in innovations match with troughs in the Kondratieff cycle, while for the second half of the sample we see a reversal, which comes closer to our a priori expectations.

For further work, we see two avenues. The first concerns the notion of the reversal of cycles, as we saw in the previous section.

The second, and quite a challenging issue, concerns the cycle lengths themselves. As we already could observe from Table 6 in Chapter 2, the lengths of the cycles are remarkably close to the familiar Fibonacci numbers. Also, the innovations cycles are very close. We could think of possible reasons why cycles should obey such a regularity, but we need more empirical evidence to substantiate these thoughts.

Chapter 3.4 Stability through Cycles

3.4.1 Introduction

Economic variables like GDP growth, employment, interest rates and consumption show signs of cyclical behavior. Many variables display multiple cycles, with lengths ranging in between 5 to even up to 100 years. We argue that multiple cycles can be associated with long-run stability of the economic system, provided that the cycle lengths are such that interference is rare or absent. For a large sample of important variables, including key variables for the US, UK and the Netherlands, we document that this is indeed the case.

Economies of industrialized countries show cyclical patterns. Recessions since WWII seem to emerge every 8 to 10 years, which is usually associated with the business cycle, and long swings like the well-known 55 year Kondratieff cycle can be observed for a variety of variables. In fact, many economic variables seem to have even more than one cycle.

Roughly speaking, there are two views on the presence of one or more economic cycles. The first is that cycles are caused by shocks that are exogenous and largely unpredictable. These shocks can be associated with wars, technological innovations, fashion, generational conflicts and many more. The response of economic entities to such shocks sometimes can last a while, that is, some shocks are very persistent. Approximate models for such variables, at least in reduced form, are typically of the autoregressive (AR) kind, where the parameters take such values that some of the solutions of the autoregressive polynomial are complex-valued (that is, they are functions of $i^2 = -1$), see Steehouwer (2005) and the literature cited therein.

Basically this view at cycles assumes that in the absence of shocks, there should be no cycles. This assumption is extrapolated when making forecasts, as when long-run forecasts are made from AR models with complex solutions, eventually these forecasts tend towards the mean of the time series under scrutiny, and hence by definition the cyclical patterns disappear.

A second premise that follows from this view is that when economic variables have multiple cycles with various lengths, these multiple cycles are caused by exogenous shocks that apparently also display multiple cycles. Indeed in the previous section it is documented that technological innovations show multiple cycles, and perhaps, due to such cycles in shocks, economic variables also have cycles. This argument however assumes that such innovations are truly exogenous. As already suggested in the previous section, this is doubtful as it is most likely that economic progress and technological innovations, and maybe even shocks like wars and generational conflicts, are somehow intertwined, even so that it is difficult to state which type of shock is truly exogenous. In the previous section it is documented that a time series of the technological innovations experiences similar cycles (and of similar length) as those reported for major economic variables.

A second view on the presence of economic cycles, which is also the view taken up in our current section, is that, loosely speaking, there have always been multiple cycles and there always will be. Hence, these cycles are not fully stochastic and caused by external shocks, but are in fact partly deterministic. This is perhaps not so much of novelty, but the main new argument we make is that overall economic growth patterns are stable due to the very fact that there are multiple cycles. Basically, the argument is as follows. A first notion is that if there are economic cycles it cannot be a single, say lengthy, cycle. Indeed, if we were all to know how this cycle would look (say each 55 years a severe dip), we would behave accordingly or we would try the cycle to stop, or we would try to dampen its amplitude. With these last two efforts, governments issue policies and producers and consumers start to behave differently, and hence they start to behave anti-cyclically. This in turn can lead to some trembling, which in turn leads to other cycles.

The main characteristic of the cycles, though, should be that these cycles do not or do almost not peak or dip at the same time. If that happened, that is, that cycles at the same time could take their lowest values, then that would give an opening for an eruption or substantial crisis, perhaps one that can never be undone. Hence, for economies to be stable it is preferable that they have cycles and that the interference of these cycles does not lead to an enormous peak or trough because all cycles peak and dip at the same time. Ideally one would like to see a "smooth" development. A first impression of this phenomenon could be seen in the previous section where a graph with all the cycles in innovations series seems rather erratic but stable, while there are five major underlying cycles. Hence, we conjecture that cycles in economic variables have lengths such that economies are resistant enough to major shocks. So, there are shocks, and they do have an impact, but due to the constellation of the cycles there will not be any instability.

It should be remarked that when this second view, that is also ours, is adopted, models should include descriptions of these cycles as these cycles in the sample should be extrapolated into the future. In other words, if one believes in multiple cycles of a deterministic nature, one should also generate long-run forecasts with such cycles[25].

The outline of this Chapter is as follows. In Section 2 we briefly summarize the relevant findings on cycles in economics and we mention a few economic theories that seek to explain such observations. In Section 3 we outline the main ideas behind our notion that economies can be stable if they experience multiple cycles, where these cycles have lengths such that they do not interfere. To see if we find evidence of such non-interference in empirical data, in Section 4 we consider 33 series of 3 countries and few related ones. Our results are remarkable. We document a total number of 90 cycles. The best way to describe the cycle lengths turns out to be a mixture of four normal distributions, with mean values around 10, 28, 58 and 92. Note that these values are close to the Fibonacci numbers 8, 21 (34), 55 and 89, which we believe would entail cycle lengths with maximum stability. Indeed, for cycles of length 21 and 55 to interfere, one would need 21 times 55 years of data. In Section 5 we conclude with a review of the main findings and we provide openings for discussion by summarizing the limitations of our study as well as the challenges for further research.

[25] We assume that the nature of these cycles does not change over time, that is, there are no changes in amplitude or length. Allowing for such changes complicates the econometric analysis quite substantially. Moreover, as of yet we would not have any firm arguments which causal forces could establish such changes.

3.4.2 Stability and Cycles

In this section we outline our thoughts on the nature of economic development. As others do, we conjecture that most economic variables cannot be described by a single cycle but by multiple cycles. Together, these longer and shorter cycles with different lengths and amplitudes form constellations of cycles within each of the variables. The constellations do not consist out of simple multiplications of shorter cycles but out of various independent cycles which run more or less in their own domain.

All cycles, when summed, give a representation of the economy. When taken together the cycles form an erratic pattern which resembles the oscillation, the growth and decline, of an economy.

Stability is an important feature of the economic system. The total set of cycles expresses stability. We will give two examples of the stability of the system as a whole. First, within the constellations the individual cycles all have an own domain. Second, the interferences of the cycles with different lengths and amplitudes counterbalance each other, hereby creating an inherently more stable system. The difference in lengths of the cycles provides that the system never fully implodes or explodes due to unforeseen shocks, which of course can still occur. This harmonic and cyclical development of the economy, alternating periods of prosperity and decline, is a token of stability of the economic system as a whole.

We accept that shocks and impulses are necessary to create cyclical behaviour. We also believe that those shocks and impulses will always exist. Individuals, firms and governments will always act and cause impulses and cause economic growth and decline. The economy will therefore always oscillate and will never tend towards a static equilibrium in the classical sense. There is simply no reason to believe why shocks would be absent in the future.

In conclusion, we do not consider the concept of a single big wave to be valid any longer. Erratic patterns can be decomposed into multiple shorter, smaller and longer, larger cycles. We believe that economic variables can be decomposed into a constellation of cycles.

Following the concept of multiple cycles, we take into consideration that, after decomposing an economic variable into a constellation of cycles, an underlying structure may be revealed. Indeed, in stable economies one might expect to find cycles that, taken together, do not cause enormous peaks or dips. Hence, it should be unlikely to find cycles of length 4, 8 and 16. In fact, to prevent that interferences of the cycles would lead to enormous peaks and dips because of the cycle lengths, an optimal set of cycle lengths would match with the numbers of the Fibonacci sequence as cycles with lengths of 8, 13, 21, 34, 55 and 89 years do not interfere within a time span of thousands of years.

3.4.3 Empirical Results

In this section we analyze the cyclical properties of 33 key variables for 3 industrialized countries, that is, the US, UK and the Netherlands, as well as 7 series for wages, prices and innovations that have been considered in related studies. The first database was kindly made available by Hens Steehouwer, and they appear in Appendix F of Steehouwer (2005). In Tables 11a and 11b we summarize the variables and the time spans in years. In Figures 9a, 9b and 9c, we give the graphs of first 33 series per country.

Table 11a: Variables taken from Steehouwer (2005)

Country	Variable	Time span
USA	National product index	1870-1999
	Industrial production index	1860-1999
	Employment	1890-1999
	Consumer price index	1820-1999
	Wage index	1786-1999
	Short interest rate	1831-1999
	Long interest rate	1798-1999
	Equity price index	1800-1999
	Dividend yield	1871-1999
	Population	1790-1999
	Corporate bond yield	1857-1999
UK	National product index	1855-1999
	Industrial production index	1855-1999
	Employment	1855-1999
	Consumer price index	1600-1999
	Wage index	1829-1999
	Short interest rate	1820-1999
	Long interest rate	1700-1999
	Equity price index	1800-1999
	Dividend yield	1923-1999
	Population	1870-1999
	Corporate bond yield	1929-1999
	Equity total return index	1800-1999
The Netherlands	National product index	1870-1999
	Industrial production index	1921-1999
	Employment	1911-1999
	Consumer price index	1813-1999
	Wage index	1926-1999
	Short interest rate	1828-1999
	Long interest rate	1814-1999
	Equity price index	1816-1999
	Dividend yield	1824-1999
	Population	1839-1999

Table 11b: Seven other variables and their sources

Variable	Time Span
Wholesale Price Index, UK	1750-1975
Wholesale Price Index, France	1798-1975
Wholesale Price Index, Germany	1792-1918
Wholesale Price Index, US	1801-1975
South English Real Wages	1736-1954
South English Consumer Price Index	1495-1998
Innovations	1764-1976

Sources: Goldstein (1988) for the price and wages series and Silverberg and Verspagen (2000) for innovations.

Figure 9a: Annual time series, The United States

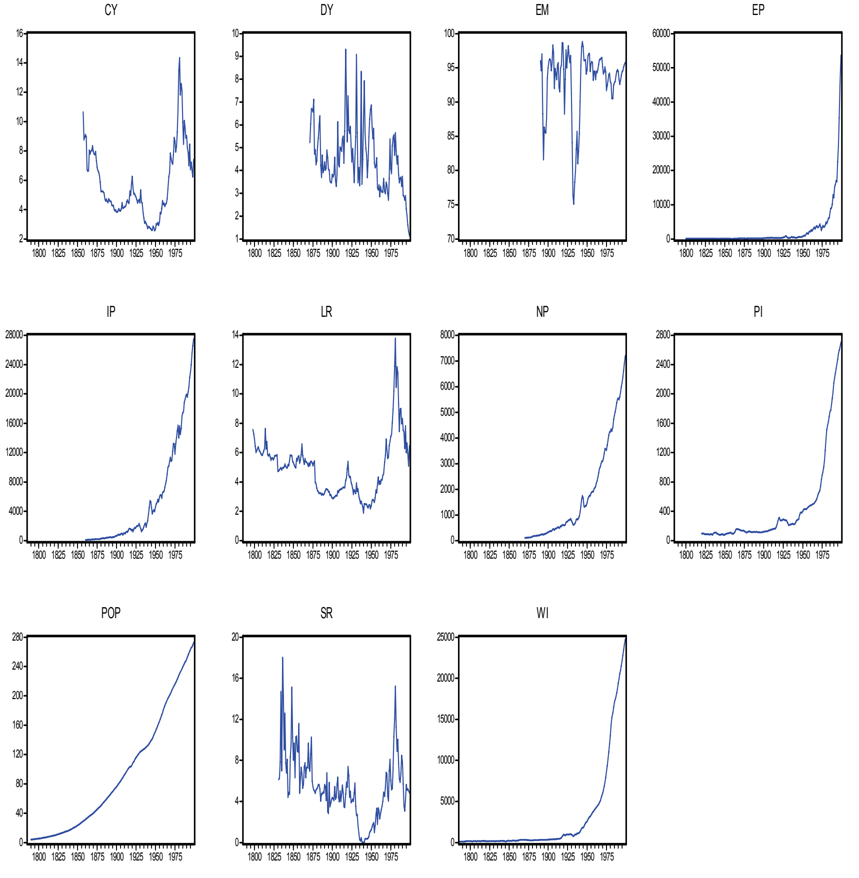


Figure 9b: Annual time series, The United Kingdom

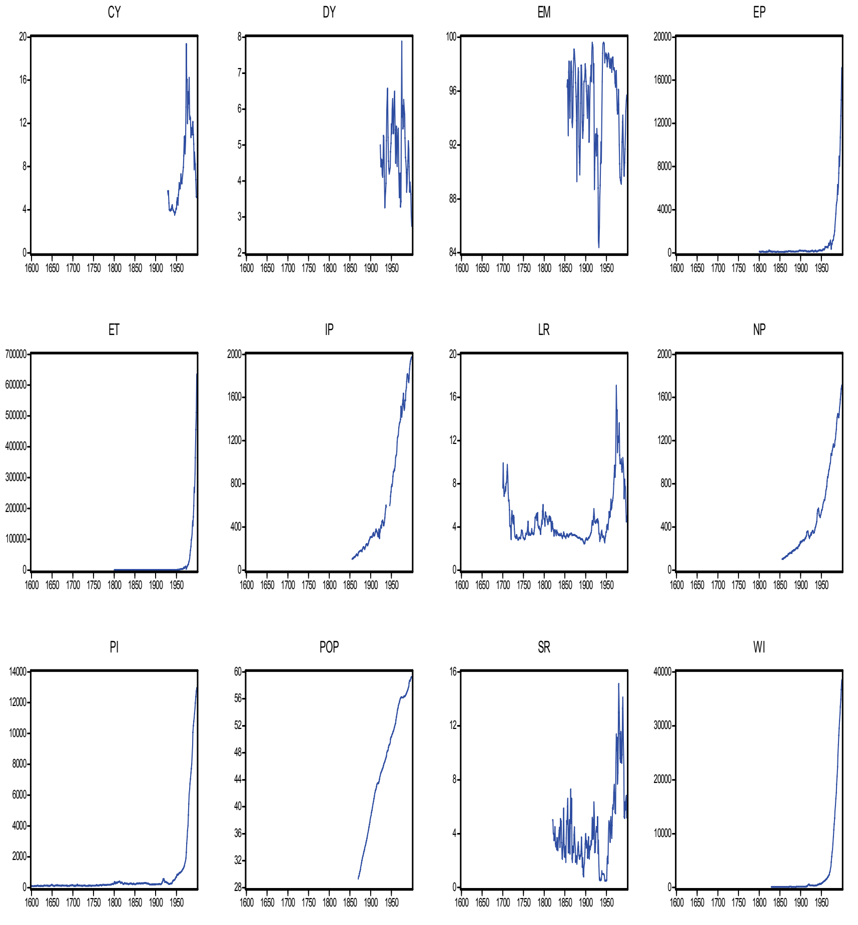
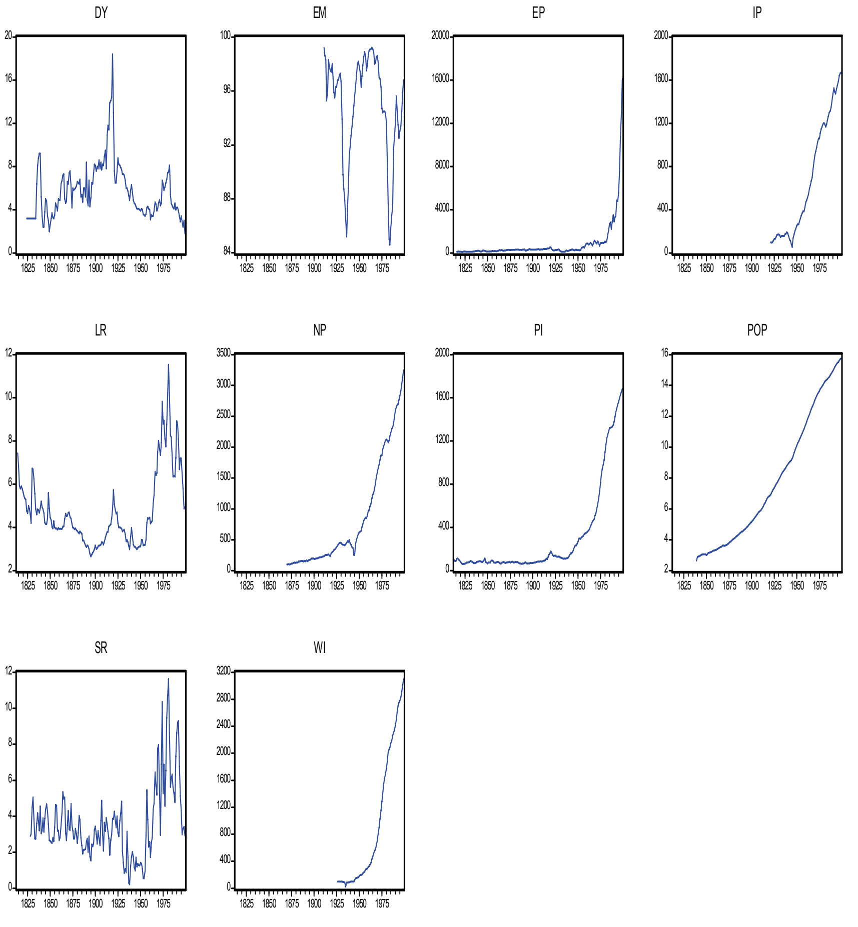


Figure 9c: Annual time series, The Netherlands



Our research methodology is the same as outlined in the previous section, where in that study the focus was on a count data variable, whereas we have continuous variables. All variables below are considered in stationary format. This means that some variables are first log-transformed and then first-order differenced to render growth rates (like the National Product Index and Population), while others are left intact (like the interest rates). We denote the final series as Y_t.

For each Y_t we consider the following regression

$$Y_t = \mu + \varepsilon_t,$$

where ε_t has mean zero and common variance σ^2 . Sometimes the ε_t is replaced by

$$u_t = \rho u_{t-1} + \varepsilon_t,$$

to capture prominent autoregressive dynamics. To translate this unconditional model to a conditional model that is useful for our purposes, we assume that

$$\mu = \alpha + \sum_{i=1}^{C} [\beta_{1,i} \sin(\frac{2\pi t}{C_i}) + \beta_{2,i} \cos(\frac{2\pi t}{C_i})], \qquad (2)$$

which is a harmonic regression model. In words, this model says that economic variables show cycles of length C_1, C_2, and so on. The amount of cycles is C. The unknown parameters in this model are α, $\beta_{1,i}$, $\beta_{2,i}$, and notably C_i.

An important empirical decision to be made is the amount of cycles that can be discovered in the data. In a test regression we set μ at

$$\mu = \alpha_0 + [\beta_1 \sin(\frac{2\pi t}{C_i}) + \beta_2 \cos(\frac{2\pi t}{C_i})].$$

For $C_i = 1$, 2, and so on we run this test regression. The R^2 values of these regression models are stored. Next, the largest values are taken as starting values for the full non-linear regression model in (2). An initial guess of the amount C is obtained from the first 100 partial regressions, where all relatively large values are taken aboard. Usually, C ranges from 2 to 7 at maximum. Next, C times an F-test is performed for the joint significance of $\beta_{1,i}$ and $\beta_{2,i}$ for each $I = 1,2,..,C$. When we do this test we fix the relevant value of C_i and treat it as known[26]. Deleting insignificant cycles, we end with the estimation results as they are documented in Tables 12a, 12b and 12c for the first database, and in Table 12d for the second set of seven series.

[26] We are aware of the fact that under the joint null hypothesis of $\beta_{1,i}$ and $\beta_{2,i}$ is zero, the parameter C_i is not identified. Hence, this situation involves the familiar Davies (1977) problem. There are various solutions possible here, but for the sake of simplicity we stick to the current approach and leave such solutions for further work.

Table 12a, Significant cycles of the US

Variable	Cycles (standard errors)						
National product index	6.27	7.64	15.5	19.7			
	(0.06)	(0.08)	(0.38)	(0.53)			
Industrial production index	6.19	7.69	12.2	14.1			
	(0.05)	(0.10)	(0.24)	(0.33)			
Employment		8.81	13.1	20.7		44.8	
		(0.11)	(0.23)	(0.38)		(1.43)	
Consumer price index					28.5		60.9
					(0.59)		(3.4)
Wage index				18.2	29.9		
				(0.29)	(0.72)		
Short interest rate							66.7
							(4.4)
Long interest rate							60.2
				(4.0)			
Equity price index				19.2		41.4	
				(0.48)		(2.3)	
Dividend yield	4.78				33.3		
	(0.04)				(1.4)		
Population						51.5	
						(2.9)	
Corporate bond yield							56.5
							(7.0)

Table 12b, Significant cycles of the UK

Variable	Cycles (standard errors)						
National product index			12.2	14.0			
			(0.17)	(0.24)			
Industrial production index	4.90	7.59	12.7				
	(0.03)	(0.07)	(0.24)				
Employment			12.7	25.4		53.2	
			(0.20)	(0.53)		(1.20)	
Consumer price index		7.97			36.3		
		(0.04)			(0.72)		
Wage index				23.1	29.7		81.5
				(0.64)	(0.72)		(4.9)
Short interest rate						65.5	
						(1.6)	
Long interest rate						55.3	91.1
			(2.4)	(6.1)			
Equity price index		8.00					
		(0.07)					
Dividend yield		8.76	12.6	21.3	30.4		
		(0.11)	(0.20)	(0.76)	(1.4)		
Population					29.2	65.2	
					(0.94)	(3.1)	
Corporate bond yield		7.29					
		(0.19)					
Equity total return index							102.2
							(13.1)

Table 12c, Significant cycles for the Netherlands

Variable	Cycles (standard errors)					
National product index		13.1 (0.29)				
Industrial production index		10.4 (0.29)				
Employment		10.1 (0.08)	16.0 (0.22)	23.3 (0.33)		50.4 (0.65)
Consumer price index		12.8 (0.16)	14.7 (0.29)	28.0 (0.98)	35.0 (1.3)	
Wage index		no cycles				
Short interest rate						64.1 (4.2)
Long interest rate		8.91 (0.09)				61.2 (5.4)
Equity price index	4.92 (0.03)	10.1 (0.10)	14.4 (0.29)		42.3 (2.3)	
Dividend yield	6.81 (0.05)					
Population		10.7 (0.14)	18.3 (0.43)			61.6 (4.0)

Table 12d, Significant cycles for various variables

Variable	Cycles (standard errors)				
Wholesale Price Index UK 1750-1975	8.98				
	(0.07)				
Wholesale Price Index France 1798-1975	10.0		28.1		
	(0.11)		(0.59)		
Wholesale Price Index Germany 1792-1918	9.12	12.4		62.4	
	(0.09)	(0.27)		(5.4)	
Wholesale Price Index US 1801-1975	9.24	13.4	27.6	52.2	
	(0.07)	(0.20)	(0.74)	(3.7)	
South English Real Wages 1736-1954	8.84		35.9		
	(0.04)		(1.62)		
South English Consumer Price Index 1495-1998	9.00	14.85	35.8		
	(0.03)	(0.10)	(0.56)		
Innovations	5	13	24	34	61

For the USA in Table 12a, we find (out of the eleven series) three series with 4 cycles (National Product Index, Industrial Production Index, and Employment), where there is a strong resemblance between the cycle lengths. For four series we find just 1 cycle (the two Interest rates, Population and Corporate Bond Yield), where also these cycles are very similar in length (around 50-65 years). The results for the UK and the Netherlands are qualitatively similar, as are also the results in Table 12d. We now turn to an analysis of all 70 documented cycles for the first database (Tables 12a-12c), and of all 90 cycles if we take the results in all tables together.

Figure 10a: 70 cycles

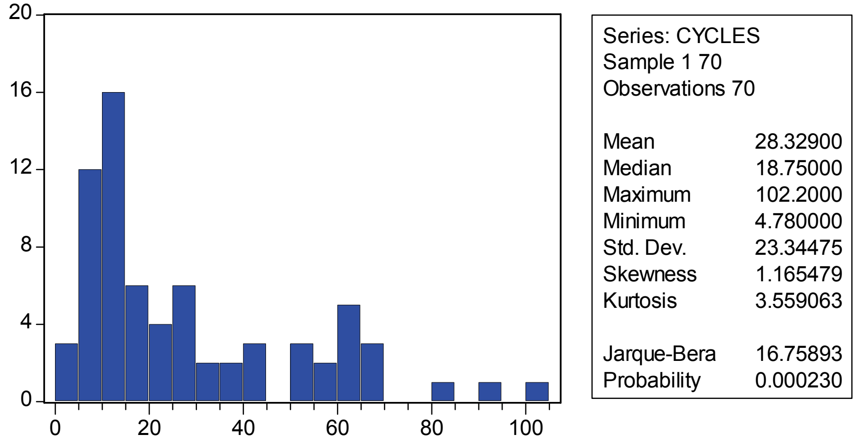
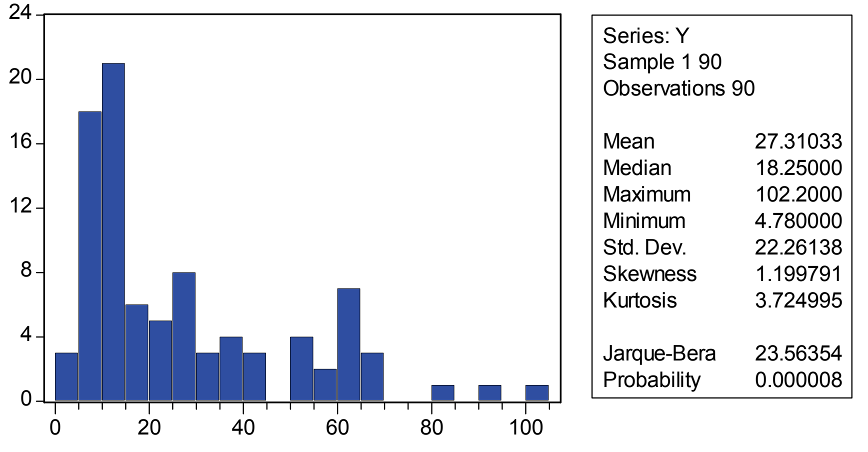


Figure 10b: 90 cycles



In Figures 10a and 10b we depict the histograms of all 70 and 90 cycles, respectively, that were documented in Tables 12a, 12b, 12c and 12d. Clearly, this histogram shows multiple modes, and hence we proceed with estimating the parameters of a mixture of normal distributions. An example of the Eviews program that we use to estimate the means and variances of these distributions is given in Appendix B, as a courtesy to the reader. To find the number of distributions and the amount of communality across the variances, we try to estimate 8 versions. We allow for 3 and 4 normal distributions (as 2 was clearly rejected by the data), and we consider the cases where (i) the variance of all distributions is the same, (ii) are all different, or (iii) are the same for the distributions with the largest means. We also tried to estimate a mixture of 5 distributions, but that did lead to estimation problems.

Table 13a: Bayesian Information Criteria values for mixtures of normal distributions (smallest values are underlined) [70 Cycles]

70 cycles			
		Variance	
Number of distributions	Common	All different	First different from rest
3	8.868	8.866	8.806
4	8.803	8.863	8.775

Table 13b: Bayesian Information Criteria values for mixtures of normal distributions (smallest values are underlined) [90 Cycles]

90 cycles			
		Variance	
Number of distributions	Common	All different	First different from rest
3	8.770	8.573	8.587
4	8.590	8.615	8.535

Table 13 gives the Bayesian Information Criterion (BIC) value for each of these eight cases. The smallest BIC value is preferable, and we observe that this is the case for 4 normal distributions, where the last three distributions have the same variance. This holds in both cases.

Table 14a: Mixtures of normal distributions for 70 cycle lengths

Distribution	Mean	Variance	Probability
1	10.3	3.5	0.576
2	25.7	8.0	0.190
3	57.7	8.0	0.192
4	92.0	8.0	0.042

Table 14b: Mixtures of normal distributions for 90 cycle lengths

Distribution	Mean	Variance	Probability
1	10.4	3.3	0.483
2	27.9	7.3	0.191
3	58.3	7.3	0.294
4	91.9	7.3	0.032

The estimation results for the 70 and 90 cycles appear in Tables 14a and 14b, and they must be read as follows. For the case of 70 cycles, the first distribution has a mean value of 10.3 and a variance of 3.5. The final column of Table 14a and 14b gives the probability of a cycle being assigned to this distribution. Hence, with probability 0.576 (0.483) a cycle is associated with that first distribution. That is, economic variables have with reasonably high probability a cycle with an average length of 10.3. Obviously, one reason for finding this high probability is that shorter cycles are easier to measure for relatively shorter spans of time series data than are longer cycles.

In sum, we obtain empirical evidence that economic cycle lengths, where we now focus on Table 4b, can be classified into four distinct groups, with cycle lengths on average of 10.3, 27.9, 58.3 and 91.9. Again, and similar to the findings in the previous section, we find cycle lengths that are remarkably close to Fibonacci numbers, here 8, 21 (34), 55 and 89. In fact, with the estimation results in Table 14a, we can compute that 8 is 0.66 standard errors away from 10.3, 21 is 0.59 standard errors away from 25.7, and 55 and 89 are just 0.34 and 0.38 standard errors away, respectively. Of course, our findings are no proof of the link between Fibonacci numbers and "optimal" cycle lengths, but we believe that the correlation is striking. Mind the reader, we only have considered 70 (90) cycles for only a few countries.

3.4.4 Conclusion

The empirical results documented in this section substantiate our argument that economic variables display multiple cycles, with cycle lengths that apparently do not interfere. The sum of all these cycles mimics erratic behavior, but underlying are constellations of cycles of such a nature that stability of economic variables is preserved. Hence, due to these sets of cycles, economies can handle exogenous shocks that might otherwise put them off balance. Some of these shocks, like key technological innovations, are shown to have similar constellations.

Hence, behind all this are forces that, without knowing and without purpose, establish stability. What are these forces? There are various literatures on fractals[27], chaos[28], complex systems[29] and ecological economics[30] that seek an answer to questions like this one, but, to us, no useful overarching theory has been developed.

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[27] Mandelbrot (1977, 1983) created the concept of fractals. He proposed the name fractal for the non-euclidean geometry, which have a fractional dimension. Scale invariance and self-organized criticality are terms that are central to the debate in complex systems and chaos theory. Complex systems may manifest themselves as temporal scale invariance or fractals, temporal scale invariance or flicker noise or 1/f noise where f is the frequency of a signal and power laws when there is scale invariance in the size and duration of events in the dynamics of the system.

[28] The word chaos describes the dynamics of systems which do not display any periodicity in their behaviour and are exponentially sensitive to change in their initial conditions. Chaos is very much related to Lorenz (1963) who discovered the simple set of non-linear differential equations to describe weather forecasting. An attractor can be a point in which case the system tends towards equilibrium.

[29] Bak, Tang and Wiesenfeld (1987) presented the principle of self-organized criticality. It is a principle which governs the dynamics of systems, leading them to a complex state characterized by the presence of fractal and power law distributions. The state is critical. Here it is the dynamics of the system itself which leads it to a scale free state, it is therefore self-organized. The introduced the classic example of the sandpile. Bak went on to show that fractal fluctuations show scale invariance or selfsimilarity Since a chaotic system has a short memory and therefore it does not remember where it was for very long it might not be a good approach to describe systems that must adapt and learn over time. The characteristics of self-organized –criticality however are: long term correlation, scale invariance and

One of the potential limitations of our research is that it is largely empirical, and hence the outcomes heavily rely on the quality of the data and of the model. Indeed, more detailed data and also data for other countries could have led to other results although we tend to believe that our results are reasonably robust, as we have used various variables from various countries. What could have happened of course is that there are breaks in the data, and that we think we have measured cycles of length x while in reality they are of length y, interrupted once in while for some reason. Future research where we allow the parameters in the models to be time-varying could be illuminating. Finally, if stability really is the key reason why we see certain cycles, then an analysis of highly unstable economies could be insightful, although there one might face the problem of having a shortage of reliable data.

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the absence of any fine tuning in signals. These qualities make self-organized criticality an attractive principle to explain the dynamics of scale free behaviour.

[30] Other lines of research are econophysics and ecological economics. Econophysics applies methods from physics to economics. This is a very recent field of research. Relevant studies are Mantegna and Stanley (2000), McCauley (2004), and Roehner (2002). Ecological economics applies concepts from ecology and biology to economics in a systemic framework, mostly by means of analogy. Mutatinovic (2001, 2002) is a proponent of this approach.

Chapter 3.5 Conclusion

The conclusion we derived from the literature study in Chapter 2 was that the current approach of the long wave researchers does not work, the field is in an impasse and a different perspective is needed. The multiple cycle approach was identified as a promising alternative. In Chapter 3.2 we described Schumpeter's original multiple cycle theory and other contemporary multiple cycle approaches. The most important subject Schumpeter brought into the limelight is the role of innovations in the economy. Therefore it seemed useful to investigate whether the supposed multiple cycle structures could be found in an innovation dataset. We examined various innovation theories and eventually investigated whether multiple cycle structures were present in an innovation series. This proved to be the case. We found five cycles with lengths of 5, 13, 24, 34 and 61 years. Again these lengths are remarkably close to the Fibonacci sequence. Furthermore we found evidence for the clustering of basic innovations.

In Chapter 3.4 we examined whether our results from the innovation series could also be found in other macroeconomic variables. We investigated 33 series from three countries and 6 classic long wave datasets and discovered multiple cycle structures in all investigated variables with in total 90 individual cycles. Here we also observed that the found cycle lengths seem to approach the Fibonacci sequence.

One of the features of Fibonacci cycle lengths is that there is not a single moment in time in which all cycles simultaneously reach their maximum of their minimum. Thanks to this property the discovered multiple cycle structures can be associated with stability in the economy. Because the peaks and the troughs of the cycles are not simultaneous they blunt each others extremes. This implies that macroeconomic policy is useful. By means of policy, cycles can be enhanced or supported which can counterbalance unwanted extreme fluctuations. These findings update the traditional image of the single cycle to that of a multiple cycle economy.

Contents

Chapter 4. Long-term Forecasting for the Dutch Economy

Chapter 4.1 Introduction

Now we have established that economies experience cycles, which can partly be described by harmonic regressions, we are ready to make the next step. We extrapolate the regressions and generate long run forecasts. In this chapter this is pursued for the Dutch economy, notably in real GDP.

As we will demonstrate in this chapter, a good predictor for real GDP is a staffing services variable. We show that it has similar cycles as real GDP and that the two variables also have the same stochastic trend. The explanatory variable concerns the Randstad company.

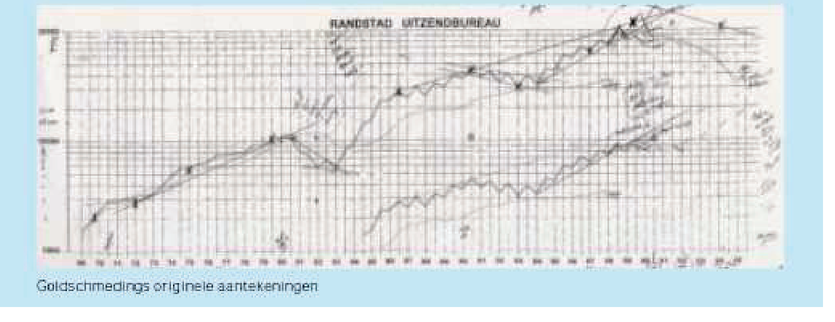
It is readily accepted that the staffing services industry is a good indicator of the current state of the economy during periods of prosperity as well as during recessions. Entrepreneurs, businessmen, politicians, government agencies and many others have a keen interest in reliable forecasts of the direction in which the economy is heading. Therefore they often turn to the information provided by the staffing services industry. Staffing services was picked up as a leading indicator even though scientific evidence of the forecasting abilities of staffing service data has never been provided.

From its establishment in 1960, Randstad, a staffing service provider based in the Netherlands, which over the course of the years has become a world player in the staffing industry, showed great interest for labor statistics. By comparing their own data to other economic data they were able to obtain information which they used for their policy decisions. At first very little data was available but every year the amount of data at their disposal grew cumulatively. Originally Randstad was very much interested in how long people would be willing to have a temporary labor contract rather than a steady job, how long they would stay with Randstad and how long a contract with the client-firm would last. In 1969 the various European staffing firms exchanged their information on these matters. They found that the results showed a remarkable resemblance across countries.

This information became very valuable and at times of economic crises the life-line for management since it provided optimal information on the behavior of the staffing market and more in general on the development of the labor market and the economy as a whole.

The growth pulses and the contractions of the development of Randstad are clearly visible in Figure 11. The weekly output of all the employees who were under contract at Randstad staffing agency is shown in the logarithmic graph below. The original drawing was made with a pencil by Dr. F.J.D. Goldschmeding.

Figure 11: Logarithmic representation of the number of temporary labourers per week at Randstad the Netherlands between 1970 and 1997.



Between 1980 and 1982 the company experienced its first significant downturn in the Netherlands. A little later Germany also experienced a downturn. In 1982 the ratios changed and new employees were hired and trained and a lot of effort was put into marketing. The market took off and the Randstad market share increased tremendously. Between 1990 and 1994 the same thing happened. Again the life threatening lessons of 1980-1982 were not forgotten. A fast execution of measures proved to be successful and in 1992 with an acquisition in the Netherlands and in 1993 with the start in the USA, Randstad was right on track.

Since the growth and decline of Randstad appeared to resemble the economy, Dr. F.J.D. Goldschmeding and the author forecasted, by using the figure depicted in Figure 11, early 1998 that the growth would continue until the third quarter 2000 and that from then on the economy would make a downturn which would see its trough in 2004. Interestingly enough this is almost exactly what actually happened!

In this Chapter we will elaborate on the hypothesis arisen from practice that with staffing data from Randstad forecasts for the development of Dutch GDP can be made. We will discuss the origins of this hypothesis and will describe the relationship between Dutch GDP and staffing data from Randstad. First we will show that a cointegration relationship exists between Dutch GDP and Randstad. The two annual series share a stochastic trend and two long-swing deterministic cycles. Granger causality appears to run from temporary staffing to GDP and not vice versa. This makes it possible to make forecasts based on a model. Moreover we will test whether multi cycle structures are also present in Dutch GDP and Randstad staffing data. This appears to be the case. The cycles found in both Dutch GDP and the Randstad data have lengths of respectively 5 and 11 years. Based on these findings we will develop a simple long-term multiple cycle forecasting model for Dutch GDP. With the help of the model we will give a forecast for Dutch GDP for the period 2005-2015. The forecasts suggest growth rates around 2 per cent, with a dip to be expected around 2012-2013.

Chapter 4.2 Univariate Models

4.2.1 Introduction

Empirical experience reported in De Groot and Franses (2005) suggests that quarterly data on Randstad's temporary staffing services and on real GDP in the Netherlands are strongly correlated. This correlation concerns the long run, as a cointegration relationship is found and the shorter run, where contemporaneous and lagged correlations exist between growth rates. De Groot and Franses exploit these correlations to forecast the most recent quarter of real GDP growth, 6 weeks before the Central Bureau of Statistics makes available their first flash value. In order to do that, the authors rely on a model for quarterly data on staffing services that fits and predicts rather well.

An interesting feature of the quarterly data, and also for the annual data, of both series of interest is that the data experience cycles. These cycles are the main issue of the present paper. The reason for this is that most studies on real GDP adopt autoregressive models for the growth rates, where the order of these models typically is 2 or more. It is well known that when the solutions of the characteristic polynomial of such an autoregression are complex valued, the model implies that the data experience cycles. However, when these cycles are stable, then, due to very nature of autoregressive models, long-term forecasts will show cycles with ever decreasing amplitude, see Section 2 below. In order to make the cyclical patterns to continue in a similar fashion in the forecasting sample, one can rely on harmonic regressors, and this is what we will do in the present paper.

In Section 4.2.2, we will discuss the data (which are displayed in Table 1). It should be stressed here that the real GDP data concern those data that were available in June 2005. After that month, the Netherlands Central Bureau of Statistics started a revision process, which was announced to be finished no earlier than by the end of 2006. As the main focus is to deliver forecasts for annual real GDP growth rates, we could expect that these revisions will not change the forecasts. However, Nijmeijer and

Hijman (2004) show that on average on may expect 0.35 percent increases in growth rates. Indeed, the growth rates for 2003 and 2004 for the old data (the data we use in the present paper) are -0.4 and 1.4, while for the new data (for which at this moment only 2001-2005 is available) these annual growth rates are -0.1 and 1.7. So, both increased with 0.3. In sum, we will add 0.35 to all of our long-term forecasts, thereby incorporating upward tendencies in the next few years.

For each of the series, we first fit univariate time series models, allowing for cycles. It is shown that suitable models for both series are AR(1) models with two harmonic regressors, implying cycles of around 5 and 11 years.

Section 4.2.3 takes a next step by examining the possible presence of a common stochastic trend in the log-level series, while we allow for deterministic cycles. As expected, given the results in De Groot and Franses (2005), there is such a common trend. However, when the cointegration variable and current and lagged growth rates of GDP are added to the univariate model for Randstad, these terms appear statistically irrelevant. Hence, we proceed with a single equation error-correction model for real GDP. This model includes lags of both growth rates as well. Diagnostic tests indicate the adequacy of this model, and also that there is no need to add any harmonic regressor.

Section 4.2.4 takes all together and uses these to generate forecasts for 2005-2015 for both the Randstad data and the real GDP series. An important conclusion is that the Dutch economy on average will grow with around 1.5 percent per year, while a future dip may be expected around 2012-2013.

Section 4.2.5 concludes. One of the main novelties of this chapter, which is quite in contrast with much recent research on business cycle forecasting, is that the forecasts are based on very simple single-equation models where only a single predictor variable is used.

4.2.2 Univariate Models

This section first discusses the annual data (see Table 15) of interest, and then turns to univariate models for the Randstad series and for real GDP in The Netherlands.

Table 15: The quarterly data on Randstad staffing services (number of individuals) and on real GDP (in millions of euros), as available in June 2005

Year	Randstad	Real GDP
1967	856	
1968	1268	
1969	1855	
1970	2684	
1971	2899	
1972	2892	
1973	3902	
1974	5314	
1975	5982	
1976	7128	
1977	7619	205870
1978	8494	219085
1979	9737	214862
1980	9904	218478
1981	7116	217355
1982	6034	214566
1983	7700	218338
1984	13054	225149
1985	21152	231129
1986	25632	238352
1987	27631	242763
1988	30131	249998
1989	34395	261960
1990	38972	272607
1991	37174	279164
1992	34776	283322
1993	34622	285167
1994	40675	293336
1995	54417	302233
1996	65717	311419
1997	74347	323373
1998	79329	337435
1999	71172	350919
2000	62727	363081
2001	52096	368259
2002	45316	370355
2003	41376	367098
2004	44070	372382

The two series

The original Randstad data concern weekly data on the number of staffing employees (in all industries and sectors) employed through Randstad the Netherlands for the years 1967 to 2004. In univariate analysis we will use the full sample. For multivariate analysis we consider the sample starting from 1977, as from then onwards also reliable GDP data are available, published by the Netherlands Central Bureau of Statistics (CBS). In our analysis we use annual staffing data, where we have constructed the data by averaging over all 52 weeks.

Both series are transformed by taking natural logarithms. We denote by y_t the log-level of real GDP and by x_t the log-level Randstad data. For the growth rates we use the notation $\Delta_1 y_t$ and $\Delta_1 x_t$, where Δ_1 denotes the usual first-differencing filter.

Figure 12 gives the two series. It is clear that they both have an upward trend[31], and also that they display cycles. These cycles show some correspondence, as their peaks and troughs roughly coincide, where the peaks in the Randstad data seem to occur a little earlier than those in the GDP data. Next, and not unexpectedly, we see that the amplitude of the Randstad data is much larger than that of GDP.

Figure 13 gives the growth rates of the two series. Comparing the axes on the both sides, we see again that the amplitude of the Randstad data is much higher than that of GDP. We also see, now more clearly than for Figure 1, that the cyclical patterns in the two growth rates are broadly similar. Dips in the series seem to occur each 10 years. Indeed, peaks and troughs in both series seem to occur roughly in the same years, where perhaps the peaks and troughs in the Randstad series sometimes seem to lead with one year.

[31] We do not formally test for unit roots in these data, as we believe that the alternative hypothesis, that is, trend-stationarity, suggests an implausible model. Such a model would imply overly confident long-term forecasts. So, we assume that both series have a unit root.

Figure 12: Gross Domestic Output in millions of euros (left axis) and Staffing in number of employees (right axis), observed per year

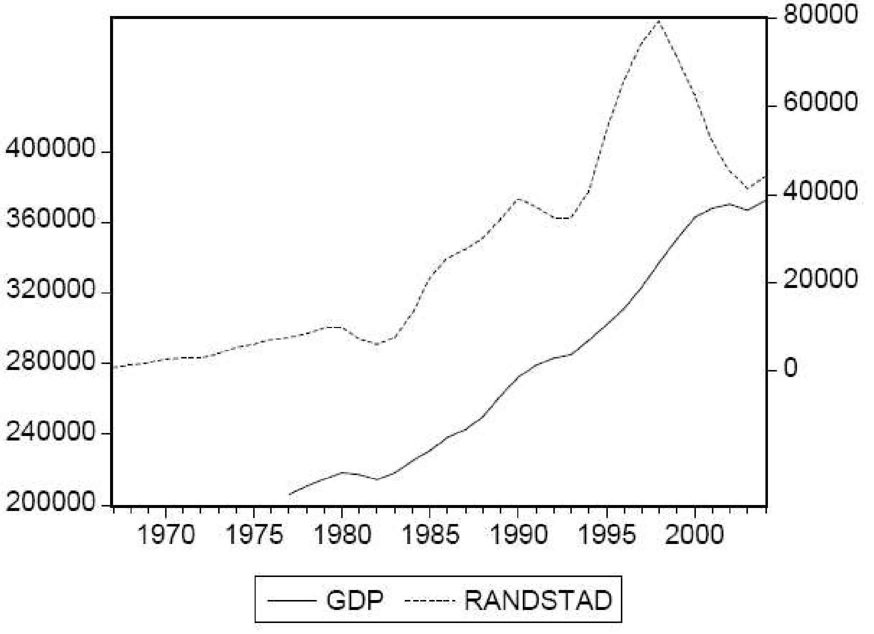
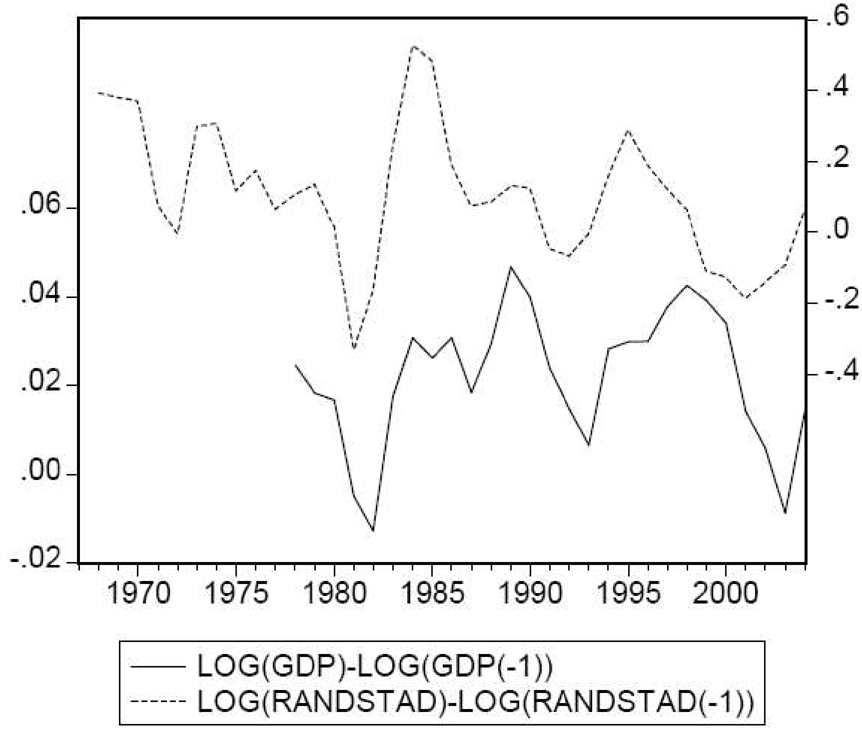


Figure 13: Growth rates of Gross Domestic Output (left axis) and Staffing (right axis), observed per year



A model for Randstad

We first start with a univariate model for the Randstad data, for which we fit an AR(2) model for the growth rates. The estimation results are

$$\Delta_1 x_t = \underset{(0.025)}{0.055} + \underset{(0.148)}{0.963}\,\Delta_1 x_{t-1} - \underset{(0.146)}{0.532}\Delta_1 x_{t-2}, \tag{3}$$

where the estimated standard errors are in the parentheses.

As the solution of the characteristic equation for this estimated AR(2) polynomial has complex components, we can compute the implied cycle length from this AR(2) model, see Franses (1998, page 42). It turns out to be around 7 years. This seems odd, as the graph in Figure 12 seems to suggest a cycle of length 10 to 11 years.

It is possible that the value of 7 amounts to the mean length of two or more cycles. Indeed, an AR(2) model only allows for a single cycle, and perhaps an AR(3) or AR(4) model would have been better. However, adding more lags to the AR(2) model leads to insignificant parameter estimates.

Another possibility, which, as it appears to us, is not very often used in practice, is that the cycles are not stochastic (and caused by sequences of observation) but that they are deterministic[32]. That is, perhaps the model fit would benefit from including harmonic regressors, which means terms like

$$\alpha_1 \cos(\frac{2\pi t}{C} - \alpha_2) \tag{4}$$

where t runs from 1 to T, and α_1, α_2 and C are unknown parameters.

The focus here is on values of cycle length C. Adding more than one harmonic regressor can quickly lead to estimation problems and hence proper starting values are very helpful, see also Chapter 3.4. We decide to run 15 auxiliary regressions where each time the AR(2) model in (3) is enlarged with a single such harmonic regressor, that is for C = 1, C = 2, through, C = 15. We compute the R^2 values of these auxiliary test regressions, and we observe that the fit is highest C = 5 and C = 11. Including these two harmonic terms at the same time makes the second order lagged regressor obsolete, so the final model includes only an AR(1) term. We take C = 5 and C = 11 as the starting values, and our final estimation result is

$$\begin{array}{rl} \Delta_1 x_t = & \underset{(0.026)}{0.031} + \underset{(0.164)}{0.639}\, \Delta_1 x_{t-1} - \underset{(0.027)}{0.115}\cos((2\pi t / \underset{(0.101)}{5.144}) - \underset{(0.630)}{0.268}) \\ & - \underset{(0.028)}{0.088}\cos((2\pi t / \underset{(0.576)}{10.511}) - \underset{(0.659)}{1.431}), \end{array} \tag{5}$$

[32] An example of an economic mechanism that generates cyclical behaviour in the neighbourhood of the steady state is a credit cycle, see Kiyotaki and Moore (1995).

where the estimated standard errors are in the parentheses.

The in-sample fit of this model is depicted in Figure 14. We observe a close fit, which is also reflected by the fact that the R^2 was 0.573 for the AR(2) model, while it has increased to 0.731 for this AR(1) model with harmonic regressors. The Jarque-Bera test for residual normality has a p-value of 0.894, the test for residual autocorrelation at lag 1 has a *p*-value of 0.553, and a test for first order ARCH gets a p-value of 0.831. In sum, the model seems very adequate.

The estimation results show that the Randstad growth rates display cycles of length 5.14 and 10.51 years, which also comes close to the visual impression obtained from Figure 13.

When we add $\Delta_1 y_t$ to this model, its t-value is 0.665. Also, adding levels of log(GDP) does not lead to significant parameters. In sum, we believe that we can use this model for out-of-sample forecasting, but we first need to see how a multivariate model looks like.

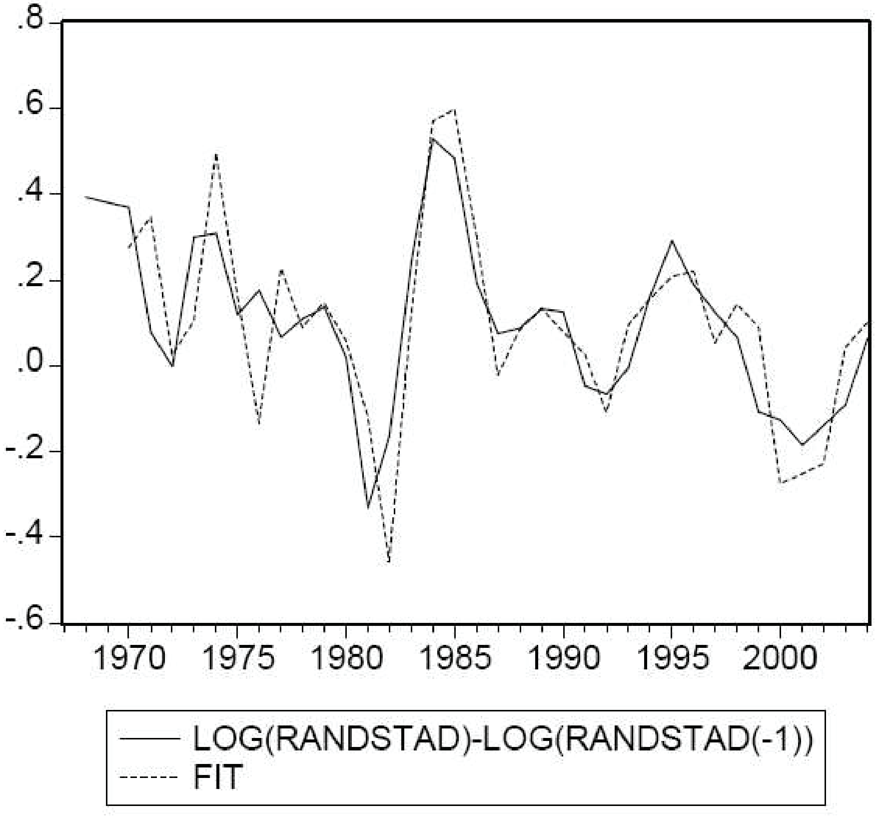
A model for real GDP

Along similar lines we arrive at an AR(1) model with two harmonic regressors for real GDP growth. The relevant estimation results are

$$\begin{aligned} \Delta_1 y_t = \underset{(0.005)}{0.013} + \underset{(0.214)}{0.439}\, \Delta_1 y_{t-1} - \underset{(0.002)}{0.009}\cos((2\pi t / \underset{(0.185)}{5.218}) - \underset{(1.149)}{4.577}) \\ + \underset{(0.003)}{0.010}\cos((2\pi t / \underset{(0.730)}{10.667}) + \underset{(0.961)}{1.078}). \end{aligned} \tag{6}$$

The R^2 of this model is 0.776, and diagnostic tests do not suggest serious misspecification. Intriguingly, the model for real GDP growth provides estimates for cycle lengths which are roughly the same as for the Randstad data in (5).

Figure 14: The fit of an AR(1) model with two harmonic regressors for the growth rates in the Randstad data



There is one major difference though, and this follows from adding the current variable $\Delta_1 x_t$ and the lagged variables x_{t-1} and y_{t-1} to. Each of these variables is significant, which is also reflected by the increase of the R^2 from 0.776 to 0.929. In sum, it is now time to consider the two series jointly, as we will do in the next section.

4.2.3 Multivariate Analysis

To construct a model for real GDP we wish to account for the possibility that the two series under scrutiny have a common stochastic trend. Indeed, even though our prime focus is on forecasting real GDP growth rates, we should allow for a common trend if there is one, see Lin and Tsay (1998) for simulation results that show that properly incorporating cointegration leads to better forecasts.

We apply the Johansen cointegration test, where we need to include two lags of the first differenced series. As is well known, when the data can also have a deterministic trend, we need to include such a trend in a restricted way in the error correction term, while the model also includes intercepts, outside and inside the error correction term. For Eviews, this means we need to follow option 4. We also include as exogenous regressors two sets of harmonic terms, with fixed cycle lengths of 5 and 11 years[33]. The first eigenvalue is estimated to equal 0.521 and the second as 0.393, where only the first is significantly different from zero. Hence, there seems to be one cointegration relation.

The next step is to estimate a bivariate vector error correction model with one cointegration relation. The estimation results show that the cointegration variable only has an impact on real GDP growth. Also, lagged GDP growth rates do not have an effect on growth in Randsatd employees.

Taking all this together implies that we can proceed with a model for Randstad as in (5), while for real GDP growth we proceed with a single equation error correction model. The final estimation results for this last model are

$$\begin{aligned} \Delta_1 y_t = \ & \underset{(0.273)}{0.560} - \underset{(0.027)}{0.060}\,(y_{t-1} - \underset{(0.059)}{0.335}x_{t-1}) \\ & + \underset{(0.013)}{0.056}\,\Delta_1 x_t - \underset{(0.017)}{0.023}\,\Delta_1 x_{t-1} + \underset{(0.191)}{0.375}\,\Delta_1 y_{t-1}. \end{aligned} \quad (7)$$

This model shows strong similarity with the model used in De Groot and Franses (2005) for quarterly data. The long-run parameter is 0.335. The in-sample fit of this model is depicted in Figure 15, and it is important to see that turning points seem to be picked up by the model. As with the Randstad data, we observe a close fit, which is

[33] We are aware of the fact that the inclusion of such harmonic regressors changes the asymptotic distribution theory. We are however unaware of such a theory, but we do expect that critical values must become larger.

also reflected by the fact that the R^2 of this model is 0.764. The Jarque-Bera test for residual normality has a p-value of 0.528, the test for residual autocorrelation at lag 1 has a p-value of 0.995, and a test for first order ARCH gets a p-value of 0.217. In sum, the model seems very adequate.

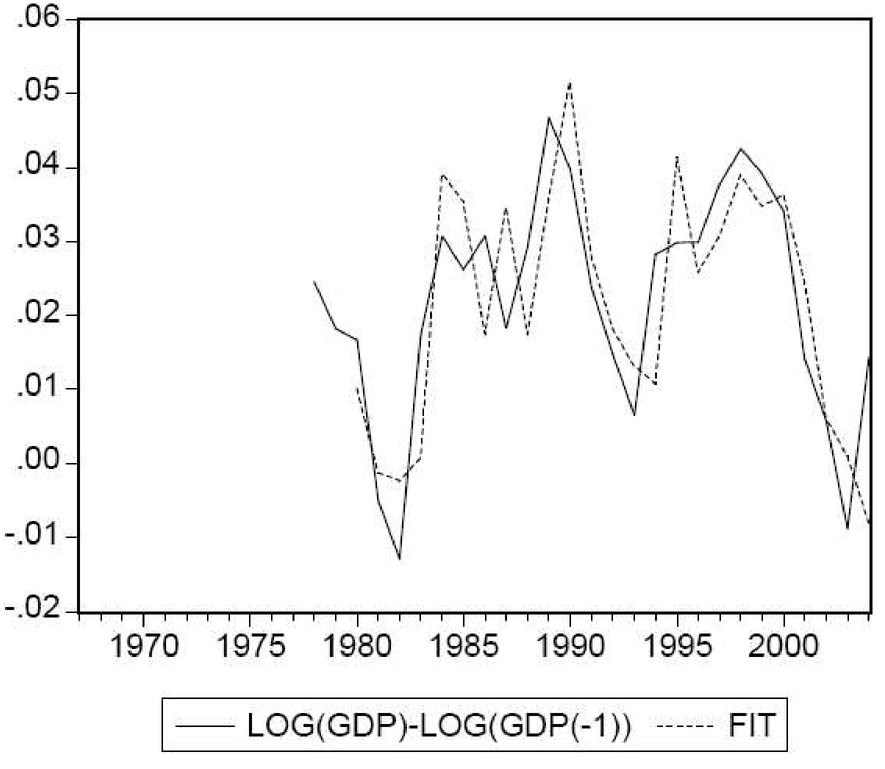
Notably, LM-tests based on a regression of estimated residuals on harmonic regressors in (4), for $C = 1$, $C = 2$, through $C = 15$, all turn out to obtain insignificant values. Hence, the error correction model does not need to be enlarged with harmonic regressors.

4.2.4 Forecasts for 2005 to 2015

We now use the above models to create forecasts for 2005 to 2015. First we give the forecasts for the Randstad series. For this, we use model (3). We create these forecasts in December 2005, so we have already available the figures for the quarters 1, 2 and 3 of 2005. These are 43108, 48143 and 50859, respectively. When we consider an autoregressive time series model to predict quarter 4, and combine this with expert opinions, we set the quarter 4 observation for 2005 at 53500. This makes the 2005 observation to become the average of these four numbers, that is 48903. We re-estimate model (3) now for the sample 1967-2005, and we create forecasts for 2006-2015.

The annual forecasts shows that the years 2006 and 2007 will be prosperous, but the next years thereafter suggest a slowdown. The first signs of a dip appear in 2011, while recovery can be expected around 2014.

Figure 15: The fit of an error correction model for the growth rates of real GDP



The second column gives the for real GDP growth when the univariate model in (6) is used. We observe substantial fluctuations in these growth rates, with some values perhaps too large, like in 2010, and too low as in 2013. We believe that these forecasts have too large an amplitude.

The penultimate column gives the forecasts from an AR(2) model. As expected, these forecasts mark the disappearance of cyclical patterns, which we, in the first place, found less reliable. Indeed, we foresee that cycles will persist in the future, and hence our focus on the error correction model for GDP.

Finally, when we plug in the forecasts for Randstad in the error correction model, and we add 0.35 to each of these (as mentioned in the introduction) we obtain forecasts for real GDP growth as in the last column of Table 16. We see that these forecasts are more dampened and, to us, there are much more plausible. The dampening is caused by the link with the Randstad forecasts. On average, growth will be around 1.5 percent per year, with a slowdown to be expected in 2012 and 2013.

Table 16: Forecasts

Year	real GDP growth without Randstad (harmonics)	real GDP growth without Randstad (AR(2))	real GDP growth with Randstad
2005	2.7	3.0	1.5
2006	3.0	3.3	1.4
2007	2.7	2.9	1.2
2008	2.9	2.4	1.5
2009	3.8	2.1	2.0
2010	4.2	2.1	1.8
2011	3.2	2.2	1.1
2012	1.2	2.3	0.4
2013	0.1	2.4	0.6
2014	0.7	2.3	1.4
2015	2.0	2.3	1.9

4.2.5 Conclusion

This chapter has put forward two simple models, one for annual staffing services of Randstad and one for real GDP growth in the Netherlands. Dutch GDP and staffing data share a common stochastic trend. Dutch GDP shows cycles with length of 5 and 11 years. These cycles can be used to produce long-term nowcasts of Dutch GDP. The two models have been used to generate forecasts for the longer horizon, and the main conclusion is that the next slowdown in the Dutch economy may be expected around 2012 and 2013.

A key feature of this chapter is that we have used just a single explanatory series to generate long run forecasts for the Dutch economy, which seems to be in contrast with many current studies where hundreds of variables (or combinations) are used. Given the in-sample fit of the two models, we are reasonably confident that these models can reliably be used to generate long-term forecasts.

There is one major caveat to make. Our forecasts are based on models with data until and including 2004. At the moment, only revised GDP data are available from 2001 onwards. As revisions usually occur upwards, we added 0.35 to our forecasts from the error correction model. Of course, when revise data become available for more years, we will re-estimate the models and create new forecasts.

New insights arisen during the making of this thesis lead to the introduction of multiple cycles into the model. An analysis of the data revealed that for both Randstad and Dutch GDP two dominant cycles were active. These cycles had lengths of respectively 5 and 11 years (numbers rounded). These findings lead to the development of the harmonic model. With that model a forecast was given for the development of the Dutch economy for the coming ten years. The most important proposition of the harmonic model is that cyclical patterns in the past will repeat itself in the future, although the outcomes will not be exactly the same. Once the CBS releases the GDP data for the rest period a re-estimation the model will be made and the estimations will be refined. At the annual meeting of Dutch business cycle research community in the first quarter of 2006, DNB announced that it would revisit its forecasting model. Rabobank also stated it would reassess its model.

Contents

Chapter 5. Nowcasting Quarterly GDP

Chapter 5.1 Introduction

Companies and governments always have to deal with uncertainty regarding economic prospects. Economists recognize short and long cycles in the economy which, according to some researchers, make it easier to foresee economic changes due to their repetitive character. In the area of business cycle fluctuations nowcasting and forecasting models can at least partly reduce uncertainty by providing reliable predictions.

In Chapter 4 we elaborated on the hypothesis arisen from practice that staffing data from Randstad can forecast the development of Dutch GDP. We described the relationship between Dutch GDP and staffing data from Randstad and showed that a cointegration relationship exists between Dutch GDP and Randstad which makes it possible to make forecasts based on a model.

In this thesis a new nowcast indicator of Dutch GDP is introduced. In this Chapter we will delve into the possibility to develop a reliable nowcast indicator of Dutch GDP based on the weekly available staffing data from Randstad. This nowcast indicator, named EICIE, is unique because it is based on only a single explanatory real variable and has an extremely model structure. Other GDP indicators are complex models based on many variables. It should be remarked that the explanatory variable of the EICIE displays factual behavior and thus is not composed from surveys. Because the Randstad data become available soon after the quarter has ended and the EICIE can be easily calculated it is possible to publish a reliable quarter forecast within two weeks after the quarter has ended. This is well in advance of the publication of the first official estimate of the CBS. This indicator is also very interesting on a corporate level. Randstad can moreover use the forecasts of the indicator for its own policy planning.

Chapter 5.2 EICIE

5.2.1 Introduction

In ESB 4425 of February 6, 2004, an overview article appeared on the subject of economic indicators and forecasting. Four institutes, the CPB (Centraal Plan Bureau), the DNB (De Nederlandse Bank), the Rabobank and the VNO-NCW presented their models, methodologies, variables and data. Even though all institutes applied the concept of the deviation cycle, their approaches were different. The indexes had correlations between 0.81 and 0.89, but always had to be published with a time-lag since the data was not available real time.

In the ESB 4450 of January 14, 2005, the EICIE (Econometric Institute Current Indicator of the Economy) was presented with the claim that it could forecast the most recent quarter of Dutch GDP within 14 days after it ended. The EICIE is able to achieve this by using only a single explanatory variable, staffing data from Randstad and can predict rather accurately. The model displayed a correlation of 0.93 which is remarkably high for a univariate model. The EICIE indicator can be published in fact during the quarter, two months earlier than the (pre)official release of the CBS and six months earlier than the first official release. The outcome for the year 2004 and the estimation from EICIE were remarkable close to the official final numbers.

A quarterly and an annual indicator were based on the co-integration relationship between Randstad and Dutch GDP and were presented in a 'simple' multivariate model (see De Groot and Franses, 2005). In order to improve the model and enable it to take into account the differences between the upward and downward movements of the business cycle a switching model was developed. Both models did well for the first half year.

In June 2005 the CBS announced that the National Accounts and therefore the official GDP data of the past thirty-five years would be revised. It turned out this did not just imply a small adjustment but a real structural change. The forecast of the EICIE for that particular quarter was incorrect. The nowcast generated quite some attention in the newspapers and other press. It became clear the model had to be revised. The data on which the original model was based contained some thirty-five years, however initially the CBS was only able to release the revised GDP data for the last four years. The data as they are currently available are given in Table 21. The remainder of the revised data is set to be published by the end of 2006. The new model could therefore only be based on this relatively small sample.

It turned out that the nowcasts for 2005 Q3 and 2005 Q4 were remarkably close to the CBS. In January 2006, again in the first ESB release of the New Year, a first estimation with the new model was for the growth of the year 2005 was published. Again, this turned out to be very close.

5.2.2 Outline

In this chapter we outline the development of a Current Indicator of the Dutch Economy, where we assume that real Gross Domestic Product (GDP) adequately summarizes the state of the economy. As the research carried out at the Econometric Institute of the Erasmus University Rotterdam, we will call this the EICIE indicator, as it was used for the nowcasts published quarterly in the ESB in 2005 and 2006.

The main motivation to develop our indicator is that official, and preliminary, data on real GDP are released with a time lag of at least one quarter. We aim to publish the EICIE indicator with a time lag of less than two weeks[34]. This short time lag is caused by our belief that we have an explanatory variable for real GDP with strong explanatory power, with the additional feature that this variable can be observed weekly, with a delay of just a few days. Hence, once a quarter is over, it takes just a week or two to obtain the relevant data on this explanatory variable. Moreover, the data on this variable are adequately measured, that is, measurement errors are not to be expected. Finally, in contrast to other predictive variables like stock market prices

[34] This publication will appear in the Dutch language two-weekly journal *Economische Statistische Berichten* (ESB).

and interest rates, which are sometimes found to be relevant to forecast real GDP, values of our variable can partly be set by the company involved.

Our explanatory variable concerns temporary employment and the data are provided by Randstad Staffing Services. For stock exchange related reasons we will obtain the data one quarter later from Randstad and thus have to make a forecast for the current quarter ourselves. In Section 5.2.3, we outline why we believe that fluctuations in temporary employment correlate with fluctuations in GDP[35]. Next, in section 5.2.4, we discuss the data that we use for constructing a model linking real GDP with staffing data. In 5.2.5, we examine the univariate time series properties of each of the series, and we construct two models, one for the annual growth rates of real GDP and one for the quarterly growth rates. We show that the variables real GDP and staffing (after taking natural logs) are cointegrated, and also that they are strongly correlated, both contemporaneously as well as dynamically. We do not take the cointegration relation as an important variable that requires an interpretation, but merely we interpret our finding only as that the two variables share a common stochastic trend. Section 5.2.6 describes the way we release the EICIE values. Section 5.2.7 concludes with a summary of further research topics which might lead to future improvements to our indicator.

5.2.3 Theory

The following quote is from the American Staffing Association, that is, ”Many economists view temporary employment as a leading economic indicator because businesses can immediately adjust to changes in demand by scaling up or down their use of temporary help. Historically, demand for temporary employees has shifted quickly as businesses adjust to changes in the economy.”, and the quote is from Professor Lawrence Katz, Harvard University. Professor Katz consistently advises to keep an eye on the temporary labor market. This is because temporary employment

[35] A search on the internet reveals that various practitioners share the notion that temporary employment can have predictive value for the state of the economy. Interestingly, to our knowledge there are no academic studies on this topic.

was used reliably in the past two recessions as a leading indicator of real employment and sustained economic recovery.

These quotes suggest that there are reasons to consider temporary employment as a possible measure concurrent with fluctuations of the economy. During times that demand for personnel is lower than the supply, the mobility of personnel, that is, switching activity towards other employers, is reduced. Most of the time HRM managers think that the latter has to do with good HRM policies, however we believe it is simply due to market conditions. During the time that such a situation is present, customers' orders have a short duration, where the customer means the firm which hires temporary personnel. A firm rather cancels the labor relation with the temporary staffing personnel and renews the relationship within a short period than to continue the relationship. Economically, the customer gains a couple of days or weeks of salary cost without running a risk that new temporary staffing personnel is no longer available. In a tight labor market, a customer would never do this since the risk of non-availability of temporary staffing personnel becomes too high. The reverse of this temporary labor market description, when demand for personnel is higher than supply, also holds.

The above described situations alternate in time. The shifts from a tight labor market towards a labor market with an abundance of temporary staffing supply follow the same patterns of growth and shrinkage as real GDP. Intuitively, this reasoning is very appealing also because of its simplicity, that is, a growth in staffing employees at work corresponds with a growth of GDP. Furthermore, this two-variable relationship reflects real and factual behavior.

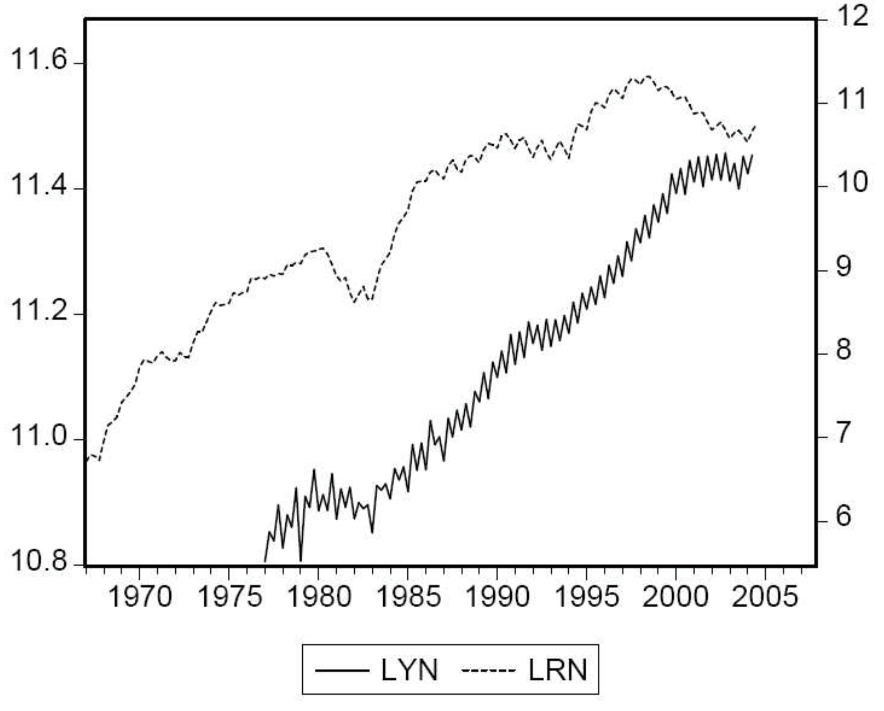
Randstad Staffing Services in the Netherlands (hereafter: Randstad) data are available on a weekly basis. Hence, insights into the direction of real GDP can be improved in a relatively short period. This gives certain advantages for policy makers of the company and also for others when the information becomes publicly available for other policy makers.

Ever since the founding of Randstad in the year 1960, each year branches were opened to accommodate the growing market demand. From 1960 until 2001 the staffing services market grew from its inception as a percentage of the Dutch labor force from 0% to 4%. As of the first year a recording was done on a weekly basis of all staffing employees employed through Randstad.

5.2.4 Variables

It is shown in Chapter 4 that the natural log of annual real GDP and the annual natural log of Randstad staffing services are strongly correlated. This correlation concerns the long run, the short run, as well as contemporaneous correlation. This is the same result as earlier findings for quarterly real GDP and Randstad data, as shown in De Groot and Franses (2005). Then the quarterly series were available from 1977 up to and including 2003. These original series are no longer valid because of the current revision of the National Accounts. For the remainder of this Chapter we will focus on using quarterly data from 2001 up to and including 2005. When by the end of 2006 the revised data as from 1977 will become available again we will use this data again. Now, we shall look at the old data in more detail. The data used to obtain the estimation results below are displayed in the graphs in Figure 16. The data themselves are given in Tables 17 and 18. Electronic versions of these data can be obtained upon request. All computations in this paper have been done using Eviews, version 5.

Figure 16: The log of Gross Domestic Output and the log of Staffing, observed per quarter



Staffing data

Randstad data encompasses weekly data on the number of staffing employees employed through Randstad the Netherlands for the years from 1967 onwards.

The data of Randstad the Netherlands are reliable as the data are obtained directly from the administrative source of the company. The data are an integral part of the weekly business process. Every single data detail is linked to an invoice to the customer (firm) and to the salary slip of the staffing employee. Moreover, these data are part of the monthly, quarterly and annual business appraisal of the branches (the outlets) of the company, its regional management and its policy making board. Randstad data are also representative for the Dutch staffing sector as they cover about 40% of the staffing market in the Netherlands, from its inception until today.

Table 17: The quarterly data on real GDP, as available on September 30, 2004

Year	Quarter 1	Quarter 2	Quarter 3	Quarter 4
1977	49282	51691	50961	53936
1978	50381	53088	52072	55444
1979	49342	54690	53746	57084
1980	53469	54838	53483	56688
1981	52764	55354	53765	55472
1982	52809	54152	53649	53956
1983	51625	55650	55267	55796
1984	54489	57181	56155	57324
1985	55123	59421	57032	59553
1986	57078	61707	59418	60149
1987	57904	61952	60159	62748
1988	60816	63387	61137	64658
1989	63608	66639	63960	67753
1990	66172	68976	66644	70815
1991	67544	71110	68282	72228
1992	69847	71859	69069	72547
1993	69522	72495	70166	72984
1994	70994	74550	72145	75647
1995	73769	76385	74329	77750
1996	75134	79102	76877	80306
1997	77744	82132	79679	83818
1998	82041	85633	82688	87073
1999	84784	88657	85967	91511
2000	88738	92281	88600	93462
2001	90365	94030	89716	94148
2002	90712	94408	90656	94579
2003	90530	93081	89393	94094

Table 18: The quarterly data on Randstad staffing services S, as available on September 30, 2004

Year	Quarter 1	Quarter 2	Quarter 3	Quarter 4
1967	824.5000	893.1154	876.1154	836.8462
1968	1058.519	1277.250	1323.404	1412.212
1969	1677.077	1780.461	1890.962	2071.115
1970	2540.904	2792.173	2726.961	2676.115
1971	2921.808	3058.808	2868.192	2745.654
1972	2757.000	3034.385	2881.000	2894.077
1973	3420.539	3903.077	3894.923	4390.846
1974	4997.462	5526.308	5329.846	5401.462
1975	5489.462	6210.385	6013.231	6215.500
1976	6270.231	7431.000	7302.154	7509.500
1977	7343.923	7744.231	7585.692	7801.846
1978	7783.154	8616.231	8636.077	8941.231
1979	8810.769	9763.154	10150.46	10222.15
1980	10430.31	10587.46	9882.923	8715.923
1981	7623.154	7158.923	7444.077	6236.192
1982	5563.000	6097.538	6700.904	5774.327
1983	5755.789	7117.673	8633.673	9294.713
1984	10060.96	12538.08	14332.27	15285.85
1985	16676.52	21015.29	23331.88	23582.85
1986	23711.63	26361.29	27129.40	25323.83
1987	24343.88	28364.42	30316.62	27497.55
1988	26330.31	30535.23	32149.00	31509.38
1989	29523.92	34476.46	37153.46	36427.00
1990	35157.69	40555.69	41698.15	38474.62
1991	35087.31	38586.46	39856.46	35163.85
1992	31471.08	35538.46	38547.23	33545.38
1993	30603.92	34689.92	38284.31	34911.54
1994	31106.85	39397.69	46646.23	45547.85
1995	43764.00	54262.62	60285.85	59353.62
1996	56953.00	66101.62	71670.62	68144.23
1997	63870.92	74387.92	80134.23	78993.23
1998	74775.54	82288.62	82945.08	77308.08
1999	70078.77	73109.15	72916.08	68582.23
2000	62948.15	64378.31	64753.69	58827.38
2001	52874.23	53856.38	53571.15	48080.62
2002	43813.00	45595.46	48005.92	43851.54
2003	39435.08	42043.77	43297.38	40727.92

When do GDP data become released?

To give an impression of the release process of real GDP data by the CBS, consider the contents of Table 19. About one-and-a-half month after the end of a quarter, the CBS releases a so-called Flash value of real GDP. We will denote this value as GDP_{Flash}. Again, one-and-a-half month later, the Regular Quarterly Forecast (RQF) is published, which we will denote as GDP_{RQF}. The RQFs for an entire year are adjusted in July of the subsequent year, to be labeled as GDP_{ARQF}. One year later, the preliminary definitive values, that is, GDP_{PD}, are published and yet again one year later, the final definitive value is published, which is GDP_{D}.

Given this special scheme of data releases, it seems unwise to seasonally adjust the data, as the seasonal and other components are allowed to change reasonably often[36]. Next, another reason for not seasonally adjusting the data is that we also want to forecast the annual growth per quarter, and this is already seasonality-free.

It is our intention to provide an estimate of quarterly GDP, just two weeks after the end of a particular quarter. We make use of the most recent and available information from the CBS. This means that we make use of available Flash, RQF and ARQF data, whenever possible.

[36] As mentioned, it takes about three years for the final definitive values of real GDP are known. This means that the part of GDP that is attributed to seasonality not only needs revisions due to changing seasonal factors, but also since the very value of GDP is unknown for a long time. Hence, we believe that a seasonally adjusted GDP_{Flash} value is not of much practical use.

Table 19: The Central Bureau of Statistics in the Netherlands (CBS) is responsible for releasing GDP data. The CBS follows the following sequence of events in communicating data. Source: Central Bureau of Statistics, The Hague, The Netherlands.

Number	Name of communication	When
1	Flash	Within 45 days after Quarter end, year T
2	Regular Quarterly Forecast	90 days after the Quarter end, year T
3	Adjusted Regular Quarterly Forecast	After July, in year T+1, following the annual estimate of the year T
4	Preliminary Definitive	After July, in year T+2, following the adjusted annual estimate of year T
5	Definitive	After July, in year T+3, following the adjusted and definitive annual estimate the year T

When do our new estimates become available?

We re-estimate the model parameters each year in September. We use the sample starting in 1977 quarter 1, and then end in quarter 4 of the year before the current year. This is because in September of year T, we should have reasonably precise information on the data points in all quarters in year $T-1$. That is, by then we can use the GDP_{RQF} of all quarters of year $T-1$, and the GDP_{ARQF} of all quarters of year $T-2$ and the GDP_{PD} values of year $T-3$. The models in the next sections have been constructed in September 2004, and hence cover data from 1977 to and including 2003.

We use the model parameters to make estimates of the natural log of real GDP, which we use to construct year-to-year growth per quarter as well as quarter-to-quarter growth. Based on the releases of modified GDP data, we create new estimates. In Table 20, we give a time table in calendar time.

Table 20: Release dates of quarterly figures of Gross Domestic Product data and the dates when new information becomes available. EICIE is short for the Econometric Institute Current Indicator of the Economy, and CBS denotes the Dutch Central Bureau of Statistics. The CBS publishes a flash value of GDP, a regular quarterly forecast (RQF), an adjusted RQF (ARQF), a preliminary definitive (PD) value and the definitive (D) value. EICIE publishes the value of the indicated quarter, and all previous values.

Date	EICIE	CBS (Flash)	CBS (RQF)	CBS (ARQF)	CBS (PD)	CBS (D)
2003, January 15	2002Q4	2002Q3	2002Q2	2000Q1-4	1999Q1-4	1998Q1-4
2003, April 15	2003Q1	2002Q4	2002Q3			
2003, July 15	2003Q2	2003Q1	2002Q4	2001Q1-4	2000Q1-4	1999Q1-4
2003, October 15	2003Q3	2003Q2	2003Q1			
2004, January 15	2003Q4	2003Q3	2003Q2			
2004, April 15	2004Q1	2003Q4	2003Q3			
2004, July 15	2004Q2	2004Q1	2003Q4	2002Q1-4	2001Q1-4	2000Q1-4
2004, October 15	2004Q3	2004Q2	2004Q1			
2005, January 15	2004Q4	2004Q3	2004Q2			

5.2.5 Old Data, Revision, New Data

The EICIE indicator as first presented on January 14 2005 in the ESB is based on a model in which GDP growth is explained by the growth in the staffing market and by a long-term equilibrium relationship of the economy with that same staffing market. That last relationship indicates that the economy and the staffing market have a common trend. Indeed, when the staffing market prospers, the economy also prospers and vice versa. The model parameters have been estimated by using GDP data, as made public by the CBS via Statline, and by using data from Randstad, of which we are allowed to use the quarterly data after these have been made public. In order to make an indicator which is real time, we thus have to rely on a forecast of the Randstad data each quarter. From our own research it turns out that these forecasts are very accurate. Notice that because of this, in principle, we are able to publish the indicator halfway through the current quarter.

The advantages of the EICIE are that it is quickly available, simple to calculate, that in hindsight it is simple to see why a forecast has or has not been sufficiently correct, and that the staffing market is a good indicator of the economy, see also Den Reijer (2005), De uitzendconjunctuur, ESB, 9-9-2005, p. 401.

As been said, an important component of the EICIE is also the GDP itself, of the most recent quarter and of the comparable quarters from one year back. Since the numbers of the national accounts are always undergoing revisions, we always use the most current data available on the dates in question. We did exactly that on July 6th 2005, the day on which we made our forecasts for 2005Q2. Much to our surprise it turned out that the national accounts had been drastically changed that day. Available were the revised numbers for 2003 and 2004, and those deviated substantially from the old numbers. In Table 21 we give the GDP numbers which were available at September 27 2005 (by today various numbers have changed again). Notice that the revised data for 2000 and earlier are not yet available.

Table 21: GDP against constant market prices (2001, new) and (1995, old), as available on September 27 2005

Quarter	Old	New
2001Q1	90365	110992
Q2	94030	114268
Q3	89716	107626
Q3	94148	114845
2002Q1	90712	110758
Q2	94408	114371
Q3	90656	108209
Q4	94579	114735
2003Q1	90530	111172
Q2	93081	113601
Q3	89393	107686
Q4	94094	115021
2004Q1	91595	112473
Q2	94394	115182
Q3	90839	109859
Q4	95554	117642
2005Q1	na	111865
Q2	na	116661

Table 22: Mutations from the quarter now concerning the same quarter of the year before, as available on September 27 2005.

Quarter	Old	New
2002Q1	0.4	-0.2
Q2	0.4	0.1
Q3	1.0	0.5
Q4	0.5	-0.1
2003Q1	-0.2	0.4
Q2	-1.4	-0.7
Q3	-1.4	-0.5
Q4	-0.5	0.2
2004Q1	1.2	1.2
Q2	1.4	1.4
Q3	1.6	2.0
Q4	1.5	2.3

Out of the twelve mutations in Table 22, four changed signs. The previously bad year 2003 now turns out to be a somewhat bad summer. In contrast, 2002 has been considerably worse than we thought at the time. The end of 2004 appears to be much better than we originally knew. Moreover, not only GDP has changed, the "savings ratio" has gone from 2% in the plus to -2%, see zie Ed Groot (2005), CBS verblindde het kabinet, Financieel Dagblad, September 2005.

The numbers in Table 22 reveal that, as we are concerned, not only the values but actually the whole structure of the GDP has changed. This implies that the model behind our EICIE has to be fully specified all over again. One could be tempted to approximately reconstruct the GDP data from before 2000 with a simple adjusting calculation, but given that the structure seems to have changed significantly we won't do that. This showcases one of the advantages of the EICIE since we can create a new model quite easily by using only 16 observations. We only have two variables. With such a short data collection a long-term relationship cannot be specified, thus we confine ourselves with a model for growth rates only. When the newly revised GPD data become available, for the years before 2001, we of course can study such a relationship again. Then we will also revive the approaches from our two earlier papers, a simple multivariate model and a switching model.

5.2.6 Current Data, Current Model

We decide to create a model only for the observations from the years 2002, 2003 and 2004. Our model remains very simple.

$$\begin{aligned}\log GDP_t - \log GDP_{t-4} = \;& \underset{(0.001)}{0.009} + \underset{(0.015)}{0.082} (\log RN_t - \log RN_{t-4}) \\ & - \underset{(0.064)}{0.881}\, \hat{\varepsilon}_{t-4},\end{aligned} \tag{8}$$

Where RN denotes Randstad

The fit of this model is exceptionally high, the R^2 of this model is 0.88. The results of the calculations are shown in Table 23.

Table 23: The model which forms the basis of the EICIE for 2005Q3, YNEW stands for revised GDP numbers, and RN for the Randstad numbers

Dependent Variable: LOG(YNEW)-LOG(YNEW(-4))
Method: Least Squares
Date: 09/21/05 Time: 10:02
Sample: 2002Q1 2004Q4
Included observations: 12
Convergence achieved after 8 iterations
Backcast: 2001Q1 2001Q4

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.009128	0.001239	7.369646	0.0000
LOG(RN)-LOG(RN(-4))	0.081911	0.014976	5.469384	0.0004
MA(4)	-0.880960	0.064036	-13.75734	0.0000

R-squared	0.878037	Mean dependent var	0.005485
Adjusted R-squared	0.850934	S.D. dependent var	0.009519
S.E. of regression	0.003675	Akaike info criterion	-8.162079
Sum squared resid	0.000122	Schwarz criterion	-8.040853
Log likelihood	51.97248	F-statistic	32.39644
Durbin-Watson stat	1.844409	Prob(F-statistic)	0.000077

Inverted MA Roots	.97	.00+.97i	.00-.97i	-.97

The contribution of the yearly growth in the staffing market is very relevant, considering the significant parameter. The fit is exceptionally high. In Table 24 we give the EICIE values, afterwards, for the 12 quarters in 2002, 2003 and 2004, and we see that the EICIE is surprisingly close to the actual values. When we remove the staffing market from the simple model, the forecasts become substantially less good.

Table 24: Forecasts of the EICIE, with and without the Randstad data

Quarter	Real data	With Randstad	Without Randstad
2002Q1	-0.2	0.3	0.3
Q2	0.1	-0.5	0.3
Q3	0.5	0.3	0.3
Q4	-0.1	-0.1	0.3
2003Q1	0.4	0.5	1.0
Q2	-0.7	-0.3	0.6
Q3	-0.5	-0.1	0.0
Q4	0.2	0.3	0.8
2004Q1	1.2	0.7	1.1
Q2	1.4	1.5	2.0
Q3	2.0	1.9	0.9
Q4	2.3	2.4	1.0

Strengthened by the outcomes in Table 24 we calculate the EICIE values for the quarters of 2005. For the third quarter we use a forecast of the Randstad numbers, and also incorporate the 90% upper limit and lower limit in the calculation of a pessimistic and an optimistic forecast. The numbers in Table 25 show that the EICIE again had been wrong in the first quarter of 2005, while we had indicated 1.7% (in stead of the 1.5 % decline) for the second quarter. For the third quarter we predict a growth between 0.9% and 2.3%.

Table 25: The EICIE for 2005, quarters 1, 2 en 3

Quarter	Real data	Our model average	Pessimistic	Optimistic
2005Q1	-0.5	0.6		
Q2	1.3	1.7		
Q3		1.6	0.9	2.3

We expect the GDP numbers in the Netherlands will undergo revisions for a long time, and thus that our EICIE also has to be re-calibrated again. Bearing in mind the simplicity of the EICIE this re-calibration is possible and simple. For 2005Q4 we used the same model.

The growth in the first quarter of 2006

The EICIE, which now has been published five times, gave a forecast for 2005Q4 of 1.8% with a bandwidth of 0.6 and a forecast of 1.0% for 2005 overall. The press release of the CBS from February 14 2006 reported a first estimation of 1.6% for 2005Q4 and a yearly growth of 0.9%, and on March 29 2006 these estimations were adjusted. In Table 26 can be seen that the EICIE has been very close to the CBS estimations for the last three quarters.

After the staffing market has been in decline in the years from 2000 until 2004, we see that the staffing market from May 2004 on can rejoice in a growth in the number of people working via Randstad. The economy has also developed positively. The development of the economy goes hand in hand with the development of the staffing markets, and the new staffing data are thus anticipated with much interest.

Our original intention was to develop an indicator which, besides a great simplicity and reasonable accuracy, first and foremost should be published early, preferably even during the current quarter. We hope to accomplish this in the future. Taking into account the recent achievements of the EICIE, and considering the fact that we are able to predict Randstad's quarterly data reasonably well, we will now already give the number of the first quarter of 2006.

In the past half year, the EICIE has shown that it can give accurate forecasts for the economic growth in the most recent quarter. Strengthened by these results, the EICIE for the first time is given only just after the quarter has ended. In the first quarter of 2006 the economy has grown with 2.3%.

Since the most recent CBS numbers are being adjusted, we re-estimate the equation which forms the basis of the EICIE once a year, when we have the complete annual figures. The model is the same as before, and it concerns a model which explains GDP growth from the growth in the Randstad numbers and a so-called moving average term. The new parameter estimates have been made for the data of 2002Q1 up and including 2005Q4 and they barely diverge from the earlier estimates.

Now we also need a prediction for the Randstad data for 2006Q1. We base this on a simple autoregressive time series model[37] for which we take recent developments during the quarter. We also include 90% of the lower limit and the upper limit in our calculations of an optimistic and a pessimistic forecast. The numbers in Table 26 show that the EICIE predicts a growth between 1.8% and 2.8%.

Table 26: The EICIE for 2005, quarters 1, 2, 3 and 4, for the whole year, and for the current quarter 2006Q1

Quarter	CBS data, 14-2-2006	CBS data, 29-3-2006	EICIE Average	Pessimistic	Optimistic
2005Q1	-0.5	-0.3	0.6		
2005Q2	1.3	1.6	1.7		
2005Q3	1.3	1.6	1.6	0.9	2.3
2005Q4	1.6	1.6	1.8	1.2	2.4
2005	0.9	1.1	1.0		
2006Q1			2.3	1.8	2.8

[37] For 2005Q4 this model gives an estimation error of 0.4 percent in absolute sense.

Chapter 5.3 Conclusion

This chapter describes the components of the EICIE, the Econometric Institute Current Indicator of the Economy. This measure concerns quarterly growth of Dutch real Gross Domestic Product. The key component of our real-time forecasting model for Dutch quarterly GDP is weekly staffing services obtained from Randstad company, which is single explanatory variable. Nowcasts for quarterly and yearly Dutch GDP can be done reliably with the help of a single explanatory variable from the real economy which, displays factual behavior.

Contents

Chapter 6. Conclusion

Chapter 6.1 Introduction

In this Chapter we will give a summary of Chapter 2 up to and including 5. We will also indicate which cycles were found in which data. The most important conclusion of this thesis is that constellations of cycles were found in innovation and macroeconomic data of which the lengths of the individual cycles remarkably approach the Fibonacci sequence. These multiple cycle structures can provide stability in the economy. Moreover it has been shown that reliable nowcasts for Dutch GDP can be made based on staffing data from Randstad. Subsequently, we will give recommendation for policy makers and determine possibilities for future research.

Chapter 6.2 Summary and Conclusions

6.2.1 Cycles from the literature

Our first topic deals with the cyclical development of economic variables.

In the long wave literature, five different economic cycles have been discussed at length. The so-called Kitchin, Juglar, Kuznets, Kondratieff and the Hegemony cycles have been described. All these cycles have their own original theoretical and empirical foundations. The observation can be made that the longer these cycles are, the more controversies surround them. From the long wave debate, as discussed in Chapter 2, it has become clear that a new approach is needed.

It can be noted that the shorter cycles tell us something about the behavior of firms. The Kitchin cycle is stock related and the Juglar cycle has something to do with investment. The intermediate length cycles are associated with the economy as a whole. The Kuznetz cycle is linked with construction and housing whiles the Kondratieff cycle encompasses basic innovations and infrastructure. The Kondratieff cycle serves as a pivot. The longer cycles deal with generations in society and (geo) political subjects such as hegemony and war. In other words, the sequence of cycles runs from the microeconomic behavior of firms, via industry and national economies towards politics, world hegemony and war.

6.2.2 Multiple cycle structures in innovation and macroeconomic variables

In “Business Cycles” (1939) Schumpeter articulates the concept of real world multiple economic cycles. Other authors have elaborated on this notion. Common elements in the various multiple cycle perspectives are: an indefinite number of independent cycles, varying cycle lengths and the possible interlinking of cycles.

We take up Schumpeter's idea and also conjecture that most economic variables cannot be described by a single cycle but by multiple cycles. Together these longer and shorter cycles with different lengths and amplitudes form constellations of cycles within the variables. The constellations do not consist out of simple multiplications of shorter cycles but out of various independent cycles which run more or less in their own domain.

The whole of all constellations of cycles gives a representation of the economy. When taken together the cycles form an erratic pattern which resembles the oscillation, the growth and decline, of the economy.

The concept of multiple cycle structures which are comprised of cycles of different lengths and have ever changing combinations of peaks and troughs underpins the ideas of the SSA (Social Structures of Accumulation) school which state that during certain periods in history specific agreements made by institutions, companies and society will stay in place for a yet undetermined period of time. The environment in which this SSA exists changes continually. After a while, the needs of the environment will have diverged to such an extent that the institutional constellation of an SSA can no longer withhold and will change in order to fit the specific requirements of the new era. New arrangements have to be made since the world and the economy have changed the people, institutions, companies and governments have to reinvent a new SSA. Looking at the constellations of cycles in the multiple cycle approach, one can easily recognize that the cumulation of the interaction between the various cycles in time will give a different outcome for every period even though it is more or less stable in the short run. This outcome is very similar to the SSA perspective on economic development.

First we take up another bit of Schumpeterian heritage and examine an innovation series. We documented the presence of multiple cycles in innovations series. These cycle lengths are remarkably close to the Fibonacci sequence, i.e. 5, 13, 24, 34 and 61. Also we found evidence of the clustering of basic innovations.

Then we investigate a large sample of important macroeconomic variables for the US, UK and the Netherlands. We document that economic variables, such as GDP growth, employment, interest rates and consumption show signs of cyclical behavior. Most variables display multiple cycle structures, with lengths ranging in between 5 to even up to 100 years.

We obtained empirical evidence that economic cycle lengths can be classified into four distinct groups, with cycle lengths on average of 10.3, 25.7, 57.7 and 92.0. We find cycle lengths that are remarkably close to Fibonacci numbers, here 8, 21, 55 and 89. In fact, with the estimation results in Table 4, we can compute that 8 is 0.66 standard errors away from 10.3, 21 is 0.59 standard errors away from 25.7, and 55 and 89 are just 0.34 and 0.38 standard errors away, respectively. Of course, our findings are no proof of the link between Fibonacci numbers and "optimal" cycle lengths, but we believe that the correlation is striking.

Stability is an important feature of the economic system. The composites of cycles also express stability. We give two examples of the stability of the system as a whole. First, within the constellations the individual cycles all have their own domain. Second, the interference of the cycles with different lengths and amplitude counterbalance each other hereby creating an inherently more stable system. The difference in lengths of the cycles provides that the system never entirely implodes or explodes. This harmonic and cyclical development of the economy, alternating periods of growth and decline, is a token of stability of the economic system as a whole.

We accept that shocks and impulses are necessary to create cyclical behaviour. We also believe that those shocks and impulses will always exist. Individuals, enterprises and governments will always act and cause impulses and cause economic growth and decline. The economy will therefore always oscillate and never tend towards a static equilibrium in the classical sense.

After the investigation of 40 economic variables a pattern was found in the lengths of the 90 cycles that closely resembled the Fibonacci sequence we took another look at Table 6 in which all classical cycles from the literature have been tabulated. Surprisingly the lengths of the cycles mentioned in Table 2 also gravitate towards the domains of the Fibonacci sequence.

6.2.3 Long-term forecasting for the Dutch economy

It is readily accepted that the staffing services industry is a good indicator of the current state of the economy during periods of prosperity as well as recession. From its establishment in 1960, Randstad, a staffing service provider from the Netherlands, which over the course of the years has become a world player in the staffing industry, showed great interest for labor statistics. The growth and decline of Randstad appeared to be very much parallel to the state of the economy.

We investigate whether staffing data from Randstad can be used for forecasting purposes. We elaborated on the hypothesis arisen from practice that with staffing data from Randstad forecasts for the development of both Randstad and Dutch GDP can be made. The correlation between Randstad's temporary staffing services and Real GDP in the Netherlands concerns the long run, as they share a common stochastic trend and the shorter run, where contemporaneous and lagged correlations exist between growth rates. An interesting feature of the quarterly data, and also for the annual data, of both series of interest is that the data experience cycles.

Most studies on real GDP adopt autoregressive models for the growth rates, where the order of these models typically is 2 or more. It is well known that when the solutions of the characteristic polynomial of such an autoregression are complex valued, the model implies that the data experience cycles. However, when these cycles are stable, then, due to very nature of autoregressive models, long-term forecasts will show cycles with ever decreasing amplitude. In order to make the cyclical patterns to continue in a similar fashion in the forecasting sample, one can rely on harmonic regressors, and this is what we did in this thesis.

We examined the possible presence of a common stochastic trend in the log-level series, while allowing for deterministic cycles. As expected we found such a common trend. However, when the cointegration variable and current and lagged growth rates of GDP were added to the univariate model for Randstad, these terms appeared statistically irrelevant. Hence, we proceeded with a single equation error-correction model for real GDP. This model included lags of both growth rates as well.

Diagnostic tests indicated the adequacy of this model, and also that there was no need to add any harmonic regressor.

Given the in-sample fit of the two models, we were reasonably confident that these models can reliably be used to generate long-term forecasts. We found cycles of around 5 and 11 years. The forecasts suggest growth rates around 2 per cent, with a dip to be expected around 2012-2013.

There is one major caveat to make. Our forecasts are based on models with only revised GDP data that are available from 2001 onwards. The CBS announced that by the end of 2006 the full revision of the National Accounts and therefore the GDP data from 1977 until 2005 will become available.

6.2.4 The EICIE indicator

Our final topic is the development of the EICIE indicator, a real time quarterly and yearly indicator of the GDP of the Netherlands based on a single explanatory variable.

In this thesis we describe the components of the EICIE, the Econometric Institute Current Indicator of the Economy. This measure concerns quarterly and annual growth of Dutch real Gross Domestic Product. The key component of our real-time nowcasting model for Dutch quarterly GDP is weekly staffing services obtained from Randstad company, which is single explanatory variable. The staffing variable helps to give quarterly GDP figures within the quarter.

The main motivation to develop our indicator is that official, and preliminary, data on real GDP are released with a time lag of at least one quarter. We aim to publish the EICIE indicator with a time lag of less than two weeks and even during the quarter. One of the main novelties of this indicator, which is quite in contrast with much recent research on business cycle forecasting, is that the forecasts are based on very simple single-equation models where only a single predictor variable is used.

Chapter 6.3 Contributions

This thesis investigated whether classic single cycle long waves could be found in innovation data, in various macroeconomic variables and in classic long wave series. It was concluded that the classic view of single cycles no longer holds. Research made clear that economic variables usually display a multiple cycle structure. These findings concur with Schumpeter's original multiple cycle hypothesis. The examination of the innovation set also revealed evidence for the clustering of basic innovations.

A remarkable observation could furthermore be made. The cycle lengths of the individual cycles from the multiple cycle structures appeared to be surprisingly close to the Fibonacci sequence. In conjunction to this a tabulation of the cycle lengths of all known classic single cycles from the literature revealed a pattern which also seemed to approach the Fibonacci sequence. An interesting feature of Fibonacci-like cycles is that the individual cycles will never reach their minimum or their maximum simultaneously. This entails that the individual cycles counterbalance each other's extremes and therefore can be associated with stability in the economy.

Practical experience at Randstad staffing agency led to the insight that staffing data is a good indicator for the economy as a whole. When investigating this hypothesis a common stochastic trend between staffing data from Randstad and Dutch GDP was found. The understanding that cyclical behaviour will always be a part of the economy and the knowledge that economic data could be represented very well by multiple cycle structures led to the conclusion that forecasting models should also contain cyclical elements. With the inclusion of multiple cycle structures in our model we provided a more dynamic alternative to the static equilibriums of other forecasting models. Examination of the Randstad data and of Dutch GDP revealed two cycles of respectively 5 and 11 years. We used these finding to create a model and made a forecast for yearly growth in the Dutch economy for 2005-2015.

In this thesis the Randstad staffing data were moreover used to develop a new real time indicator of Dutch GDP named EICIE. In contrast to other models this real time nowcast indicator is based on only a single explanatory real variable, namely staffing data from Randstad, and has an extremely simple model structure. The single variable is furthermore based on factual behaviour, people that go to work every day via a staffing service agency and thus is not composed from surveys. Because the information from Randstad becomes available fast, the nowcasts can be published well in advance of the first official quarterly and yearly estimates of the CBS. This indicator is also very interesting on a corporate level. Randstad can use the forecasts and the nowcasts of the indicator for its own policy planning.

By recognizing the presence of multiple cycle structures in both business and macroeconomic variables a better understanding and insight in the workings and interactions of such variables can be gained. This knowledge can also be used for creating an outlook on the future via scenario planning. Thinking in terms of cyclical rather than linear progression can prevent that during times of above average prosperity or depression temporary trends are continued into long-term in scenarios. This avoids expectations becoming either much too positive or too negative.

In this thesis a better understanding is developed of the cyclical behavior of economic variables and consequently of the cyclical behavior of a firm and the economy. The scientific findings are used to create understandable and practical forecasting solutions for decision-makers in companies and the government.

Chapter 6.4 Future Research Agenda

1. Investigate why the Fibonacci sequence is found as the underlying pattern

2. Develop an EICIE indicator for other countries

3. Investigate the dynamics within the constellations of cycles

Summary in Dutch

Bedrijven en de overheid hebben altijd te maken met een situatie van onzekerheid met betrekking tot de economische vooruitzichten. Economen herkennen korte en lange cycli in de economie die het volgens bepaalde onderzoekers vanwege hun repetitieve karakter makkelijker kunnen maken om economische veranderingen te voorzien. In dit proefschrift zal worden onderzocht of, en zo ja, in welke hoedanigheid, deze lange cycli in de data terug te vinden zijn. Op het gebied van business cycle fluctuaties kunnen forecasting en nowcasting modellen door het aanleveren van betrouwbare voorspellingen de onzekerheid op de korte termijn voor een deel weg te nemen. In dit proefschrift zal een nieuwe real time nowcast indicator van de het Nederlandse BBP worden geïntroduceerd.

Klassieke cycli onderzoekers gaan over het algemeen uit van enkelvoudige economische golven. In Hoofdstuk 2 wordt een uitgebreid overzicht van de lange golf, Kondratieff, literatuur gegeven. Ook de andere uit de literatuur bekende golven zoals Kitchin, Juglar, Kuznets en hegemonie worden in dit hoofdstuk besproken. De openstaande vragen en controverses van het lange golf debat worden geïdentificeerd waardoor duidelijk wordt welke onderdelen verder onderzocht zouden kunnen worden en met behulp van welke aanpak dit het beste kan gebeuren. De conclusie die wij uit deze literatuurstudie trekken is dat de huidige benadering van de lange golf onderzoekers tekort schiet, het vakgebied in een impasse is geraakt en een andere aanpak nodig is. Opmerkelijk is verder dat de lengten van de in de literatuur onderkende cycli de Fibonacci reeks[38] lijken te benaderen.

Een kansrijke invalshoek is de meervoudige cyclus benadering. In Hoofdstuk 3 beschrijven wij de originele meervoudige cyclus theorie van Schumpeter en andere contemporaine meervoudige cyclus benaderingen. Vervolgens bekijken we diverse innovatie theorieën om uiteindelijk te onderzoeken of er meervoudige cyclus structuren in een innovatie dataset te vinden zijn. Dit blijkt het geval. We vinden vijf cycli met lengten van 5, 13, 24, 34 en 61 jaar. Deze lengten liggen opvallend dicht bij de Fibonacci reeks. Daarnaast vinden we bewijs van clustering van basisinnovaties. In

Hoofdstuk 3.4 gaan we na of hetgeen we bij de innovatie set gevonden hebben ook in andere macroeconomische variabelen terug te vinden is. We onderzoeken 33 series uit 3 landen en 6 klassieke lange golf datasets en vinden meervoudige cyclus structuren met in totaal 90 individuele cycli bij alle onderzochte variabelen. Ook hier observeren we dat de gevonden lengten van de cycli de Fiboancci reeks lijken te benaderen.

Een van de eigenschappen van Fibonacci cyclus lengten is dat er geen enkel moment in de tijd is waarop alle cycli gelijktijdig hun maximum of hun minimum bereiken. Dankzij deze eigenschap kunnen de gevonden multi cycli structuren kunnen worden geassocieerd met stabiliteit in de economie. Omdat de pieken en dalen van de cycli niet gelijktijdig zijn vlakken ze elkanders extremen immers af. Dit impliceert dat macroeconomische politiek zinvol is. Door middel van beleid kunnen cycli worden ondersteund die verwachte ongewenste extremen kunnen effenen. Het traditionele beeld van de enkelvoudige cyclus wordt door deze bevindingen bijgesteld naar dat van een meervoudige cyclus economie.

In Hoofdstuk 4 gaan we in op de vanuit de praktijk ontstane hypothese dat met behulp van uitzenddata van Randstad er voorspellingen voor de ontwikkeling van het Nederlandse BBP kunnen worden gemaakt. We staan stil bij de totstandkoming van deze hypothese en beschrijven de relatie tussen het Nederlandse BBP en uitzendgegevens van Randstad. Allereerst moet worden aangetoond dat Randstad en het Nederlandse BBP een gezamenlijke stochastische trend delen. Dit blijkt het geval. Hierdoor wordt het mogelijk om op basis van een model voorspellingen te doen. Vervolgens stellen we vast dat in de Randstad data en in het Nederlandse BBP eveneens meervoudige cyclus structuren aanwezig zijn. De gevonden cycli lengten in zowel het BBP als in de Randstad data zijn respectievelijk 5 en 11 jaar. Op basis van deze bevindingen ontwikkelen we een lange termijn meervoudige cyclus voorspel model voor het Nederlandse BBP. Met behulp van dit model geven wij een nowcast voor het Nederlandse BBP voor de periode 2005-2015.

In Hoofdstuk 5 gaan we dieper in op de mogelijkheden om op basis van de wekelijks beschikbare uitzendgegevens van Randstad een betrouwbare real time indicator van

[38] Fibonacci reeks: 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, …

het Nederlandse BBP te ontwikkelen. Deze real time indicator, EICIE gedoopt, is uniek omdat deze gebaseerd is op slechts een enkele reële verklarende variabele en een uitermate eenvoudige modelstructuur kent. Andere BBP indicatoren zijn complexe modellen gebaseerd op vele variabelen. Opgemerkt dient te worden dat de verklarende variabele van de EICIE feitelijk gedrag weergeeft en dus niet op basis van surveys of pulling van data is samengesteld. Doordat de Randstad gegevens snel na het einde van het kwartaal beschikbaar zijn en de EICIE zich eenvoudig laat berekenen is het mogelijk om binnen twee weken na afloop van het kwartaal en zelfs binnen het kwartaal een betrouwbare kwartaalvoorspelling te publiceren. Dit is ruim voor de bekendmaking van de eerste officiële raming van het CBS.

In Hoofdstuk 6 geven we een samenvatting van hetgeen in Hoofdstuk 2 tot en met 5 besproken is. Ook geven we aan welke cycli in welke data gevonden zijn. De belangrijkste conclusies van dit proefschrift zijn dat er in innovatie en macroeconomische data constellaties van cylci gevonden zijn waarbij het opmerkelijk is dat de lengten van de individuele cycli de waarden van de Fibonacci reeks benaderen. Deze meervoudige cyclus structuren kunnen worden geassocieerd met evenwicht in de economie. Daarnaast is aangetoond dat op basis van uitzendgegevens van Randstad betrouwbare voorspellingen van het Nederlandse BBP kunnen worden gemaakt, zowel voor de korte als de lange termijn.

Curriculum Vitae

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Bert de Groot is Rector Magnificus and Dean of Nyenrode Business Universiteit. He is a former member of the Randstad Holding N.V Board of Directors.

De Groot has held numerous leading positions on a national and international level in sectors ranging from telecommunications to the pharmaceutical industry and from life sciences to the computer sector. In addition to his position at Randstad (staffing services) he was associated with the Royal Dutch Navy, biotech and pharmaceutical company Gist Brocades N.V, Unisys Inc. (information management and computer industry), telecom multinational KPN, Boer & Croon (executive management), Pharming N.V. (life sciences), AM NV (project development), the Faculty of Economic Sciences at the Erasmus Universiteit Rotterdam and the Erasmus Universiteit Rotterdam Holding B.V. (commercial research). De Groot gained extensive experience in corporate recovery (at Pharming and others) and corporate delisting (at AM). He holds various supervisory board memberships.

Bert de Groot studied econometrics at the Erasmus Universiteit Rotterdam (EUR) and has followed management programs at IMD (previously IMI), Nyenrode, Wharton and INSEAD. De Groot was awarded his PhD by the EUR for his thesis '*Essays on Economic Cycles' and* is member of the Econometric Institute of the Faculty of Economic Sciences at the EUR. He has a number of publications on economic cycles to his name and makes short- and long-term predictions for Randstad and the Dutch economy in general.

At Nyenrode, Bert de Groot holds the chair in 'Business and Economic Cycles'. The Research focuses on the development of the international economy and individual companies and the cyclical development that can be observed. This is done from an economic and business perspective and from a technological, institutional, social-societal and ecological perspective. Key research issues include how cyclical developments are influenced by innovation, and the decisions and actions of business leaders, entrepreneurs, managers, governments and non-governmental organizations. Insights in future developments are used to enhance scenario analysis. Bert de Groot is a member of the Nyenrode Research Group and a member of the Econometric Institute at the EUR.

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Appendix A: Innovation and Diffusion

- **Introduction**

The process of innovation diffusion plays a central role in various long wave theories. A cluster of innovations drives the economy, according to Schumpeter, Mensch, van Duijn and Kleinknecht. Freeman and Perez and Tylecote state that a good match between a cluster of basic innovations and the social and institutional system of a society causes the long wave upswing. Kondratieff, Rostow, Forrester, Gordon, Goldstein and Boyer mean that basic innovations are less determinative than the authors mentioned before suppose but nevertheless play an important supporting role in the long wave mechanism. However, as was already concluded in Chapter 2.4.4 Unanswered Questions and Controversies, the long wave researchers are internally divided about the exact place of the process of innovation diffusion. The diffusion process itself is also largely seen as black box. More insight into the diffusion process can be gained by studying the theories of non-long wave researchers.

In this chapter the role technological development plays in some macroeconomic theories will first of all be briefly discussed. Attention will be given to the supply push and demand pull argumentations and to the ideas of the evolutionary economists. Subsequently, some micro-economic, business, sociological and psychological theories about the different factors which are important for the diffusion of innovations will be looked upon. Amongst others the theories which explain the forming of the S-curve, the specific factors which play a part in the innovation and diffusion process and the influence of characteristics of innovations, users and the environment will be studied. General Purpose Technologies and the theories of Utterback will furthermore be discussed. Finally this chapter will be concluded with a consideration on the direction of the innovation research according to the macro- and micro-economists from this chapter and the long wave researchers from Chapter 2.

- **Theory**

The Role of Innovation in Macroeconomic Theories

Technological innovation plays a part in various macroeconomic theories. In this section some of the most important applications will be briefly discussed. Attention will be given to the way innovations are fit within the traditional economic analysis. Then the principles of the Real Business Cycle models, the differences between the supply push and demand pull models and finally the ideas of the evolutionary economists will be discussed.

Neoclassical Exogenous and Endogenous Growth Theory

According to the neoclassical theory all economic growth converges to zero in the long run. Making a profit is thus impossible in the equilibrium situation. This steady state equilibrium can only be temporarily be broken by exogenous shocks, this means by an impulse which is generated by non-economic forces. Only these exogenous impulses such as innovation can for a short period of time make profits exceed the interest and risk premiums. However, because competition is perfect, which implies that market participants are completely rational and have full information, this situation will not hold in the long run due to imitation and accession. In the stationary equilibrium logically speaking there will be technological uniformity. Classical and Neoclassical theory is thus not suitable for the analysis of the influence of technological progress on economic developments.

Within the neoclassical school productivity growth is seen as a measure of technological progress which is considered to be exogenous. Endogenous growth theory emphasizes on the contrary that technological progression and productivity increases are more or less independent and can develop themselves autonomically.

The principle that learning effects are the foundation of technological changes forms the basis of the endogenous growth model developed by Arrow (1962). Silverberg (2001) states that for neoclassical growth models as well as for endogenous growth models hold that: "(…) there are no identifiable 'discrete technologies', and growth inevitably takes the form of an exponentially steady state." The models differ from each other in the fact that in endogenous growth models growth does not converge to zero in equilibrium but is constantly positive.

Real Business Cycles

Because markets are always equilibrium according to the Real Business Cycle literature, originally developed by Prescott and Kydland. They state that there should be another explanation for the short run variations in output. They consider random exogenous technology shocks as the most important cause of business cycles. This shock mechanism in Real Business Cycle models is according to Fiorito and Kollintzas (1992) generated by the optimizing behavior of economical agents operating in a competitive environment. When the speed of technological development slows down the marginal productivity of the employees diminishes which causes a decrease in the real wage. Employees will react to this development by working less. During this period the growth of output will diminish and the economy will eventually get in a recession. In times of prosperous technological development the contrary happens. According to Real Business Cycle adepts this is how periods of booms and recession arise. The practical applicability of the Real Business Cycle ideas is controversial amongst some economists.

Supply Push vs. Demand Pull

Economists differ in opinion about the nature of the relationship between economic growth and innovative activity. Some follow the supply push model where others agree with the principles of the demand pull model.

Within the supply push school most authors presume that the causality in the relationship between innovations and economic growth runs from the first to the latter. They assume that the development of innovations is driven by exogenous scientific progress. Fluctuations in innovative activity are random because increases in the general level of scientific knowledge are unpredictable. According to Geroski and Waters (1995) many supply push followers hold the opinion that clustering of innovations takes place.

Supporters of the demand pull school mean that the causality in general runs from economic growth to innovative activity. Furthermore they state that factors such as consumer behavior, market structure and the degree of profitability are determining for the development of innovations.

Geroski and Waters (1995) investigate the clustering of innovations and the influence of demand on the moment of diffusion. Geroski and Waters mention three arguments why innovations appear in clusters and run parallel with movements in demand. The first argument states that the opportunity costs of the development of radical innovations are too high for established companies. Innovative activity is anti-cyclical in this argument. The second demand pull argument concerns the limited possibility of markets to absorb new products. Every new product has to face the competition of the established companies for the limited budget of the consumer and, when successful, has to deal with imitation. In periods of economic expansion consumers have more to spend which increases the chance for success for new products. The third argument encompasses the fact that businesses preferably would like to introduce their products under the most favorable market conditions. This is the case in periods with increasing demand. Both the second and the third argument state that it is more likely that innovations are produced during booms than recessions.

Research by Geroski and Walters (1995) confirms that clustering of innovative activity takes place: “Nevertheless, there is evidence in the data of some clustering of innovative and patenting activity above and beyond that created by a random walk, and it is clearly possible that this clustering is linked to variations in demand.” The demand pull principle that economic growth leads to the development of innovations and not vice versa is also supported: “(…) and found fairly strong evidence to support the assertion that output Granger causes innovations, but no evidence whatsoever to suggest that innovations Granger cause variations in output.”

Schmookler (1966) states that technological changes are endogenous and driven by economic forces. In his vision the scientific breakthroughs which form the basis of inventions are driven by cost problems and profit possibilities. He sees innovations as a function of the effective demand, there is supposed to be a so-called demand pull: "(…) demand determines the allocation of inventive effort among alternatives (…)."

Freeman (2003) declares that Schmookler developed his ideas on the innovation process after his empirical finding that in various industries clusters of patents arise after large investments: "He maintained that the appearance of clusters of patents in various industries after major productive investment in those industries demonstrated that invention and innovation were generally demand-led and not technology-led."

Schumpeter (1939) had an opposing position which stated that the supply side should be emphasized. In his point of view the emphasis is put on the ingeniousness of the entrepreneurs and the dominant role of the supply of technology in the development process of an innovation.

Barras (1990) integrates both: "This continuous process of adaptation implies that both the 'demand pull' factors stressed by Schmookler, and the 'technology push' factors stressed by Schumpeter are equally important influences on innovation, supporting the opinion that proponents of one model rather than the other in this long-running debate are inevitable taking only a partial view."

Dosi (1982) also discusses the influence of demand pull and supply push factors on the innovation process. He comes to the conclusion that the exogenous scientific impulses of the supply push model are more important than the endogenous market influences of the demand pull model. However, not only supply push variables play a role in the development of a technology. In reality there is a complex interaction between supply push and demand pull factors. The demand pull influences become more important as the development process becomes more incremental.

Sahal (1985) means that the choice between supply push and demand pull factors is irrelevant because the importance of both individually is negligible: "According to the results of our investigation, the considerations of demand and supply are of little significance in and of themselves. Rather, their importance depends on their bearing on the internal structure of technology. It is the process of morphogenesis rather than demand or supply as such that is central to the process of innovation."

Evolution

Some economists, who where inspired by Schumpeter, apply the principles of the originally biological evolution process on economic hypotheses. They state among other things that innovations develop along a more or less stable trajectory.

Evolutionary economists Nelson and Winter introduce in 1977 the concept of natural trajectory. The authors suppose that after their introduction radical innovations develop along a relatively ordered path. Silverberg and Verspagen (2003) state that the course of such a development trajectory on the one hand are influenced by "incremental improvements that take place during the diffusion process of the basic design" and on the other hand by "external circumstances such as characteristics of demand, factor prices, patterns of industrial conflict, etc." According to Barras (1986, 1990) the development along a natural trajectory can be compared to following a learning curve.

Dosi (1982) also supposes that the innovation process goes along relatively orderly so-called technological trajectories. In his point of view the innovation process is not entirely random. Paradigms and trajectories limit the set of possible future alternatives and thus limit the possibilities for development. The development via paradigms through trajectories also gives an explanation for the cumulative nature of the innovation process. Both small entrepreneurial companies driven by original ideas as well as large corporation which operate with the help of R&D can be at the basis of the development of an innovation. In both cases knowledge and science are primarily the driving variables.

The framework in which Dosi develops his ideas on the innovation process is based on Kuhn and Lakatos science philosophy in which the division in paradigms, heuristics and trajectories originates. Paradigms determine the possible application and development area of certain technology. The formation of a new paradigm causes discontinuity and is comparable to the development of radical or basic innovations. In biological terms this is about determining the direction of the mutation. The evolution of the technology along the specific development trajectory is comparable to continuous or incremental change. Heuristics provide the further delineation of the trajectory within the boundaries set by the paradigm. Positive heuristics indicate paths that should be followed whereas negative heuristics point out development possibilities which should be avoided. The exact trajectory along which the development of the technology takes place is co-determined by the interaction with the economical, social and institutional environment. As a certain technology trajectory becomes more unique and has developed further it becomes more difficult for companies to leave this path. There is a lock-in effect. This can cause problems since companies cannot determine with certainty beforehand which trajectory is the best. Except at the realization of the paradigm ex post selection also takes place between the "end mutations" (products). Here the market determines the outcome via a Schumpeterian process of trial and error.

Sahal (1985) also supposes that technological development goes along relatively ordered trajectories. In his analysis he speaks of so-called technological guideposts: "(…) technological progress is invariably characterized by the existence of what may be called technological guideposts and innovation avenues that lay out certain definite paths of development." The success of a new technology according to Sahal depends on its size and structure which are determining for the direction of the further development.

Dosi (1982) states that the concept of technological trajectories can also be relevant for the long wave discussion because it can provide a possible explanation for the clustering of innovations: "One of the variables affecting long-run cycles of capitalist development may be the establishment of broad new technological trajectories, which could explain the 'clustering' of groups of innovations and, even more important, the 'clustering' in time of their economic impact."

The S-Curve

In section 5.4 it has been stated that evolutionary economists hold the opinion that the diffusion trajectories of innovation run along relatively ordered pathways. From the innovation literature the empirical observation is made that the diffusion process follows the shape of an S-curve. Geroski (2000) discusses various models from the literature which can provide a possible explanation for the development of the S-shaped curve.

The most popular explanation for the S-curve, so explains Geroski (2000), states that the adoption of an innovation is limited by the spread of information about the innovation. An analogy can be made between the spread of innovation and the spread of an epidemic. At first the population consists mainly of non-users. For users it is thus relatively easy to contact non-users. However, because of the limited number of users the spreading goes slowly. In the later phases of the diffusion process there are many users but is the chance that they meet one of the few non-users small which keeps the growth of the degree of adoption low. In the period in between the adoption goes successfully.

Geroski acknowledges the limitations of the epidemic model. He states that the diffusion of information in general is much faster than the diffusion of innovations. Furthermore it is usually not enough that potential users are informed about the existence of an innovation but they should be explicitly be persuaded of the use of purchase. Except the availability of information many mote factors can be appointed which possibly could play a part in the faster or slower adoption of a certain new technology.

Such difficulties of the epidemic model have led some researchers to use probit models in order to explain the diffusion process. Probit models are concerned with the adoption decision of individuals. The transaction costs which are connected to the receiving and sending of information are taken into account as well as the learning ability of individuals and the degree of risk-aversion. Every potential user in this model has an individual appreciation for the innovation. This appreciation is based on the needs and possibilities of potential users. Company specific factors such as the size of the corporation, the relationship with suppliers, learning costs, switching costs and opportunity costs play a part in determining the appreciation. In the beginning the price of the innovation will be high and only the potential users with the highest appreciation will be served. Subsequently, the price will lower and ever more potential users will proceed to purchase.

The third model comes from the organizational ecology literature and assumes the principle that the S-curved is shaped by two forces, legitimation and competition, which determine the birth and death of corporations. Legitimation is the process through which a new organization establishes its reputation and is accepted. Competition arises when scarcity limits the number of survivors in a certain setting. During the legitimation phase the barriers which thwart new companies disappear and the number of businesses increases. As this period of growth proceeds scarcity will increase on the market and the competition phase sets in. The competition advantage that the new technology gives new users slowly disappears and the diffusion process will eventually come to a halt.

The legitimation-competition model greatly depends upon the number of companies in the market. This principle is too simple to provide a good explanation for strategic behavior. In reality, agents will anticipate on changes in market density and coordinate their actions on this, which will change the market structure.

In practice diffusion curves in general have an asymmetric shape. Every real model should thus take into account the fact that most innovations fail. Concluding Geroski discusses the information cascade model in which at the introduction of an innovation the users have to make a choice between the different versions of the new technology. Making an assessment between the alternatives is risky and expensive in the beginning because only limited information is available about the different variants. So-called early adopters are prepared to experiment and will eventually develop a preference for one of the alternatives. Some factors which can play a part in making the decision are the time of introduction, the effectiveness of the advertising campaign, the price, the quality of the product, the level of service, the presence of a good infrastructure and the enthusiasm of the users in spreading information about the product. This process takes time, which causes the diffusion to go slowly at first. Agents who enter the market at a later time can take advantage of the pioneering work of the early adopters. They can skip the process of extracting information and copy the choice of their predecessors. The presence of network externalities will further strengthen this principle. So a lock-in in one of the variants of the innovation arises. Increasing numbers of potential users will be convinced which creates a bandwagon effect. The speed of adoption will increase until the market is saturated and the diffusion process is finished.

Hall (2004) also gives a short description of the two most famous models, which provide an explanation for the S-shaped innovation diffusion curve. The first model is based on the heterogeneity of consumers and is comparable to the probit model Geroski (2000) discussed. The second model is aimed at the learning ability of consumers and is also known as the epidemic model discussed by Geroski (2000). The heterogeneity model supposes that different consumers have different appreciations for an innovation, which makes them proceed to purchase at different prices. In the learning model consumers have homogenous tastes. They will only buy an innovation when they are informed about it. This causes the adoption to run slow at the beginning and the end and fast in between.

The Bass model (1969) is a famous example of the epidemic model. It supposes that mass media play an important part in spreading information at the beginning of the diffusion process, later on personal communication becomes more important.

Factors that play a Role in the Innovation- and Diffusion Process

Now we have determined that the diffusion trajectory of successful innovations runs along an S-curve, we investigate in this section which elements are important in this process. Many both economical and sociological factors play a part in the innovation and diffusion process. Rogers (1962, 1971, 1983, 1995 and 2003) is the authority for the study into these variables.

Hall (2004) gives a short overview of the five categories in which Rogers (1995) divides the factors which are of influence to the adoption decision on the individual level: the relative advantage of the innovation; the compatibility with the current working methods of the potential user and the social values; the complexity of the innovation; the ease with which the innovation can be tested by the potential user; the ease with which the innovation can be evaluated after the test period.

Subsequently, Hall (2004) sums up the external influences which can speed up or slow down the adoption process as mentioned by Rogers (1995): whether the decision is taken collectively, individually or by a central authority; whether the communication channels which are used to gather information about the innovation are mass media or interpersonal; the nature of the social system of the potential users, the current standards and the level of solidarity; the size of the promotional campaign.

In this section an overview will be given of factors that play a role in the diffusion process of innovations by discussing some recent articles. The division of this section is based on Wejnert (2002). Wejnert establishes a conceptual framework in which the sociological aspects of the diffusion process are investigated by dividing the relevant variables into groups. She distinguishes three main categories: characteristics of innovations, characteristics of innovators and characteristics of the environment. In the category, which encompasses the characteristics of the innovators, Wejnert not only deals with the properties of producers of innovations but actually predominantly with the properties of the users of innovations. This category will thus be renamed in the category which is related to the characteristics of users of new innovations. The categories and external influences mentioned by Rogers (1995) will be taken into consideration throughout the section.

Characteristics of Innovations

First of all the influence of the characteristics of innovation on the diffusion process will be discussed. The following properties will be taken into consideration: the public and private consequences of innovations, the costs and benefits of innovations and the influence of the scope and degree of radicality of innovations.

In Wejnert's (2002) analysis the component of the characteristics of innovations encompasses two sets of variables. First of all she makes the distinction between the public and private consequences of innovations. The diffusion of innovations, which have public consequences especially, takes place when the relevant information is distributed uniformly over the entire application area and there is a broad social basis. The media can play an important role in the diffusion of such innovations. Geographical proximity and the pressure from social networks are important drivers for the diffusion of innovations which have a private impact. Public and private consequences do not necessarily have to be in contradiction with each other.

Subsequently, Wejnert discusses the influence benefits and costs have on the adoption process. Direct costs are costs which relate financial risks directly to the innovation. Indirect costs are costs and uncertainty which can be reduced less clearly. They also do not always have a monetary nature. Both types of cost delay and limit the diffusion process.

Hall (2004) remarks that the diffusion speed can differ greatly per innovation. Subsequently, he gives an overview of the factors which play a role in the adoption of an innovation. He makes a division into four categories: factors that influence the benefits of innovations, factors that influence the costs of adoption, factors that are related to uncertainty and information problems and factors that are connected to the influence of the environment. The two categories mentioned first will be discussed in the first part of this section whereas the two categories mentioned last are taken into consideration in the second and third part of this section. Concurringly with Wejnert (2002), Hall starts with the discussion of the influence of the costs and benefits of innovations on the diffusion process.

The most important benefit of the adoption of an innovation, according to Hall, is the improved performance of the new technology with respect to the old technology. This effect diminishes as better substitutes enter the market. Another delaying factor in the adoption process is the fact that new innovations often do not yet have their definitive form on the moment of diffusion as a result of which the difference in performance with the old technology will be relatively small at the beginning of the diffusion. People learn how to handle the innovation during the diffusion process. Thanks to consumer feedback producers are able to introduce improvements to the original innovations during this phase. The maximum number of potential users will not be reached and the diffusion process will not take of until the definitive model is on the market. Another factor keeping the difference between the old and the new technology relatively small at the beginning of the diffusion process is the phenomenon that old technologies which are about to be replaced after years of stagnation suddenly are able as a last resort to introduce significant improvements to their product. This argument will be elaborated on in section 5.8 in which the findings of Utterback are discussed.

Status can also be important for the diffusion of an innovation. Telis, et al (2002) for instance state that the diffusion of status increasing products, such as durable consumer goods in the fields of entertainment and information provision, takes place remarkably faster then the diffusion of household products.

Finally also network effects play an important role in determining the benefits of a new innovation. The value of the new technology compared to the old technology is often co-determined by the extent to which other consumers use the product. A direct network effect is the necessity of other consumers to be able to use the product. This is the case for instance for communication devices. Indirect network effects mean that the development of additional products, such as software, depends upon on the presence of a large number of customers.

Different factors determine the costs of adoption. The most noticeable factor is the purchase price. This can be considered as sunk cost expense. So-called sunk costs are costs which are paid for at the beginning of the adoption and cannot be retrieved later on. The influence of these costs on the diffusion process is twofold. First of all sunk costs are responsible for potential users to postpone their decision to proceed to adoption in a situation of uncertainty until they have enough information to be able to make a good assessment. After all they would like to limit the risk to invest the sunk costs into the wrong innovation as much as possible. Besides that sunk costs prevent almost certainly that consumers will fall back to the old technology once the adoption of a new innovation has started. The expenses made by then are already so large that it is almost impossible for the net benefits of a return to the old technology to surpass them.

Forward-looking enterprises will also take into account the costs of the use of the innovation into their decision whether to proceed to purchase or not. These can after all amount to a considerable sum and will in some cases even greatly surpass the purchase costs. Certain innovations namely need physical input in order to be able to function and employees will have to learn how to handle the new technology. In some cases, it is also necessary to adapt existing processes in order to be able to fit in the new innovation. Moreover when the investment is externally financed interest will have to be paid over the loan.

The last property of the characteristics of innovations which will be discussed here is the influence of the degree of radicality and scope of an innovation on the diffusion process. Lee, Smith and Grimm (2003) have done empirical research after the effect the degree of radicality and scope of new innovations has on the number of imitators and the speed of diffusion. They suppose that a larger degree of radicality makes it more difficult for potential users to gather information about the innovation which will increase the level of uncertainty and thus slow down the speed of diffusion and limit the number of actors who are prepared to proceed to purchase. The scope of the innovation concerns the number of potential users. Lee, Smith and Grimm create a second hypothesis in which they state that when an innovation has a larger scope this means that more information about the innovation will be available. The imitation bandwagon effect will increase because of this. More potential users will buy the innovation and the diffusion will go faster.

The hypothesis with regard to the influence of the degree of radicality on the diffusion process of a new innovation is rejected by Lee, Smith and Griffen. It appears that the more radical an innovation is, the larger the number of imitators will be and the faster the diffusion process will proceed. A possible explanation for the found relationship could be that certain companies find the information about radical innovations so difficult to comprehend that they are not able to make a rational purchase decision for themselves. Out of fear of being left behind by the competition which already made the transition they will then blindly proceed to purchase.

The scope hypothesis is at least partially accepted. The size of the scope of the innovation does indeed have a positive effect on the speed of diffusion.

Characteristics of Users of New Innovations

The influence of characteristics of users of new innovations on the diffusion process will be discussed secondly. The following properties will be taken into account: the societal entity of the users, the familiarity of the users with the innovation, the status characteristics of the users, de socio-demographic characteristics of the users, the position of the users in their social network, personal characteristics of users, the size of the user and the type of sector to which to user belongs.

This part again starts with Wejnert (2002). The component of the characteristics of innovators encompasses six sets of variables. Wejnert discusses for this component first the effect the societal entity of the adopters has on the diffusion process. Individuals, small groups and large groups each focus themselves on a different type of innovation and gather their information differently.

The familiarity of the user with the innovation is related to the degree of radicality. The more radical an innovation is, the larger the uncertainty perception will be and thus the lower the adoption speed will be. Information gathering via the media and especially via social networks can counter act this delaying effect by enlarging the familiarity of potential users.

The status characteristics of a potential user relate to the relative position of an actor within a population of actors. This position depends upon the personal social status and the degree of homogeneity of the social network of an actor. High status persons in general are the first to proceed to purchase a new innovation. The higher the status of the first adopters and the more homogenous the network, the bigger the chance is for a fast adoption. With controversial innovations it can however be that high positioned people are not willing to put their reputation at stake by behaving non-conformistically so that persons with a relatively low status will be the first to proceed to purchase.

Economical and socio-demographical factors of the persons themselves, next to environmental factors, also have a large influence on the degree of probability of adoption.

The position of an actor within his social network is determined by looking at his interaction with other individuals in four different spheres. The first sphere encompasses the interpersonal networks of individual actors. In this sphere the degree of solidarity of the network and the degree of openness with respect to new information are determining the adoption speed. The second sphere consists of the organizational networks for collective actors. Horizontal and vertical channels influence diffusion here. The former channel encompasses the influence top managers of competing companies have on the diffusion process. Managers with a comparable background generally seem to adopt the same innovations. Vertical channels encompass the top-down information stream within an organization. As an organization is more centralized the vertical influence will increase and the adoption will go faster. The third sphere consists of the structural equivalence of individual and collective actors or the perception of the relative position of the network of an actor with respect to that of other actors. The structural equivalence of an actor is determined by demographic, social and cultural factors. The structural equivalence of collective actors is formed by economic, cultural and behavioral factors. The smaller the differences in structural equivalence are, the more homogenous the composition of the population will be and the faster the adoption of an innovation will proceed. The fourth and last sphere is the social density and encompasses the number of actors within a network that already have proceeded to purchase. The risk perception of the non-users will decrease as more people in the network use the innovation. They will thus also proceed to purchase sooner.

Personal characteristics of actors such as self-confidence, the degree of independence and the degree of risk-aversion are partly formed by society and can be determining for the adoption decision.

Wejnert’s (2002) analysis predominantly focuses on individual users. Hall (2004) and Freeman and Soete (1997) specifically focus on companies. Hall (2004) remarks that large corporations generally speaking proceed to adoption sooner. An explanation for this observation could be that large dominant corporations are able to spread the costs over many units. Satisfaction with the status quo, on the other hand, may withhold them from implementing new innovations. According to Hall empirics prove that the first argument is the most determining.

Freeman and Soete (1997) discuss the relationship between R&D and the innovative behavior companies. They observe an order and a subdivision in the adoption of technologies by companies. A new basic technology will in the beginning mostly find applications in fast growing sectors in which investments are high and there is a greater acceptation of innovations. The second group of companies who will intensively use the new technology are those in which the subsystem to which the new technology belongs constitutes a substantial part of the production costs and where the required skills to handle to new technology are already available or could be obtained rapidly. The third consists of innovative companies who have growing market expectancies. In older and slow growing sectors within the economy it takes very long before the new technology is implemented.

Characteristics of the Environment

Finally the influence of characteristics of the environment on the diffusion process will be discussed. The following properties will be taken into account: the geographical setting, the societal culture, the political situation, globalization and information uncertainty.

The component in Wejnert's (2002) research which encompasses the characteristics of the environment consists of four sets of variables. For this component she describes first the influence which the geographical setting can have on the diffusion process. The local applicability of an innovation is strongly influenced by the specific environmental characteristics. The ecological infrastructure and the geographical distance are two relevant factors of this variable. The former, for example, includes the characteristics of the climate and the weather. The geographical distance is determining for the spread of information, among other things via the formation of local networks, spillovers, local externalities, local lock-ins and local bandwagons. The larger the geographical distance, the smaller the chance of adoption.

The societal culture also plays a role in the adoption process. The standards and values, religion, language and degree of cultural homogeneity within a society can be very determining for the acceptation of an innovation.

The political situation in an area can also be of influence on the diffusion of an innovation. The political system, regulation and degree of bureaucracy all are factors that can speed up or slow down the process.

Finally Wejnert discusses the influence of globalization on the adoption process. Institutionalization, the spreading of technology and modern communication devices, connects ever-increasing parts of the world and creates a certain degree of homogeneity. The diffusion of new innovations will go faster and on a larger scale as long as globalization perseveres. This development however will not be executed without any opposition. The resistance which this process of globalization encounters may lead to the withdrawal of certain actors and possibly even of whole areas.

Finally Hall's (2004) last two factors will be taken into account. The factor which encompasses uncertainty and informational problems will be discussed first and the factor which occupies itself with the direct influence of the environment last.

Hall states that companies have to be informed about the existence of an innovation and have to have certain information concerning the properties before they can make the assessment whether or not to adopt the technology. The diffusion will go faster as the information uncertainty in a market is smaller.

The environment of a company can, according to Hall, also have a substantial influence on the speed of adoption. Knowledge about consumer preferences can speed up the diffusion. Even so, the market structure, the legal legislation and cultural and social factors can influence the adoption decision.

General Purpose Technologies

Brashnahan, Helpman and Trajtenberg developed a growth model which is driven by successive improvements in General Purpose Technologies (GPTs). Helpman and Trajtenberg (1994) state that GPTs are innovative input factors that can be applied to a broad spectrum of sectors and are able to bring about substantial productivity growth. Their influence stretches out over the entire economy. Remarkable is that GPTs have an incubation period with slow or even negative growth. The diffusion will only take off when sufficient complementary applications are available to achieve better results than is possible with the old GPT. GPTs keep on developing themselves after their introduction. As long as the demand for a certain GPT rises more complementary innovations in user sectors will be developed which will lead to an even further rise in demand. This is how a positive spiral arises which spreads the GPT throughout the whole economy. The rise of a new GPT will eventually make the old GPT redundant. Examples of GPTs are the steam engine, electricity and micro-electronics. Although the GPT concept was developed independently of the long wave field it shows many similarities with the basic innovation from the long wave discussion.

Utterback

One of the most important authors in the research area of innovations is James Utterback. In this section there will be an elaboration on his ideas concerning the innovation process and a concluding section in which the commentary of other others on these thoughts will be discussed. Utterback (1994) distinguishes in his book “Mastering the Dynamics of Innovation” two types of industry based on the number of steps in the production process. Markets in which the production process consists of many steps are called market for assembled products. Industries in which the production process consists of few steps are defined as markets for non-assembled products.

The innovation process in the market for assembled products can according to Utterback be divided in two parts. The first part is characterized by unrest. Small entrepreneurial companies compete on the basis of product innovations. Eventually after this turbulent period the market will stabilize when the dominant design is announced.

The dominant design is the design which sets the standard in the market: “the design in a product class that wins the allegiance of the marketplace, the one of competitors and innovators must adhere to if they hope to command a significant market following.” Utterback declares that the process of the formation of a dominant design is not fixed in advance: “the emergence of a dominant design is not necessarily predetermined, but is the result of the interplay between technical and market choices at any particular time.”

In markets for assembled products, according to Utterback, radical innovations which eventually will lead to the development of a dominant design are predominantly introduced by new companies or already existing corporations who enter a new market. This does not diminish the fact that most radical innovations are based on old technologies. Innovations are often a combination of design elements of older products or prototypes. They are a synthesis of technologies.

Relative outsiders have less to lose in a market in which they are not active themselves. They are thus, sooner than insiders, who have a far less flexible cost structure, willing to take risks with new radical innovations: “Industry outsiders have little to lose in pursuing radical innovations. They have no infrastructure of existing technology to defend or maintain and, (…), they have every economic incentive to overturn the existing order.”

There are numerous reasons why insiders in assembled product industries mostly limit themselves to incremental change. Incremental changes can, at least in the short run, be very profitable. Companies often develop path dependent.

Companies often develop path dependent and thus experience difficulties in changing to a radical new technology. Radical changes simply bring about to many costs. Businesses can also focus on incremental innovations because their customers have to deal with high switching cost and thus, at least in the short run, will not be prepared to change to a new product. When this is the case, insiders want to protect their market shares and only carry out incremental changes. Furthermore insiders are often corporations who carry the responsibility for many shareholders. In order not to put their interests too much at stake these companies will behave relatively risk-avers. Established businesses often have a managerial culture which, in contrast to the more adventurous entrepreneurial culture, also leads to risk-avers behavior.

The invasion of a radical innovation will trigger a sudden outburst of improvements in established products. When established companies are threatened by a new superior product they all of a sudden, often after years of stagnation, are able to make substantial improvements in the product design: "Purveyors of established technologies often respond to an invasion of their product market with redoubled creative effort that may lead to substantial product improvement based on the same product architecture."

Eventually, it also becomes clear for insiders that the change to the radical new product or production process in inevitable. However, it happens regularly that these established corporations do see the necessity of change but are unable to let go of their old products. They develop a hybrid form which in the short run can possibly make a profit but is destined to fail in the long run: "Bridging a technological discontinuity by having one foot in the past and the other in the future may be a viable solution in the short run, but the potential success of hybrid strategies is diluted from the outset compared to rivals with a single focus." When only a small number of companies remains in the market of the old product these businesses can possibly survive as niche producers.

When the dominant design finally arrives the time of experimentation is over and the phase of incremental change starts. Only a few companies will be able to make the change: "Once the dominant design emerges, the basis of competition changes radically, and firms are put to tests that very few will pass." Businesses will no longer have to focus on product innovations but predominantly on process innovations. Competition will no longer be based on innovative product designs but on costs, economies of scale and product performance. Standardization will be stimulated. The market will, during this phase, be populated by large, vertically integrated corporations.

The production process of non-assembled products consists of much fewer steps than that of assembled products. For non-assembled products process innovations are logically relatively much more important than product innovations. After all, substantial productivity gains and thus lower costs per unit can be realized by removing a step from the production process or by improving one. For non-assembled products the dominant design is thus not determining for the competition advantage and the focus lies on radical changes in the process architecture, the so-called enabling technology: "New process architecture represents a discontinuous productivity advance – in the first case because of the entire elimination of a process step; in the second case because the new production technology is inherently more efficient."

Important radical innovations for non-assembled products predominantly come from insiders. The required investments in markets for non-assembled products are often so large that these can only be profitable for companies which are already active in the market. The arrival of a new enabling technology can be seen in advance, in contrary to the dominant design, which can only be identified in retrospect.

Reactions to Utterback

Billington and Flemming (1998) do not agree with Utterback (1994) and state that the period of incremental change can also lead to fragmentation of the supply chain and a decrease in the concentration of the number of companies in the market. The use of standard interfaces in the design of the dominant design is responsible for this development.

Barras (1986, 1990) follows Utterback (1994) and remarks that the development of a dominant design in a market can accelerate the diffusion of the technology considerably. Furthermore, he also recognizes that this process stimulates standardization and will generate economies of scale which eventually will be responsible for the companies in the market being in a technological lock-in: "The result of such standardization is the tendency for the technological trajectories of different firms within an industry to converge towards one or more ‘dominant designs’ which dictate the subsequent form of the applications that are pursued." While such standardization may considerably speed up the diffusion of a particular innovation, the corollary is that the scale economies it generates can become irreversible, creating a tendency towards technological ‘lock-in’ which may be difficult to escape.”

Barras nevertheless differs from opinion with Utterback regarding the order in which process and product innovations take place. Utterback’s product life cycle approach states that product innovations precede process innovations whereas Barras’ reverse product life cycle theory claims the opposite.

In the discussion between Utterback and Barras von Tunzelmann (2001) follows the latter. He states that General Purpose Technologies develop in the order assumed by Barras: “But these ‘general purpose technologies’ spread to new applications, a range of new products followed in their wake, in ways I have already briefly touched upon. Hence industrial revolutions involved first a revolution in processes and then a revolution in products.”

Conclusion: Innovation and Diffusion

By exploring the ideas of non-long wave researchers about the diffusion process more and better insight in the subject has been obtained. The role of innovation in the various macroeconomic theories has been studied which revealed the similarities and differences in the treatment of technology with the long wave supporters. Theories have been explored which can explain the development of the S-shaped diffusion curve and the various economic, sociological and psychological factors which play a role in the adoption decision of individual potential users of an innovation which enabled the reader to develop a richer picture of the complexity of the innovation and diffusion process than was possible within the aggregated context of the long wave in Chapter 2.

It can be stated that the discussion about the placement of the cluster of basic innovations (see Chapter 2 and see Chapter 3.3) in the long wave scheme seems to be in accordance with the difference in insight between, on the one hand, the supporters of the supply push theory and,on the other, those of the demand pull principle. The ones that position the cluster in the depression phase before the long wave minimum use the supply push argument that technology drives economic developments. The researchers who place the cluster in the upswing phase after the minimum follow the demand pull principle that the breakthrough of the innovations is triggered by demand.

Evolutionary economists, such as Nelson and Winter (1977), Dosi (1982) and Sahal (1983) introduce concepts such as natural trajectory, technological trajectory and technological guidepost. The diffusion of innovations runs, according to them, along relatively stable paths, which can give a possible explanation for the clustering of innovations.

In this chapter various names have been used for innovations which have a great impact on their sector and sometimes even on the whole economy and society. Looking at the independently developed theories of Helpman and Trajtenberg (1994) and the long wave authors it can be said that the concepts of General Purpose Technologies and basic innovation overlap. GPTs have many similarities with the ideas of Freeman and Perez. Basic innovations in assembled product sectors on industry level within the context of Utterback's (1994) analysis are radical competence destroying innovations.

The questions with regard to the clustering of basic innovations within the framework of the long wave which have been asked in Chapter 2.4.4 and in Chapter 3.3 have not been explicitly answered, however. A possible explanation for this can be that the macro- and micro-economists which have been discussed in this chapter are more focused on individual innovations and diffusion trajectories than the long wave researchers who look at the subject matter on a much larger timescale and are predominantly interested in the pattern which arises when the diffusions of many innovations are seen in time. Only Geroski and Walters (1995) explicitly discuss the clustering of innovations in their research after the influence of demand on the moment of diffusion.

Appendix B: Eviews Program

```
'Eviews program to estimate the parameters of a mixture of 3 normal distributions with the
same variance using Maximum Likelihood.

'Declare coefficients to use in maximum likelihood
coef(2) b
coef(3) mu
coef(1) sig

' specify log likelihood function for 3 component mixture model
logl mixt
mixt.append @logl loglik

mixt.append prob1=exp(b(1))/(1+exp(b(1))+exp(b(2)))
mixt.append prob2=exp(b(2))/(1+exp(b(1))+exp(b(2)))

mixt.append lcomp1=-0.5*log(2*3.14159265)-0.5*log(sig(1)^2) -0.5*((y-mu(1))^2)/sig(1)^2
mixt.append lcomp2=-0.5*log(2*3.14159265)-0.5*log(sig(1)^2) -0.5*((y-mu(2))^2)/sig(1)^2
mixt.append lcomp3=-0.5*log(2*3.14159265)-0.5*log(sig(1)^2) -0.5*((y-mu(3))^2)/sig(1)^2

mixt.append  loglik=log(prob1*exp(lcomp1)+prob2*exp(lcomp2)+(1-prob1-
prob2)*exp(lcomp3))

param sig(1) 4
param mu(1) 5
param mu(2) 13
param mu(3) 55
param b(1) 0
param b(2) 0

' estimate by MLE
mixt.ml(d)
show mixt.output

genr fitprob1=exp(b(1))/(1+exp(b(1))+exp(b(2)))
genr fitprob2=exp(b(2))/(1+exp(b(1))+exp(b(2)))

genr fitlcomp1=-0.5*log(2*3.14159265)-0.5*log(sig(1)^2) -0.5*((y-mu(1))^2)/sig(1)^2
genr fitlcomp2=-0.5*log(2*3.14159265)-0.5*log(sig(1)^2) -0.5*((y-mu(2))^2)/sig(1)^2
genr fitlcomp3=-0.5*log(2*3.14159265)-0.5*log(sig(1)^2) -0.5*((y-mu(3))^2)/sig(1)^2

genr fitpdf=(fitprob1)*exp(fitlcomp1)+(fitprob2)*exp(fitlcomp2)+(1-fitprob1-
fitprob2)*exp(fitlcomp3)

genr condprob1=fitprob1*exp(fitlcomp1)/(fitpdf)
genr condprob2=fitprob2*exp(fitlcomp2)/(fitpdf)
genr condprob3=(1-fitprob1-fitprob2)*exp(fitlcomp3)/(fitpdf)
```

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The multiple cycle approach is also applied to the Dutch economy. On the basis of a 5 and 11 year cycle present in the Dutch Gross Domestic Product (GDP) a long term forecast model is developed. At the same time a new real time indicator, also known as *"nowcast indicator"*, of Dutch GDP is developed. This indicator serves as a thermometer of the Dutch economy and is called the *"Econometric Institute Current Indicator of the Economy"* (EICIE). In contract to most other forecast models, which are much larger, this forecast model is based upon a single equation. The model is based on a single explanatory real variable, namely staffing data from Randstad Staffing Services.

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