UNIVERSITY OF SOUTHAMPTON

LONG CYCLES
with particular reference to Kondratieffs

(2 volumes)

Volume I

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Thesis submitted for the qualification of Doctor of Philosophy.
MANAGEMENT SCHOOL, FACULTY OF SOCIAL SCIENCE.
1995

UNIVERSITY OF SOUTHAMPTON
ABSTRACT
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LONG CYCLES
with particular respect to Kondratieffs
by GAYNOR MARGARET DAVIES

This thesis examines and evaluates long cycles, particularly those referred to as Kondratieffs, 47/48-60 year cycles named after the Russian economist, Nikolai Dmitrievich Kondrat'ev. The earliest long cycle theorists: the Trail-Blazers are reviewed and evaluated. Kondratieff's characteristics of long cycles are appraised, particularly the feature he identified as inventions which continues to capture long cycle researchers' interest in the 1980s-90s. The literature findings were inconclusive regarding the existence of Kondratieffs: Forrester (1978) was supportive, van Duijn (1983) found the cycles varied much in length, Kleinknecht (1987) referred to them as alleged cycles, Kindleberger (1989) called them dubious and elusive. Solomou (1987) dismissed their existence completely but Reijnders (1990) did not regard Kondratieffs as being illusory.

Given the contradictions in the literature, the hypothesis of this thesis is that Kondratieffs do not exist. Also because of the inconsistencies, careful consideration has been given to the modelling to be used to investigate for long cycles. The approach has been to construct a framework drawing on various research methodologies, allowing for 'scientific-seeing' to take place, adopting a heuristic approach and allowing for periodicity. The heuristic approach provides a model with a negative heuristic, assumptions which are core to the model, and a positive heuristic of auxiliary assumptions to allow flexibility only insofar as to facilitate the working of the model. Spectral modelling over a frequency domain was adopted as the most suitable method to allow for periodicity in the data, an approach which has no predisposition to any particular cycle length, rather than an autoregressive framework coloured by filters.

The study differs from other long cycle studies by using much longer series of empirical data, at least covering 10 potential long cycles, should Kondratieffs exist. The time series cover periods from almost 500 to 837 years. Also, the study differs by using data other than Kondratieff's, particularly non-price time series. Tin production especially has undergone changes in use and exploitation, the other series are population and battle fatalities. The study finds that the hypothesis that Kondratieffs do not exist cannot be fully accepted. There are some weak findings of long cycles across the data within the broad band of 48-60 years. It however finds stronger evidence of long-intermediate cycles centred at 26 years, ranging 23-29 years and very weak evidence of medium-term cycles 11-13 years.

ACKNOWLEDGEMENTS

I would like to thank Professor Bob Ryan who supervised the research, and for the motivational support he supplied. I would also like to express my appreciation towards the doctoral committee at the Southampton University Management School, members Dr John Axford, Ms Alison Price, Dr Steve Thomas and Professor Ryan as Supervisory Examiner. My thanks also to Dr Chris Skinner, Ms Padmini Kurukulaaratchy and Mr Andrew Clare. I am grateful for the support of the University of Brighton to enable me to undertake the research.

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THE INTRODUCTION

Why Kondratieffs?

Some city practitioners, for example, commodity advisors, refer to long-term economic movements which affects markets, as Kondratieff cycles. They even suggest that short- and medium-term cycles (which they term as seasonal) may be exacerbated by the synchronicity of a long-term cycle. A typical comment made by a commodity advisor, Bernstein (1989)[1] sums the situation thus:

> *"when seasonal cycles get in sync with long-term cycles, the force can be powerful."*
>
> *Bernstein (1989), President of Mbh Commodity Advisors*

The basis for the assumption regarding a long cycle is not entirely clear.

Extensive studies have been carried out on business cycles, the shorter- and medium-term cycles, with relatively little investigation on the long cycles. This thesis therefore focuses on, and evaluates the lesser studied long cycles. Particularly those referred to as Kondratieffs, the 47/48-60 year cycle named after the Russian, Nikolai Dmitrievich Kondrat'ev, known in the West as Kondratieff.

Initial background to Kondratieff:

Who was Kondratieff, whose name continues to be linked to long cycles? Kondratieff, born 100 years ago, was more than just an agricultural economist in his native Russia. He was a principal leader of the narodniks and the TKP, during the 1910s, when the Russian socialist movement split into broad camps: the Bolsheviks and the rest, the nonconformist groups. He had a leading role in the TKP or Labour-Peasant Party (Trud meaning Labour), one of the nonconformist groups. In 1917, Kondratieff's

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[1] Bernstein, Jake, "Futures" June 1989

political interest was such that it led, at age 25, to his becoming Deputy Minister of Food in the short-lived Provisional (Kerensky) Government following the February Revolution of that year. About 1919, Kondratieff became Director of the Conjuncture Institute (the Moscow Research Institute) and produced studies of agricultural economic interest. Kondratieff commenced the Economic Bulletins from about 1922, publishing domestic and international economic indicators. This meant that peasant farmers were readily able to identify the massive increase in agricultural output demanded by the authorities, and further, that the farmers were receiving lower prices in the face of rising costs of production. It was probably this work which ensured that anything Kondratieff published would be condemned as counter-revolutionary sabotage. The Conjucture Institute was closed down, along with the Economic Bulletin in 1928. There is some uncertainty surrounding his death.

Structure of the thesis

The originality of this thesis is particularly in the breadth and comprehensiveness of the literature review on long cycles, the development of very long data series which varies 3-5 times longer than Kondratieff's original series and the application of spectral modelling to the empirical data.

Chapter 1 reviews some broad categories of cycles, those of shorter lengths, varying from 3.5-25 years. This is intended to represent an overview only, as the thrust of the thesis is *long cycles*. In the literature review in Chapter 1, a section covers some very old ideas of cyclical fluctuations, harvest theories. The harvest theories developed by Jevons (1878) are included because of the agricultural element, Kondratieff identified agricultural changes as one of the passive manifestations of long cycles. Although the short- to medium- cycles are outside the scope of the thesis, the lengths of cycles identified by Jevons and Juglar (1852,1889) are consistent with very weak findings in the spectral modelling of the long data in this thesis. The literature search in Chapter 2 reviews and evaluates the earliest long cycle theorists: the Trail-Blazers with particular reference to the work of Kondratieff whose enduring link with long cycles continues to the 1990s. Some political perspective at the time of Kondratieff's formulation of long cycles is included. This provides a setting for the political climate at the time, which in some way explains the condemnation his work received inside the Soviet Union. His writings were set out in a number of articles and responses, so a section trails the developments. Kondratieff's methodology and statistical findings are gathered together from these trails. Chapter 3 evaluates the characteristics or empirical patterns in long cycles identified by Kondratieff, particularly the characteristic he referred to as inventions, and which continues to capture long researchers' interest in terms of inventions and innovations, particularly their clustering or non-clustering. Chapter 4 reviews selected research methodologies, and in the light of this, Chapter 5 identifies the methodological approach to modelling long cycles in the thesis, which is a heuristic approach. The negative heuristic identifies the core assumptions and the positive heuristic provides the flexibility to facilitate the modelling in the long cycles investigation. Chapter 6 examines and evaluates the data, where the data selected is to potentially run over 10 long cycles, should Kondratieffs exist. Chapter 7 draws together the actual modelling used to investigate for long cycles: the First and Second Stage Modelling via regression analysis and spectral modelling, with various sized kernel windows modelled over a frequency domain from 0 to π. Chapter 8 reports and evaluates the results from the spectral analysis of the long data of tin production, population and war (battle fatalities).

Recurring interest in long cycles:

A review of the literature suggests that interest in long cycle theories revives and recurs in long cycles *itself*, 1870/80s (very briefly), 1920/30s and 1980/90s. Further, that, should Kondratieffs exist, then researchers' interest appears to coincide with long downswing or depressions. Interest in long cycles can be traced back to the nineteenth century, and was first noted by an Englishman, Dr Hyde Clark (1838) writing in Herapeth's Railway Magazine, a commercial journal-cum-scientific review, he stated:

> *".. my impression that the period of speculation was a period of ten years, but I*

was led also to look for a period of thirteen or fourteen years.... I was led to look for a larger period, which would contain the smaller periods, and as the present famine and distress seemed particularly severe, my attention was directed to the famine so strongly felt during the French Revolution. ***This gave a period of about fifty-four years****, with five intervals of about ten or eleven years each"*

Hyde Clark (1838)

Schumpeter's (1939 pp 169, 173), schema of cycles identified three classes of cycles: Kondratieffs, Juglars and Kitchins. He suggested 3 Kitchins per Juglar, 6 Juglar cycles per Kondratieff. Van Duijn (1983) found if he took an average length for the Kondratieff as 54 years, Kuznets as 18, Juglar as 9 and the Kitchin as 4.5 years, he rather neatly suggested:

"1 Kondratieff = 3 Kuznets cycles = 6 Juglars = 12 Kitchins."

Van Duijn (1983) p 6

Kondratieffs are of particular interest because such long cycles may relate to major technological changes such as the Industrial Revolution, the Developments of the Railways, the Motor Car and Information/Communication industries. For the other cycles, Kuznets relate to generational population changes and the house-building industry, Juglars relate to fixed investment, in particular, plant and machinery, Kitchins short cycles relate to working capital changes, in particular, stocks (inventories).

The essence of long cycles:

The essence of Kondratieff's theory of long cycles is this: that capitalist production is characteristic of long upswing and downswing phases, that major changes precede the long upswing, in what he described as changes in inherent, endogenous factors. These are inventions, wars, gold production and colonialism. Kondratieff's theory rests upon explaining changes in various endogenous factors being characteristically "passive manifestations" of long cycles. The Dutch School identified the importance of inventions in economic fluctuations as far back as 1913, with van Gelderens. Current theorists in the 1980s-1990s, like Mensch, Forrester, van Duijn, Kleinknecht, Freeman and Solomou and others continue to do so. Kondratieff found inventions and the development of new techniques occurred more frequently in the long downswing but remained unexploited until the long upswing commenced, that discoveries were placed on "hold", until the time was right for exploitation. Kondratieff argued:

> *"During the recession of the long waves, an especially large number of important discoveries and inventions are made, which, however, are usually applied on a large scale only at the beginning of the next long upswing."*
>
> *Kondratieff (1935/25) p 111*

Kondratieff concluded:

> *"on the basis of the available data, the existence of long cycles (waves) of cyclical character is very probable."*
>
> *Kondratieff (1935/25) p 115*

The contradictory long cycle hypothesis and the implications for the modelling in this thesis:

Kuznets (1930) hesitated to accept the hypothesis of long cycles because of the dearth of long data, and expressed concern:

> *"the data seem(s) to be too scanty (only two complete "cycles" are in the series) for an empirical generalization to be of great weight. .... [and the] absence of factors that would explain the periodicity"*
>
> *Kuznets (1930) p 264*

Thus the data in the thesis is chosen not only for the socio-economic implication but differs from other studies by the *longevity* of the data gathered. The timespan of the data varies from almost 500 years to 837 years, with concentration on non-price series, and not value or price series which are prone to cyclicality anyway. Kleinkecht (1987) referred to approximately ten cycles of data being a necessary pre-requisite for spectral modelling.

Dewey (1971) commented:

> *"A new science which deals with the behaviour of events recurring at reasonably regular intervals throughout the universe may ultimately enable us to predict, scientifically and accurately, the events of tomorrow."*
>
> *Dewey & Mandino (1971) p 2*

Regarding the existence of Kondratieff long cycles, Van Duijn (1983) found:

> *"The lengths of cycles vary considerably and so does their severity. Yet they are self-repeating."*
>
> *Van Duijn p 3*

Forrester (1978) found support for:

> *"the 50-year repeating rise and fall in economic activity .... Kondratieff cycle ... There seems to be an alternating tide in economic affairs, spanning some 45 to 60 years, that determines the climate for innovation."*
>
> *Forrester (1978) p 127*

Kleinknecht (1987) conceded to the general agreement on its being called the "Kondratieff long wave" but still referred to it as:

"the alleged 45-60 year cycle"

Kleinknecht (1987) p 2

Solomou (1987) was quite dismissive of long cycles, he could not find regular Kondratieffs and did not believe them to exist. Kindleberger (1989) referred to Kondratieffs as:

"the more dubious and elusive ....cycle"

Kindleberger (1989) p 17

However, Reijnders (1990) stated it had:

"several promising features.....it presents a periodization of economic history....for relating distinct epochs and comparing them within in a unified framework."

and with some qualification:

"the Kondratieff wave cannot be regarded as an illusion. There is substantial evidence to the contrary which demonstrates that long waves of the Kondratieff type do exist."

Reijnders (1990) p 241

Given the contradictions found in the literature review regarding the existence of Kondratieffs, the data modelling and analysis in the thesis is undertaken under the hypothesis that in fact, no long cycles of 47/48-60 years described as Kondratieffs, exist in socio-economic life.

Another major problem that came out of the literature regarding the contradictory findings is the inconsistency in the methodologies of dealing with the trend(s) underlying long cycles. Incorrect elimination of trends can remove cycles or cause non-existent ones to appear as or within long cycles. In this thesis, regression analysis is still the preferred choice over other methods of moving averaging. However, because of the trend problem, both the raw and log data, without any prior regression, are also subjected to spectral modelling as part of the long cycle investigation in the thesis.

Spectral modelling was chosen because of its flexibility in periodicity and that it fulfils the criteria of the heuristic approach to modelling long cycles, the approach adopted in the thesis. Spectral modelling is a useful approach in dealing with an additional problem in the research, which is, should the data display cycle lengths which are nonperiodic then the average cycle length is not going to be readily identifiable by standard cyclical analysis. A further argument for the occurrence of nonperiodicity is the recognition that the natural state is far from the equilibrium state as traditionally viewed in economics, even allowing for Schumpeter's neighbourhoods of equilibrium or Kondratieff's "mobile" one. Chaos theory in the 1990s recognises the system is never in equilibrium. Peters (1991):

> *"if we look at the ecology of a living world.....we see that nature abhors equilibrium."* ... [and] ... *"Equilibrium implies a lack of emotional forces, such as greed and fear, which cause the economy to evolve and to adapt to new conditions....the far-from-equilibrium conditions (that) are necessary for development. Equilibrium in a system means the system's death."*
>
> *Peters (1991) pp 4,5*

Peters (1991) argued, albeit in relation to chaos theory, economics and capital markets, but the point is eminently valid:

> *"In any science, there come times when the existing paradigm raises more questions than it answers. At those times, the need for a new way of looking at the old*

problems becomes clear. Capital market theory and economics in general are now coming to that point. For some time, the conditions necessary to justify the use of most of our traditional analytical methods have, in general, not existed. It is time to examine alternatives."

Peters, (1991) p 201

In any time series, the statistical distribution may not change, there may be little variation in the critical state however, there are erratic signals at the edge of stability which again leads to a nonperiodic cycle. For instance, Bak & Chen (1991)'s (see Peters (1991) p 207) illustration of sand castles, with one grain of sand being added to the pile at a time where they concluded that the probability of a landslide or no landslide was about the same. Therefore again, spectral modelling is the preferred choice. It allows for some *fluidity in the periodicity of cycles* which may well be necessary in order to identify or dismiss long cycles. Rather than try to locate the peaks and troughs, which are shifting anyway, and thereby contribute to inconsistency in any findings, the thesis applies spectral analysis. Thus, through the means of spectral modelling, there should be sufficient fluidity to allow a broad periodicity to cycle lengths, thereby aiding the identification or dismissal of long cycles occurring within a frequency range.

CHAPTER 1

LENGTHS OF CYCLES AND CYCLE THEORIES

1.1 INTRODUCTION

The raison d'etre of this thesis is long cycles. The intention of this section is to identify and acknowledge in broad terms some of the shorter cycles which may/may not be underlying trends in the potentially longer cycles. This section also discusses the contribution of those early theorists whose investigations of cyclical theory has led to their enduring association to specific cycles. The long cycle theorists especially Kondratieff, are reviewed and evaluated in more depth in the subsequent sections.

The most widely known cycles are Kondratieffs, Kuznets, Juglars and Kitchins, named after the theorists who identified the length of cycles through investigative research. The findings equate to cycles, respectively:

Table 1.1 Summary of most widely known cycles:

CYCLE NAME	CYCLE LENGTH	CYCLE TYPE
Kondratieffs	48-60 years *(long-term)*	Major technological changes.
Kuznets	15-25 years *(long-intermediate -term)*	Generational population changes, construction industry.
Juglars	7-11 years *(medium-term)*	Fixed asset investment like plant and machinery.
Kitchins	3-3.3 years *(short-term)*	Working capital investment like inventory.

Kondratieff long cycles relate to major technological changes such as the Industrial Revolution, the Developments of the Railways, the Motor Car and Information Technology industries. For the other cycles, Kuznets relate to generational population changes and the house-building industry, Juglars relate to fixed investment, in particular, plant and machinery, Kitchins short cycles relate to working capital changes, in particular, stocks (inventories).

Schumpeter's (1939a) schema of cycles identified three classes of cycles rather than four: Kondratieffs, Juglars and Kitchins and he suggested 3 Kitchins per Juglar, 6 Juglar cycles per Kondratieff, (1939a, p 169,173). He did acknowledge the existence of additional cycles:

> *"We will mention, Professor S S Kuznets.....and Dr C A R Wardwell....who found average periods of roughly 25 years and 15 years, respectively."*
>
> *Schumpeter (1939a) p 165*

Van Duijn (1983) expanding on this, found if he took an average length for the Kondratieff as 54 years, Kuznets as 18, Juglar as 9 and the Kitchin as 4.5 years, he rather neatly suggested:

> *"1 Kondratieff = 3 Kuznets cycles = 6 Juglars = 12 Kitchins."*
>
> *Van Duijn (1983) p 6*

The section also examines some very old theories of economic fluctuations, the Harvest Theories. The Harvest Theories are included because Kondratieff particularly identified an empirical pattern for agriculture accompanying the phases of the long cycle. Also, in the long data analysis detailed later, persistent but slight cycles are found from 11-13 years. These theories are short- to medium-term explanations of rhythmic movements rather than long-term and so are only over-viewed.

1.2 SHORT-TERM CYCLES

Kitchins, that is, short cycles relate to working capital changes, in particular, stocks (inventories). A number of studies have independently identified a short-term cycle of around 40 months (3.3 years). Kitchin(1923) established a 40 month "minor" cycle in data from 1890-1922 in Great Britain and USA for bank clearings, wholesale (commodity) prices and interest rates. Kitchin's British data was monthly, based on London bankers' clearing house returns, Sauerbeck-Statistics's wholesale prices of commodities and three-months' bills. Kitchin's study was published around the same time as Crum's. Crum (1923) via "periodogram analysis", similar to the chained-average-difference process (periodograph) also found a visible cycle of about 40 months in New York's commercial paper rates from 1866-1922.

Contemporary reading suggested that short cycles could have been called "Crums" rather than "Kitchens" but Crum was not prepared to be as positively associated with the cycle length by firmly declaring, as Kitchin had, the existence of a short cycle. Both papers were published in the same 1923 economic journal. Mitchell (1927, 1946) used data from 1878-1923 to find a mean cycle duration of 42.05 months with a standard deviation of 12.37 months, median of 40 months. Kitchin also found a "major" cycle composed of 2-3 minor cycles. His major cycle, a length of 7-10 years and averaged 8 years was similar to Frisch's 8.5 years "primary" cycle and 3.5 year "secondary" cycle.

Kitchin on the "minor cycles" of 40 months asserted:

> *"Though single cycles may vary considerably from this average, an underaverage cycle is often followed by an overaverage cycle, and vice versa, so that the average of two or three consecutive cycles is closer than the single cycle to the general average length."*

Further, he added that these cycles:

> *"show no material change in their average length with the course of time,*

judging by studies of a period of a century back."

Kitchin (1923) p 10

In identifying the short cycles, Kitchin indexed the data, this was done by averaging all the monthly data over 1900-1913 and the average figure was subsequently charted as the base of 100. The dates of the actual maxima and minima were compared to the "ideal" date starting in 1890 and set 3.33 years apart for the "ideal" maxima with the "ideal" minima placed midway between. He argued fundamental movements or trends should not be regarded as cyclical, being dependent upon the "changing amount of world's total money". Kitchin's average of 3.33 years was identified from data covering additionally, for example, wages, income, stock market movements, trade and volumes dating from 1810.

Kitchin stated:

> *"These minor cycles are apparently the result of a rhythmical movement due to psychological causes, though, through prices of vegetable foods, they may be influenced by excess deficiency in crops which fall out of tune with the normal cycle.... (deficiencies meaning higher prices and vice versa) and by cyclical fluctuations."*
>
> *Kitchin (1923) p 10, 14*

He referred to Wright and cited him thus:

> *"Business and price cycles are due to cyclical recurrences in mass psychology reacting through capitalistic production. The rough periodicity of business cycles suggests the elastic recurrence of human functioning rather than the mathematical precision of cosmic phenomena."*
>
> *Kitchin (1923) p 14*

Kitchin attempted to identify leads and lags in the minor cycles among the differing types of data used. Without correcting for any seasonal factors or secular trends, generally he found bank clearings led commodity prices by about 6 months, while interest lagged such prices by 4 or 5 months.

Later theorists, concentrated on multiplier-accelerator models of business (inventory) cycles, and found errors in sales forecasts generated short-term inventory cycles, (see Metzler (1941)). Lovell (1975 pp 450-6)) modelled the impact of sales forecast errors on stocks and output. Assume stock-holding satisfied 3 basic motives: transactionary, speculative and precautionary; just examining the transactionary motive generated a cycle due to the lagging effect. Firms increased stock levels if they were below that required for transactions. Increased production of stock created income, later this led to increased demand. Thus even more investment in stock occurred until the point when expected sales were no longer realised. Overstocking led to fall in demand for production, income fell and sales dropped further. Stock levels had to fall to their lowest point before demand for their production started again.

The intention in this section was simply a brief overview of short-term cycles, cycles of about 3 - 3.3/.5 years in length, originally referred to as Kitchins (3.3 years) but commonly now known as business cycles. Much has been written on the subject of short-term or business cycles, they have been extensively regarded as the most long-standing and readily observable cycles but any further examination is outside the scope of this thesis.

1.3 MEDIUM-TERM CYCLES

1.3.1 Juglar's cycles

The medium-term cycles (7-11 years) known as Juglars, relate to fixed investment, in particular, to plant and machinery.

Juglar (1860, 1889) was one of the first theorists to notice the wave-like alternation of prosperity and liquidation (booms and slumps). He found periods of prosperity and high prices ended in crises, followed by periods of depression and low prices. He boldly hypothesised a single wavelike movement, which then was quite a major and innovatory step and significantly moved forward the development of cyclical theories. Juglar's conclusions were based on observations of data on population, banking, interest rates, credit, prices, wages, data from France, England and the USA.

Juglar's single wave-like hypothesis was very influential in the-then current thinking, and also influential on Schumpeter's very early work. Schumpeter did not abandon the idea of a single wave until about the First World War, until then he stated he had like many others:

> *"accepted the single-cycle hypothesis as a matter of course"*
>
> *Schumpeter (1939a) pp 163-4*

However, the shortcoming of Juglar's work was the failure to countenance the idea of multiple waves and these waves affecting each other.

Earlier, Juglar (1851) found in a population study, cyclical variations in the marriage-, death- and birth-rates in France. His interest was aroused by the variations in the rates that occurred between those years of abundance and those of scarcity. He was fully aware of the impact of scarcity, wars and epidemics but was concerned that there was some causal mechanism, benign or harmful, influencing the business cycle. The affect of the mechanism being exaggerated by some unfortunate conjunction.

Juglar, in later studies (1860) explained some of the difficulties he and his team faced in obtaining essential statistical data for their work and place the statistics in their historical context. He provided a few illustrations of crisis dates which he had not personally identified but by contemporary consensus was historically thought to be correct. Juglar's cyclical theory was founded on linked statistical data, presented in a meaningful way and set in its historical context, in France, England and the United States.

Juglar observed recurring prosperity and depression phases. He pushed the significance of major crises into the background:

> *"Les grand guerres, les revolutions ne jouent pas le role que l'on est porte a leur attributer..."*
>
> *Juglar (1889) p xvii*

[The major wars and revolutions did not play the central role that one tended to attribute to them.]

He searched for something else which he found to be the already mentioned alternating wave of prospery and liquidation, a flow-like movement, in other words a cycle but with a major crisis occurring within it.

Juglar's fundamental argument to his cyclical theory was that the symptoms which preceded the crisis provided signs of prosperity. This he detected by examining the movements "la hausse des prix", increases in the prices of goods, land and property. He examined the pay demands of workers, the fall in interest rates "la baisse a l'interet", the gullibility of the public at the first sign of success. When prices stopped rising, a crisis occurred triggering the next phase.

He recognised the "get rich quick" mentality within the general public: they were led to excessive spending, not based on income but on the expected increase in capital after the improvement in economic progress. Similarly, overspending by businesses resulted in a commercial crisis. Credit was provided by the banks who in effect, created over-development on the part of businesses by lending the deposits entrusted to them. The situation in the UK in the late 1980s/early 1990s had a resounding echo of

Juglar's evaluation given a century earlier.

In all instances, commercial distortions and bankruptcies, "les faillites", came about by banks issuing too many notes (bills) so the large movement (wave) was built on too much credit:

> *"Ce sont surtout les convulsions de credit provenant de l'extension exageree qu'il avait prise anterieurement, qui arretent tout le mecanisme de la circulation."*
>
> *Juglar (1889) p 5*

[Above all, the credit came from an over extension previously taken, which stopped the flow of circulation.]

Juglar quoted an authoritative source, the Governor of the Bank of England (1858), to support his arguments, that all this was part of human nature: one could not prevent these periodic jolts, "la secousse", of prosperity and of difficulty. Juglar regarded financial difficulty as necessary, in order for recovery, "la reprise", to occur.

Juglar addressed the globalisation of markets: business extended to all points of the globe with distances being reduced by the construction of the railways (Kondratieff's long wave of major technological change). A country's goods transported overseas by steamboats thus earning foreign exchange for the country. But as prices rose, exports were less competitive reducing the Balance of Payments (and more gold left the country). Juglar pondered whether the repercussions, "le contre-coup" of shocks in one weakened economy were felt in those countries which had most commercial contact with it. Juglar suggested that the linkages among the large markets were found by examining the respective monetary mechanisms and economic and social statistics and thereby identify the high and low points in movements. He found these coincided with the occurrence of historical crises. From this, he hoped to deduce the length of cycles between the high/high or low/low points.

Juglar identified three periods for the completion of one whole cycle, "une crise commerciale". This was broken down into a period of prosperity, a period of crisis and a period of liquidation. His research found that this phenomenan repeated in England, France and the United States, over 1800s - 1880s. His data drew on the published balance sheets of each country's central bank, that is, the Banks of England, France and the U.S.

The premise of his hypothesis concerning a cyclical movement: any economic problems were revealed initially in the bank statistics produced for that country. Observations from bank statistics enabled him to predict the commencement of a crisis or a recovery. A strong correlation was seen particularly between the French and English markets, with a tendency for the French to lead and the American market to lag the English market.

Juglar's theory of a long wave-like movement was that prices were high on the eve of a crisis, and only low at the start of a recovery following a long period of stagnation. In that period, there was a budget deficit, relatively low wage levels, unemployment, low consumption and domestic savings. This combination of influences he argued, affected the movement in the number of marriages, births and deaths in the population. The varying conditions, anything from excessive bank credit to the occurrence of war were all features which brought forward a crisis, but the predominant variable seemed to be price fluctuations. It seemed to be this which kept the successive phases recurring.

In conclusion, the periods over which Juglar hypothesised movements between bank figures, money velocity, interest rates, unemployment etc with movements in marriage- birth- and death- rates worked for his selected periods. Juglar's notion of a major crisis fitted in well with his hypothesis, although he tried not to overplay their significance, some being more major than others in his twelve different time periods. Although, his "big crisis" view per cycle did not have any importance attached to it by

Schumpeter. Juglar characterised a cycle typically as high prices, stop - crisis, low prices, liquidation, then recovery. The problem Juglar himself identified was that one could only detect these movements and turning points in retrospect. Other problems were that he did not allow for the existence of a number of cycles of differing lengths. Also he did not identify the reasons for the changing prices which brought about the crisis at the end of the prosperity phase. Juglar cycles of about 11 years are consistent with some slight spectral results found and discussed later in the thesis.

1.3.2 The Harvest Theories

1.3.2.1 Introduction

The intention in this section is to examine the origins of harvest theories of business cycles in the context of Kondratieff's work which identified the characteristic of agricultural changes accompanying differing long cycle phases. Harvest theories were probably the earliest identifiers of cycles. Juglar (1851) identified drought as a factor in the rates of birth, marriage and death in his population study. The spectral results reported later in the thesis although not investigating medium-term cycles found some weak persistent cycles in the data, ranging 11-13 years.

A very early cyclical comment by Petty in 1662 referred to an average seven year cycle in corn harvests:

> *"and the medium of seven years, or rather of so many years as makes up the Cycle, within which Dearths and Plenties make their revolution,"*
>
> *Petty (1662) pp 24-25*

Harvest theorists attempted to identify correlations, particularly crises in business cycles with cycles in agricultural yields, for example, by linking them to meteorological patterns. An exogenous variable in turn was identified as affecting the weather pattern.

Harvest theories are thought to originate from the research investigations of Jevons (1884) and Moore (1917). Moore (1917) studied rainfall and temperature, Jevons (1884) examined sunspot activity.

However, it is not necessary to return to the period of agricultural dominance when these harvest theories were formulated to see the relevance of meteorological conditions on a country's economy. In the 1990s, any economic region (cotton states in the USA) dominated by the impact of cash crops on the country's income. Any increase in exports, for example, to Newly Industrialising Countries (NICs) with increasing consumption needs, brings in foreign currency yet still maintains the economic region's domestic price for the crop. Economic theory suggests that improved exports increases a country's money supply and impacts favourably upon interest rates which in turn stimulate the economy further. Clearly, meteorological conditions will impact upon such a country or region's economy. However government actions may modify the effects of modern agricultural cycles. For example, the European Union's Common Agricultural Policy (CAP) facilities to store crop abundance in any year against later shortfalls, and accompanying government support for agricultural prices.

The significance of harvests in cyclical fluctuations indicated by Rostow (1948, 1975), where he stated:

> *"three major economic forces contributed, at intervals, to British social and political unrest: cyclical unemployment, fluctuations in domestic harvests, and technological unemployment. ...The most serious unrest, however, was a product of cyclical depression and high food prices."*
>
> *Rostow (1948) p 109*

1.3.2.2 "On the Study of Periodic Commercial Fluctuations" (1862)

Jevons' (1862) concentrated on sunspot activity in explaining harvest cyclical fluctuations. The density of spots on the sun's surface is known to cause meteorologial disturbances. His influential work drew on British, French and German papers from the 17- and 1800s covering periodic fluctuations, and he also utilised material dating from 1568. Familiar with the investigations of Dr Hyde Clark (1838, 1847), an early pioneer in cyclical work. Jevons stated:

> *".. commercial fluctuations should be investigated according to the same scientific methods with which we are familiar.....such especially as meteorology and terrestrial magnetism. Every kind of periodic fluctuation, whether daily, weekly, monthly, quarterly, or yearly, must be detected and exhibited not only as a subject of study in itself, but because we must ascertain and eliminate such periodic variations before we can correctly exhibit those which are irregular or non-periodic, and probably of more interest and importance."*
>
> *Jevons (1862) para 4, p 4*

In this paper (1862), Jevons' methodology was to show the average variations occurring monthly in the rate of discount, the number of bankruptcies, price of consols and price of wheat, over anything from 15 to 54 years. He also examined the accounts of the Bank of England since 1844. He was convinced of a mysterious periodicity of about 11 years in the data. He concluded:

> *"the most striking fluctuations are due to the gathering of the harvest, and the general termination of the year's operations. The consequences are a rapid rise in the rate of discount, a sudden flood of bankruptcy, and a fall in consol, followed by a rise."*
>
> *Jevons (1862) p 8*

He found that bankruptcies and commercial distress and panics were more prevalent in October and November showing the dates of previous panics: 1836, 1839, 1847 and 1857 (later, in the 1878 paper, adding 1866, 1878-9 crises). An interesting coincidence should be noted: both the 1929 and 1987 stock market crashes occurred in **October.**

1.3.2.3 "The Solar Period and the Price of Corn" (1875)

Jevons's later work (1875) argued that the harvest and the price of grain will depend more or less upon the solar period. Earlier, Carrington (1863) had compared the price of corn with the sunspot curve. However, Carrington was unable to assert any positive influence between the price of corn and sunspot activity but neither did he make a case for no influence, but that social and political causes were "noisome disguises". Earlier, Sir William Hershel (1801) having noticed marked variations in sunspot density, similarly failed to identify a link between the price of corn and sunspot occurrence.

Jevons felt he required at the very minimum, 100 years of data in order to look for an 11-year price cycle to equate with the sunspot activity. He referred to the work of Thorold Rogers (1866)[1] who undertook a history of agriculture and prices in England compiled from contemporary records but whose methodology and rigour in data collection has since been criticised by Beveridge (1939). This is discussed further as a problem, in the next rather than the following paragraph.

Jevons's methodology was to use Rogers' s tables of prices of grains, and in effect draw up an 11-year moving average of the prices. He ascertained the highs and lows in the prices of grain separately and combined. He counted the number of times that a

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[1] Thorold Rogers, Vols I-II (1876), Vols III & IV (1882). Jevons, being a great collector of data appeared to have access to the material before the complete voluminous publication.

maximum or minimum price occurred in each year of the 11 year intervals. He found for corn prices, an excess of maxima in the second and third years; an absence of high prices in the eighth and ninth years. Applying some basic probability and random distribution calculations he was able to infer that high prices recurred periodically. On repeating the exercise using Adam Smith's wheat prices from "The Wealth of Nations", he found less variation between the recurrence of high and low prices and sunspot density, and suggested further investigation. About the same period, Schuster (1877) reported that in Germany, good wine vintages tended to occur in those years of minimum sun-spots.

The problem with Jevons' methodology in the 1875 Paper was that probably because he was predisposed to find an 11-year cycle, he appeared to have overlooked that the cycles of 3, 5, 7 and 9 which would also fit in with Thorold's data. Also a further problem is here identified with the source material. The Beveridge Study (1939) examined the earlier Thorold Rogers work and found that there was a lack of rigour in estimates and compilation from the source records. For example, locally adopted weights and measures persisted over long periods of time. Beveridge (1929 p 17) adjusted local prices to a standard bushel measure, Thorold Rogers did not. Thus a bushel of wheat could vary over the radius of just a few miles from an eight gallon to a ten gallon measure. Therefore, doubt must be cast on the efficacy of some of Jevons' source material data.

1.3.2.4 "The Periodicity of commercial Crises and its Physical Explanation" (1878)

In a subsequent paper, Jevons (1878) retracted some conclusions in the 1875 Paper but continued to assert an 11-year cycle by linking the dates of commercial panics[2] to a sunspot cycle. He acknowledged John Stuart Mill's argument that periodic collapses

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[2] Commercial panics in 1825, 1836-39, 1847 1857, 1866 and an inferred one for 1879.

were:

> *"really mental in their nature, depending upon variations in despondency, hopefulness, excitement, disappointment and panic."*
>
> *Jevons (1875) p 203*

However, Jevons argued that such pessimism may have been as a result of outward events such as the condition of the harvest. So slight variations in the price of food may have produced violent effects. If the:

> *"money market is naturally fitted to swing or roll in periods of ten or eleven years, comparatively slight variations in the goodness of harvests repeated at like intervals would suffice to produce those alternations of depression, activity, excitement, and collapse which undoubtedly recur in well-marked succession."*
>
> *Jevons (1875) p 204*

Similar arguments were repeated in the 1878 Paper alluding:

> *"bankers are continually influenced in their dealings by accounts of the success of harvest......it becomes almost certain that the series of phenomena, credit cycles and solar variations, are connected as effect and cause."*
>
> *Jevons (1875) p 216*

Jevons's methodology in the 1878 Paper was to identify specific commercial events which were sufficiently outstanding to mark them as a crises in the period. This may have been a rise in bankruptcies, "foreign drain on bullion", a bank run, stock market mania or "stock-jobbing", remarkable price rises in wool, corn or tin, imports, exports and credit cycles. He trawled the records of over 200 years, from England and abroad, notably USA, Holland and less so, India. He found some such remarkable event occurring every 10.4 years. The mathematical methodology incorporated logs rather than the simple moving averages he used previously, he took the averages logarithmically to show a better comparative in the annual movements where he found "strongly-marked" 10-11 year variations. It is unreasonable to criticise Jevons's mathematical methodology so harshly because Econometrics was not then developed, and statistical techniques were not in an advanced stage of development, and Pearson's probability paper did not appear until around 1897.

In a later article in "Nature", Jevons (1878b), suggested a periodicity of 10.8 years, found by identifying 5 major occurrences in 54 years. However, he refined this to 10.466 with further delving into the data for major events[3]. During this period, improved scientific estimates were made concerning the length of the sunspot period at 10.45 years (Broun 1878) rather than 11.1.

Further problems with the approach in both the 1878 Paper and "Nature" article was the amount of subjectivity involved in identifying minor, medium or major panics for counting, though this was not such a drawback with the tabulated data gathered, such as bankruptcy figures. Also, an important defect was the lack of indication of how much material Jevons examined, which failed to show an 10-11 year cycle.

Later scholars, such as Sheehan & Grieves (1982) dismissed the methodologies used in establishing a relationship between agricultural and business cycles. They used Granger's Test for causality or rather, for the testing of a linked association between 2 variables. The assumption was that:

> *"the relevant information is entirely contained in present and past values of X and Y. A time series Y_t will be said to cause another series X_t if the present value of X_t can be better predicted when using past values of Y_t than it can when those values*

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[3] Jevons restated his series of decennial crises as 1701?, 1711, 1721, 1731-2, 1742?, 1752?, 1763, 1772-3, 1783, 1793, 1804-5?, 1815, 1825, 1836-9, 1847, 1857, 1866, 1878.

are excluded."

Sheehan & Grieves (1982) p 775

However Sheehan & Grieves' approach presumed the linkage between X and Y must be linear. They used annual data on sunspots from 1889-1978 and data on GNP and wholesale prices[4]. They did not report the results of using data on M1 money or Dow-Jones industrial average but stated as a footnote:

> *"Sunspots likely cause something and are likely caused by something; we just cannot be sure at the outset what are appropriate causal variables."*
>
> *Sheehan & Grieves (1982) p 776*

A further criticism of Sheehan & Grieves's study is that conclusions drawn from GNP and wholesale prices movements over an 89-year period was far too narrow in its examination of what constituted a business cycle. One presumes that the intention of this study was a lighthearted attempt to reexamine Jevons' earlier sunspot/business cycle conclusions.

Jevons deserves recognition for researching a vast amount of original source material over the previous centuries, now lost. His thoughts and comments made a valid contribution to pioneering cyclical investigations which is still acknowledged in the 1990s. He raised the phenomena of the recurrence of panics and crises, and identified[5] the months most likely to show commercial distress and panics as October/November, pre-empting both the 1929 and 1987 stock market crashes in October. Even with today's sophisticated techiques no other satisfactory explanation is yet forthcoming for

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[4] Kuiper, G P "The Sun" (1953), Univ of Chicago Press and "Sky and Telescope". For GNP date: Kendrick J W "Productivity Trends in the US" (1961) National Bureau of Economic Research. and the "Survey of Current Business". For WPI data: "US Statistics from colonial times".

[5] 1862 Paper, page 8.

such events. Also, Jevons was not far out in his calculations of short cycles, current thinking (Stamper 1994) confirmed a sunspot cycle length of 11.1 years. The spectral results reported in the later sections of the thesis found "very weak results", but persistent across the data examined, for cycles in the region 10.8-11.3 years.

1.3.2.5 Moore's view of harvest theories of cycles

Moore (1917) studied rainfall and temperature and the impact on the cotton yield in the US. At the time, the US was producing about 75% of the world's cotton consumption. He had a poor opinion of the US Government's predictive ability in estimating the yield and resulting impact on world cotton price. Moore found the US Government's Official Statistics for the prediction of cotton yield in the southern states was less accurate than his prediction based on rainfall and temperature using multiple correlation and taking account of cumulative effects, for example, Moore noted that excessive heat in July may be offset by a beneficial rainfall in August. He stated:

> *"Notwithstanding the vast official organisation for collecting and reducing data bearing upon the condition of the growing crop, it is possible, by means of mathematical methods, to make more accurate forecasts than the official reports, in the matter of the prospective yield per acre of cotton, simply from the the data supplied by the Weather Bureau as to the current records of rainfall and temperature in the respective cotton states."*
>
> *Moore (1917) p 120*

Earlier, Moore referred to some official reports as being valuable forecasts, but some were:

> *"worse than useless in the sense of supplying erroneous instruction as to the crop outlook, and thereby suggesting a misdirecting of activity on the part of farmers, dealers and manufacturers;"*
>
> *Moore (1917) p 100*

The mathematical methods that Moore referred to were at the leading edge at the time. He made use of Pearson's work developed in the 1890s on correlation, he measured dispersion by standard deviation and calculated trends with reference to the mean. He produced a frequency distribution of the fluctuation of average spot prices from their general trend for cotton. He used linear regression in his scatter data to produce a line of best fit and identify the correlation coefficient. This was useful for the correlation between spot and futures prices of cotton and enabling prediction of the most probable fluctuation in the futures as a result of a movement in the spot. His mathematical methodology was applied to data on temperature and rainfall obtained from the Weather Bureau in order to assess the likely cotton crop.

The US Government's less accurate prediction for cotton was gathered by an army of statistical agents who used marked and sealed envelopes to send data centrally, and kept under combination in safes until Crop-Reporting Day. Any data which had to be telegraphed was done so under a cipher code! There was at least monthly report gathering, with more frequent reports made during the cotton growing season. The army of compilers included State travelling agents who were specialists in statistics and crop knowledge, field agents, thousands of county and township correspondents, individual farmers and planters who reported their own results relating to acreage, condition and crop yield.

There was much criticism concerning the lack of precision regarding the definition of what may be described as "normal" in reporting the condition of the crop required by the Bureau of Statistics. In the end it was down to thousands of individuals' personal perception.

The official figures showed a tendency towards pessimism, always underestimating the probable yield. This had serious connotations. The impact was to cause an uncalled for price rise and thereby profit the producers. It would have been sensible to use this finding by taking the consistent pessimism of the farmers, and compute it into the forecast and inflate the figure to a more realistic estimate. However, a more serious omission in the official figures was that no account appeared to have been taken of the degree of correlation between the actual yield and official predicted yield. Such bias surely contributed to the lack of accuracy in the official forecast.

On the day that the Crop Reporting Board met, the data gathered was brought before them, the seals broken with no one allowed to enter or leave the room. The five member Board, the personnel changing monthly, each had to provide a separate estimate of acreage, condition and cotton yield for each State. The results were compared and final estimates made. They were announced at the same hour, same day throughout the states with Western Union reserving its telegraph lines at the designated time. The US Department of Agriculture estimated that the consequence of false reports on expected cotton yields as a result of speculation could:

> *"depress the price a single cent per pound, growers could lose $60m or more"*
> *Moore (1917) p 52*

In later work, Moore (1923) suggested an exogenous variable contributed to rainfall and temperature changes, the path of the planet Venus relative to the sun and earth. Moore made links between the planet's path and weather pattern, particularly the level of rainfall. This affected agricultural yields impacting on general business activity. He later distanced himself from this piece of work.

1.3.3. **Other medium-term cycles**

Apart from Juglar already reviewed, other wave theorists found medium-term cycles. Kuznets, reviewed in the next section as long-intermediate cycles. Briefly, Greenstein (1935) found an average of 9.4 year cycle in business failures in USA. Wardwell (1927) found an average of 15 years for his major cycle. In Wardwell's theory, particular attention was paid to the notion of fixed investment, the cumulation of optimism/pessimism influenced the fixed investment level via the shorter business cycles in the major cycle. Wardwell's starting point was a short cycle in the trough of the major cycle, which went through recession and then into depression (milder) in the first business cycle, proceeding to a prosperity cycle then to milder prosperity in the third short business cycle in the declining phase of the major cycle. However, a problem with Wardwell's theory was that the psychological influences actually accompanied rather than caused the phases of prosperities/depressions etc.

Wardwell seemed not to require any initiating impulse for the cycle movement. Theorists such as Pigou (1927) and Kuznets (1930) both referred to some stimuli outside of the fixed investment being necessary. Pigou suggested an impulse may:

> *"arise out of a good harvest, an industrial invention, the discovery of new mines, an industrial dispute, the outbreak of war, an error in business forecasts, an autonomous monetary change, and so forth."*
>
> *Pigou (1927) p 7*

Later theorists also found the existence of medium-term investment cycles, Samuelson (1980) modelled a multiplier-accelerator to explain cyclical fluctuations which proved influential for later econometric modelling. It equated consumption, income, net investment and capital stock changes with some lags. Consumers' behaviour was based on last year's income, and producers based their optimal capital stock estimate on last year's output. However, sales forecasts, interest rates and profits also needed to be incorporated in the model. Forrester's (1976, 1978) MIT System Dynamics National Model did this. Forrester's model aimed to specifically examine for *other* than short-term cycles and was:

> *"built up from the operating structure within corporations, rather than from macro-economic theory.....and allows one to untangle complex socioeconomic*

interactions."

Forrester (1978) p 128

Forrester's cycle is introduced in the next section under long-intermediate cycles with Kuznets and returned to again when evaluating Kondratieff's long cycle characteristic of inventions, Chapter 3.

1.4 LONG-INTERMEDIATE CYCLES

The long-intermediate (15-25 years) cycles, Kuznets, relates to generational population changes and the house-building industry. As with Kondratieff long cycles, there is some debate regarding their existence, especially in the UK, and such cycles are thought to be particularly relevant to the American economy. Rostow (1975 p 730) found Kuznet cycles existed only over the period 1840-1914. Forrester's (1976, 1978) team developed the MIT System Dynamics National Model which modelled a 15-25 year construction cycle, the length varying with the lag estimate input. Solomou (1987) was more pre-disposed to find Kuznets long-intermediate cycles than Kondratieff long cycles, in the US economy.

Regarding long-intermediate cycles, Kuznets's (1930) work on secular movements in production and prices found average periods of approximately 25 years. The secular movements he described as:

> *"continuous, irreversible changes which underlie the cyclical fluctuations of a time series."*
>
> *Kuznets (1930) p 60*

He cited Cournot (1897):

> *".... articles such as wheat... are subject to violent disturbances; but, if a sufficient period is considered, these disturbances balance each other, and the average*

value approaches fixed conditions...", and

> *"as in astronomy, it is necessary to recognize secular variations, which are independent of periodic variations."*
>
> *Kuznets (1930) p 59*

Kuznets (1930) investigated movements in prices, production and profitability in five countries, USA, Great Britain, Belgium, Germany and France. The original study investigated 35 price and 60 production series, some series dating from 1860 and some up to 1924. The Great Britain series studied were coal, pig iron, steel, cotton imports, ships cleared, tea consumption and savings. In later studies, Kuznets investigated the impact of population changes, particularly migration. Kuznets found that the application of simple logistic and Gompertz curves described growing industries more comprehensively than declining ones. He found distinguishable cyclical fluctuations and historical confirmation for variations in price and:

> *"The specific movements in production are usually confirmed by the history of the industry."*
>
> *Kuznets (1930) p 198, 206-7*

Specifically he found:

> *"about 22 years as the duration of a complete swing for production and 23 years for prices.* [and] *with a tendency for the price movements to precede those of production."*
>
> *Kuznets (1930) p 198, 206-7*

He pondered over the matter why movements in prices seemed to cause movements in production:

> *"Why is it that with a continuous rise and fall in prices there is a continuous acceleration or retardation in the rate of growth of industrial output?"*
>
> *Kuznets (1930) p 206-7*

He looked for an explanation towards the effects of a secondary movement in prices on GNP, in particular, the distribution of GNP among the various groups within the economy. How those groups, employees, investors, entrepreneurs interacting with each other affected the continuation of the cycle phase regardless whether it was a rise or a decline.

He found support for Hansen's assertion:

> *"real wages move inversely with the general price level"*
>
> *Hansen (1925) p 39*

that money wages did not rise so fast as the cost of living during periods of rising prices, and in effect, real wages fell. He inferred that money wages did not rise as much as the rise in the value of production output. Generally, with the wage lag and other production costs rising less quickly than the increased value of production output then:

> *"over a prolonged period of price increases, there is a rise in profits. For similar reasons, in periods of price decline there is a falling-off in net earnings, whether measured in money or commodity terms."*
>
> *Kuznets (1930) p 211*

He found that corporate profits recovered before the value (prices) of production output. The rise in the value of production output like pig iron lagged up to 4 years behind rises in prices. The profit factor motivated the entrepreneurs. So over a period of rising prices, it was this movement in profits that acted as the incentive to increase the volume of production output and so provide higher industrial growth. So higher prices, led to higher profits and more growth as the production tempo heated up.

The increased growth, over a period of rising prices, in the production of consumer goods can be explained in a number of ways. Regarding the amount of consumer savings, over a period of rising prices, although money wages were rising (but not as fast), the proportion of income saved, fell. It did not appear to Kuznets that the funds were diverted into investment nor were they necessarily spent on consumer goods. However, it did seem that wage-earners, over a period of rising prices, spent a larger proportion of their current income and saved less. Although real wages were declining, this was offset by larger volume of employment so ensuring continuation in production growth, that is until prices ceased rising and stabilised. Then as wages and other production expenses readjusted, this caused an increase in production costs which reduced profits because prices had now stopped rising. The motivator of falling profits caused falls in production output and unemployment and prices declined further.

Kuznets argued that there were influences which may have brought to an end a rising or declining phase. Anything which impacted on profits causing a reduction even over a period of rising prices will lead to a stop on the rising phase. In particular, the movement in money supply (gold production fell over a period of rising prices) and the productivity of labour (which declined). All these secondary variations may conceivably be perceived as major cycles if:

> *"the initial disturbances are due to a cause bound to occur fairly regularly or with a rough periodicity... and if the processes of exaggeration and retardation are more important than the initial disturbances and the time they take for evoking a rise and a decline fairly equal...so that the cyclical character of these processes would be sufficient to account for secondary variations as major cycles."*
>
> *Kuznets (1930) p 258*

But he did not think this could be so, believing secondary variations to be specific historical occurrences, but:

> *"The length of time covered by the series is too short to be able to draw conclusions on this point with any certainty."*
>
> *Kuznets (1930) p 258*

Forrester's (1978) MIT System Dynamics National Model modelled the interactions of the economy so as to reflect changes in demand and the time response it took for industry to gear up production (labour, inventory, capital equipment ordering) in order to meet the demand for goods. Forrester's experiments with lags in the fixed investment (capital equipment) sector between the ordering and supply of the capital equipment required to meet the demand of producers satisfying consumers needs, led to variations in his cycle, ranging 15-25 years. Forrester's work is further examined in the innovations chapter, Chapter 3 later.

Shearer (1994) confirmed the need in long-intermediate forecasting to draw on long- and medium-term socio-economic information as well as economic data. He modelled a construction cycle of 18 years drawing on long- and medium term demographic data. Shearer illustrated the misleading long-term forecast on house-building in the UK predicted by the National Economic Development Organisation (NEDO) incorporating short-term forecasts (of interest rates) incorrectly assessed. He concluded that short-term economic data like interest rates provided a useful short-term indicator of house-building activity, but

> *"their usefulness is non-existent in the long term due to the relative importance of truly long-term effects such as demography."*
>
> *Shearer (1994) p 102*

Modern theorist, Rostow (1975 p 730) found long-intermediate Kuznet cycles existed only over the period 1840-1914, but Solomou (1987) strongly disagreed and found:

> *"Kuznet swings are observed over specific historical eras and are thus critically dependent on the nature of the shocks within a given economic structure. The Kuznets swing for (Germany and) Britain is limited to the pre-1913 era.....in America a swing pattern is observed throughout the period 1870-1973."*
>
> *Solomou (1987) p 61*

The spectral results reported in the later part of the thesis found cycles slightly longer than the 22-23 years Kuznets identified. For long-intermediate cycles, the strongest finding centred on a cycle length of 26 years but its lower range varied 23-27 years, and upper 26-29 years.

CHAPTER 2

LONG CYCLE THEORISTS

2.1.1 INTRODUCTION

This section represents a review and evaluation of the earliest long cycle theorists: the Trail-Blazers with particular reference to the work of the Russian, N D Kondratieff whose enduring link with long cycles continues to the 1990s. Kondratieff, in identifying long cycles had access to about 140 years of data, mainly British, French and some American. He identified the presence of 1.5 to 2.5 long cycles, from 47/48-60 years. Kondratieff long cycles relate to major technological changes such as the Industrial Revolution, the Developments of the Railways, the Motor Car and the Information/Communication industries.

2.1.2 THE TRAIL-BLAZERS

As mentioned earlier, an Englishman, Dr Hyde Clark was one of the first writers to refer to business cycles and identify potential long cycles. He influenced Jevons's (1878) early work discussed under the Harvest Theories in Chapter 1. Hyde Clark (1838,1847) wrote in Herapeth's Railway Magazine[1], a commercial journal-cum-scientific review, and specifically referred to a 54 year cycle, so his comment is worth restating:

> *".. my impression that the period of speculation was a period of ten years, but I was led also to look for a period of thirteen or fourteen years.... I was led to look for a larger period, which would contain the smaller periods, and as the present famine and distress seemed particularly severe, my attention was directed to the famine so strongly felt during the French Revolution. This gave a period of about fifty-four*

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[1] Published only from May 1835-1840. The publication later became the Railway Magazine, issued from May 1835-1903.

years, with five intervals of about ten or eleven years each"[2]

Hyde Clark (1838)

Another important early long theorist, Tugan-Baranowsky (1894, 1901, 1913) was found to have influenced ***both*** van Gelderen and Kondratieff, evaluated later. Tugan-Baranowsky examined time series data for industrial (business) cycles and found that the cycle was long or short according to the economic conditions of each historical period. He detected an underlying long wave. Tugan-Baranowsky (1913) recognised a feature or symptom (not the cause) of the (industrial) cycle as rising demand generating prosperity. In particular, the characteristic feature of high prices for primary production materials (iron, coal, timber) because of the high demand for them in the prosperity phase. This led to additions in fixed capital (railways, buildings, factories) being made which was that part of the economy which showed the most fluctuation. Characteristically, production prices were low in depressions due to their low demand.

Hansen (1951) referred to Tugan-Baranowsky starting:

> *"a stream of thinking .....[which] finally emerged in the modern theory perfected by Keynes."*
>
> *Hansen (1951) p 284*

Tugan-Baranowsky's view of disposable capital or loanable funds influenced Kondratieff. He used the analogy of the steam engine: accumulated loanable funds was represented by steam, steam built up so that the pressure pushed the piston forward in the cylinder, thus investment in fixed capital goods got industry moving. The piston reaching the end of the cylinder, letting the steam escape and it rolled back

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[2] "which I took thus: 1793, 1804, 1815, 1826, 1837, 1847." Hyde Clark amended the dates in his 1847 paper to 1796, 1806, 1817, 1827, 1837.

to its original position. Thus when investment in fixed capital goods reached the level exhausting the accumulated loanable funds, industry reverted to its original position, in place for the next build up, and so on.

Tugan-Baranowsky's theory allowed a steady rate of saving from income but a fluctuating rate of investment, thus in the prosperity phase of the cycle, there was not enough savings from income to meet the demand for investment. He bridged the gap by the expansion of bank credit and the ingenous dishoarding: idle balances were made to work. However, there was no explanation for turning points, upper or lower. Nor did he theorise, as did Kondratieff, on inventions, innovations or growth, for moving up or down through phase cycles. In the downswing, investment was lower than savings, so the excess savings were hoarded (idly) and used for repayment of bank loans.

Tugan-Baranowsky argued the phases of the industrial cycle were determined by the rate of investment, not by consumption. It was investment which directed consumption. This was particularly influential in Keynes' theoretical development, he himself said about Tugan-Baranowsky that he was,

> *"the first and the most original,"*
>
> *Keynes (1930) p 100*

Reijnders (1990) linked the spread of the dissemination of this early long pattern work of Tugan-Baranowsky's when it was translated from the original Russian (1894) into German (1901). There was an inferred influence of Tugan-Baranowsky's work on Parvus[3] and others, which further spread when his work was translated into French (1913). Parvus (1901), wrote on agricultural crises and examined price variations, he highlighted long term changes in:

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[3] Parvus is the pseudonym used by A Helphand, the Russian Marxist, (1867-1924).

"....technology, the money market, commerce, the colonies - have evolved to such a point that an eminent expansion ..must occur...Then begins a long prosperity {Sturm und Drang} period for capital......there will be the sharpest outbreak of a commercial crisis, which will finally become an economic depression...."

Parvus (1901) p 26, as translated by Kleinknecht (1987) p 3

Parvus (Helphand), a Russian Marxist was an active member of the St Petersburg soviet during the 1905 revolution. He was probably drawing on Marx's work concerning the average rate of profit and capital accumulation within a 10 year industrial cycle and the concept of the "sturm- und drang periode". If Parvus had lived beyond 1924, would he have provided some positive critique on Kondratieff's writings on long cycles, even though a Marxist? Because, Parvus referred to an earlier article (1896), where he clearly anticipated the existence of long waves:

"the economic depression has ended - a new Sturm- und Drang period of capitalist industry begins. This should not be interpreted to mean that from now on no setbacks will be encountered and only prosperity will rule. We are dealing here with the pace of development which always follows the law of capitalist waves."

Parvus (1896), cited by van Duijn (1983) p 72

Parvus's writings, as an active Bolshevik and politically correct for the period, could not simply be ignored, in fact he supported some of the Bolshevik causes, according to Solzhenitsyn (1978), Parvus was:

"Sentenced to three years exile, he escaped abroad. He amassed a large fortune, and sometimes contributed to Bolshevik causes."

Solzhenitsyn (1978) p 543

Although, in later writings Parvus (1908)[4] did not develop long cycles any further but recognised, as did Kondratieff, the feature of the opening up of world markets and long cycles.

Tugan-Baranowsky's subsequent translation into French (1913) led to Reijnders' inference regarding influence on Lenoir (1913), Aftlion (1913) and Pareto (1913). Reijnders linked Tugan-Baranowsky's influence to van Gelderen (1913). Other cycle theorists acknowledged the important influence of Tugan-Baranowsky, being the first contribution to the:

> *"combination of history, statistics and analysis"*
>
> *Hutchinson (1953) p 377*

of crisis and cycles by the Over Investment Theorists such as Spiethoff (1953) and Under Consumption Theorists such as Hansen (1951).

It is worth briefly reviewing the investigative work on wholesale prices by the Dutch Marxist, van Gelderen (1913) who made a valid empirical contribution to long cycle theory, the Dutch socialists would say, more than Kondratieff's. Van Gelderen[5], convinced there were 2.5 cycles, and referred to the cycle phases in terms of springtide (springvloed) and ebb or lowtide, stated:

> *"Apart from the average 10 year fluctuations in the general price level the price curves exhibit an even larger wavelike movement, which in its up- and downward line embraces several decades"*
>
> *van Gelderen (1913) p 268*

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[4] Parvus A "Die kapitalistische Produktion und das Proletariat", cited by van Duijn (1983) p 72.

[5] "Springvloed", The "Springtide", a monthly review of the Dutch Social-Democrats. Van Gelderen's pseudonym was J Fedder.

Van Gelderen's other data series covered interest rates, employment and production (eg. shipbuilding, pig iron), international trade, railway capital and transport. Van Gelderen (1913) identified causal relationships between the data series and used the various prices indices to divide the length of cycles. Kleinknecht (1987) summarised those components designated as causal by van Gelderen:

- the leading sector (innovation) hypothesis
- the hypothesis of periodic over- and under-investment of capital
- credit expansion and financial crisis
- periodic scarcity and abundance of basic materials
- opening of new territories and migration waves
- gold production.

There was a striking similarity between van Gelderen's to Kondratieff's work, which led to accusations that Kondratieff's work was not original, but this similarity is explained later. So summarising van Gelderen, the springtide upswing resulted from greater production expansion and increased demand arising from new markets or new products. The rising demand spread through the economy, pressures built up and interest rates rose. Overexpansion ensued, raw material shortages led to increased costs, stagnation occurred as profitability fell and brought the prosperity phase to an end. In the subsequent downswing or lowtide, the economy went through reconstruction and was "restored through the destruction of capital" setting the scene for the next springtide, (see Tinbergen (1981), van Duijn (1983), Reijnders (1990)).

Van Gelderen's findings at the time, did not carry the same immediate impact as the later Kondratieff. On the one hand, Kondratieff's work could be said to be *more inaccessible* in terms of initially being available in Russian up to the 1925 papers, and only later (1926) being translated into German. Whereas, van Gelderen, may be thought to be more accessible from the original Dutch into German. However, Kondratieff being in a position of authority and influence, his work may possibly have had a higher profile thereby attracting more notice (and criticism).

Kondratieff clearly stated he arrived at his long cycle hypothesis *independently,* unaware of van Gelderen or J Fedder's (van Gelderen's pseudonym) work:

> *"Only at the beginning of 1926 did I become acquainted with S de Wolff's article.[1924]....De Wolff in many points reaches the same result as I do. The works of J van Gelderns, which de Wolff cites and which have evidently been published only in Dutch, are unknown to me."*
>
> *Kondratieff (1935/1925) footnote 1, p 115*

However, the independent development of the Dutch and Russian early long theorists can probably be linked by the common influence of Tugan-Baranowsky. Both van Gelderen and Kondratieff arrived at similar results, which was not surprising given their previously not identified common early influence. The link was that Kondratieff, like van Gelderen, was in fact once a student of Tugan-Baranowsky, indeed Kondratieff published a pamphlet in 1923 in Petrogad to commemorate the economist's death in 1919 where he stated[6]:

> *"Ever more shall we be inspired by the scientific and ideological inheritance which he has left to future generations."*
>
> *Kondratieff (1923) p 36*

The pamphlet contents were later used against Kondratieff, because Tugan-Baranowsky was a minister in the Ukraine government which had fought against the Bolshevik system.

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[6] The contents of the 1923 pamphlet was reported in Kondrat'evshcina (1930) p 36.

Also, Jasny stated about Kondratieff:

> *"he was privileged to be one of the 'closest' (his own expression) [meaning Kondratieff's] pupils of Professor M I Tugan Baranovsky."*
>
> *Jasny (1972) p 158*

When Kondratieff made the statement of independent thinking from De Wolff and van Gelderen above, in 1926, it was most likely not to be to Kondratieff's advantage to be closely associated with De Wolff, another Dutch socialist like van Gelderen, even if they did hold similar long cycle views. This was due to De Wolff's connection with Kautsky, despised by Lenin, discussed further in the "Political Perspective" section.

Kondratieff (1928/1926) did acknowledge the work of *other* earlier theorists, referring by name to Sismondi, Marx, Rodbertus (Jagetzow), Juglar, and Tugan-Baranowsky, Sombart and Wesley Mitchell (Kondratieff 1984, pp 27-28,30). He referred to Kautsky by name, along with Lescure, Aftalion, H L Moore, Spiethoff, Leighton and Cassel who he said:

> *"have approached the subject, although in a rather piecemeal and haphazard manner."*
>
> *Kondratieff (1984) p 30*

Kleinknecht (1987) revealed in the old archives at the University of Amsterdam, some forgotten articles from 1915-1930 documenting the Dutch discussions on long waves. He found that Tinbergen (1929) to probably be:

> *"the first quotation of Kondratieff's in the Dutch context"*
>
> *Kleinknecht (1987) p 215*

Trotsky (1921, 1923) developed a more politically acceptable version of a theory of long cycles which he debated in some robust terms with Kondratieff during the 1920s and is reviewed with Kondratieff later. Schumpeter (1939) built on Kondratieff's development of long cycles and is also examined later with Kondratieff.

Other theorists of long cycles cover quite a variety of economic and social history. For example, the Foundation for the Study of Cycles in Pittsburgh, USA, where Dewey (1971) found a 57 year cycle in wars, which is examined further in a later section. He found 3 complete cycles on data from 1765-1930.

The next section introduces the work of Kondratieff in more detail, examining the political perspective and methodology, and with his characteristics of long cycles being evaluated in Chapter 3.

2.2 KONDRATIEFF'S THEORY OF LONG CYCLES

2.2.1 Introduction

The intention in this section is to identify Kondratieff's work in formulating his hypothesis on long cycles, examine and evaluate the methodology and statistical findings in reaching his conclusion on a theory of long cycles. However, the long cycle characteristics he statistically drew out are evaluated in more detail in Chapter 3.

The essence of Kondratieff's theory of long cycles was this : that capitalist production was characteristic of *cyclical* long upswing and downswing phases, that major changes preceded the long upswing in what he described as, changes in *endogenous* factors such as swing phases, inventions, wars, gold production and colonialism. Kondratieff's theory rested upon explaining changes in various endogenous factors being characteristically "passive manifestations" of long cycles.

Nikolai Dmitrievich Kondrat'ev, known in the West as Kondratieff, identified the presence of long cycles and was almost, without exception condemned in Russia for his writings. It has been found necessary to review part of the contemporary political climate in order to provide some perspective in the evaluation of the criticisms to which the long cycle work was subjected. Some very brief, political historical details are thus provided as a setting.

The systematic analysis by Kondratieff (1935/1925), identified the presence of long cycles, from 47/48-60 years, and highlighted from 1.5 to 2.5 long cycles, 1789-1849, 1849-1896 and 1896-. By adding some generally accepted names to the long cycles, such cycles may be summarised thus:

Table 2.1 Kondratieff Cycles

ENGLAND	**First**	**Cycle**	**Second**	**Cycle**	**Third**	**Cycle**
	1789-	1849	1849-	1896	1896-	
	min	max	min	max	min	max
INDUSTRIAL REVOLUTION	1789	1814				
AGE OF STEAM & STEEL			1849	1873		
ELECTRICITY & CHEMISTRY & MOTORS					1896	1920

where min (minima) denotes the beginning of the cycle's rise, and max (maxima) peak, the beginning of the decline.

2.2.2 Political perspective at the time of Kondratieff's writings

It is necessary to provide some very brief, political historical details in order to understand why Kondratieff's work was so unwaveringly dismissed by the Communists. Trotsky's work on long cycles which provided a more politically acceptable version to the Communists, until he was assassinated under Stalin's regime in 1940, is reviewed later with Kondratieff's work because he actually undertook some serious debate with him.

Kondratieff, Head or Director of the Business Research Institute of Moscow (The Conjuncture Institute) and member of the Agricultural Academy formulated his long cycle theory over 1919-1921 and published his views over the period 1922-1928. Even now, there is still some inconsistency in the literature:

> *"he himself spoke of waves rather than cycles"*
>
> *Jasny (1972) p 158*

and:

> *"Kondratieff always uses the expression "long cycles" not "long waves."*
>
> *Garvy (1943) footnote 5, p 203*

Stolper's (Kondratieff 1935/25) translation adopted the German term of waves. However, Daniel's "Translator's Note" (Kondratieff 1984) acknowledged that Kondratieff used both terms.

Kondratieff was an experienced economist in the agricultural sector and had a reputation for great ability in organising and presenting research on agricultural matters, and regularly contributed material to central planning, including the official New Economic Plan (NEP).

Kondratieff was condemned politically because of his later association with the narodniks group. This initially began during the 1910s, when the socialist movement split into camps, broadly the Bolsheviks at one extreme and the rest, that is, all the nonconformist groups, on the other. It was not necessary to actually be a formal member of a group but merely to express sympathies, to be counted by the authorities as a subversive, and one of them. The nonconformists covered a plethora of political persuasions: at one extreme, the Mensheviks on the left and on the other, the narodniks (neo-narodniks) on the right. Kondratieff was perceived to be principal leader of the narodniks, and the TKP, the Labour-Peasant Party (Trud meaning Labour). The narodniks probably today would be seen as social democrats to the right, nearer to say, David Owen (now Lord Owen). Groman and Sukhanov were the main and deputy leaders of the Mensheviks. There was supposed to have been some sort of informal alliance between the Mensheviks and Kondratrieff's TKP agricultural party. However, Solzhenitsyn (1974), referred to:

> *"the TKP - the fictitious Working Peasant Party."*
>
> *Solzhenitsyn (1974) p 331*

but Solzhenitsyn may have been referring to what was conveniently called by Stalinists around 1930-31, the S.R. Counter-Revolutionary kulak group. Lenin was reported (CPSU 1974a) to have used the term "narodniks" as a catch-all phrase covering all socialist revolutionaries, populists and trudoviks, and the tone was certainly derogatory, (1917):

> *"5. The party must also struggle against the petty bourgeois vacillations of the majority of the narodniks and Menshevik Social Democrats, who are advising the peasants not to seize the land before the Constituent Assembly."*
>
> *CPSU (1974b) 1.157 On the Agrarian Question, p 255*

For a brief period, in 1917, Kondratieff aged 25 was Deputy Minister of Food in Kerensky's Provisional Government which lasted only a few months following the February Revolution (1917). It governed until the elections to the Constituent Assembly (Parliament) took place in October, 1917.

The Bolsheviks political campaign in the run up to the Constituent Assembly was cleverly aimed at soldiers, fighting in the First World War, in terms of getting them out of the war. In the Constituent Assembly, the Bolsheviks won at most, 25% of the votes, but The October Revolution (1917) however saw the Bolsheviks seize power, which they were able to do because the other political groups were so fragmented. The Parliament in fact lasted for only one day. Lenin assumed Bolshevik command in order to commence the social reconstruction. However, he found that the non-Commumists still had to hold key positions for some time to come, because of their expertise. Thus, in Stalin's purges in the later years, from the late 1920s until his death in 1953, any non-Communists' errors or policy differences in planning were turned into accusations of sabotage against the Communist Party's official policy for the economy. For instance, non-Communist economists built into the Five Year Plan low growth rates for their sectors, too low according to official policy, but which turned out to be realistic in the medium-term. Getty (1985) charges:

> *"chaotic 'populist terror' that now swept the party ....Any exercise of power, any mistake, could bring charges of 'bureacratism' or 'treason'"*
>
> *Getty (1985) p 171*

From about 1919 onwards, Kondratieff, at the Conjuncture Institute (Research Institute of Moscow) produced studies of agricultural interest (Kondratieff 1919-22) and importantly, commenced the Economic Bulletin of the Conjuncture in mid-1922. He started publishing some general retail prices indices he had produced and other domestic economic indicators plus foreign indicators gathered from Britain and the US. He later produced (1925-6) peasant indices particularly useful for agricultural workers and the "kulaks". The kulaks were the relatively prosperous peasants, they ranged from peasants who owned more than one cow to large local landowners. The dissemination of information on agricultural indices by Kondratieff enabled peasant farmers to identify the problem that the authorities required vast increases in output, at lower prices, during a time when farmers were facing increased costs.

It was probably this work on economic indicators which ensured that any other work Kondratieff published would be condemned. The Conjuncture Institute was closed down by the authorities, and with it the Economic Bulletin in 1928. Milyutin (1930), then Head of the Central Statistical Office and described by Valentinov[7], as an empty chatterer, stated that the information detailing the USSR economic situation supplied to[8]:

> *"foreign bourgeois institutes ...... [was] deliberately falsified".*
>
> *Milyutin (1930) p 9*

and Uzhansky (1930) accused that the:

> *"Conjuncture Institute was engaged in the study of the economy of foreign countries and described it in numerous bulletins and books"*
>
> *Uzhansky (1930) p 33*

Kondratieff's provision of other than official statistics, all counted towards him being regarded as a counter-revolutionary saboteur.

Also around 1925-26, Kondratieff published papers airing his views long cycles, discussed in detail later. He agreed his views on long cycles were similar to De Wolff's another Dutch socialist like van Gelderens, whose links go back to Kautsky. The connection to De Wolff, as discussed earlier was not likely to be to Kondratieff's advantage. De Wolff was linked with Kautsky (a German socialist politician) via a 1924 publication in support of him. But Kautsky was despised by Lenin's Bolsheviks

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[7] Valentinov N V, editor of various trade journals including the Trade-Industrial Gazette of the All-Union Economic Council (VSNKh) whose memoirs are held at Columbia University.

[8] Milyutin "On Counter-revolutionary sabotage in Agriculture", Paper presented to the Agrarian Institute of the Communist Party, October 1930, p 9. Similarly Uzhansky p 33. (Kondrat'evshcina, 1930).

and later by Stalin's Communists because of his "feeble-minded" stance on capitalism, under which he argued stability was possible. Lenin (1917 p 177-270) was diametrically opposed to Kautsky concerning Russian participation in the First World War, as identified ealier, the October Revolution saw the Bolsheviks seize power in part due to their stance in coming out of the war.

Kondratieff (1927) was also publicly outspoken regarding the methodology in drafting the central plans crucial to Lenin's and later, Stalin's view for the development of the USSR. Centrally-made forecasts were often poor, and not revised in the light of improved information. As a narodnik, and ideologically closely associated with the kulaks, Kondratieff was opposed to the even development of industrial sectors, arguing for a lower rate of growth. He believed the future to lie with the development of agriculture in order to improve the rate of growth, particularly via the more affluent peasant farmers, the kulaks, that Stalin developed a pathological hatred for. Regarding methodology, Kondratieff was critical of the detailed quantitative medium- and long-term plans. He argued detail should be confined to short-term operational plans and he could find no distinction between short- and long-term perspectives in the central planning. Shanin (1927) supported Kondratieff's views, and also argued for:

> *"a course of initially slower and more cautious development of heavy industry"*
> *Shanin (1927 cited by Spulber pp 209-10)*

Stalin was paranoid concerning foreign intervention in Russia and accused the social democrat groups of accepting foreign monies and plotting to overthrow him. Kondratieff, was accused in March 1931,[9] that at the end of 1928, he spoke at a "bloc" (TKP, Menshevik United Bureau and the Industrial Party) alliance meeting of a:

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[9] The Trial of the Counter-Revolutionary Organisation of the Mensheviks, Moscow (March 1931), (Protsess kontr-revolyutsionnoi organizatsii Men'shevikov, mart 1931), p 22. Cited by Jasny (1972) p 73.

> *"possible agreement among them to fight against Soviet rule. As objectives he indicated the liberalisation of economic relations, 'compensation' of capitalists and the establishment of a bourgeois-democratic republic: he emphasised probable support from outside in the form of an intervention."*
>
> *The Trial of the Counter-Revolutionary Organisation of the Mensheviks, Moscow (March 1931) p 22.*

Jasny was a contemporary of Kondratieff and Groman, and knew Groman well, he stated:

> *"All in all, I cannot believe that Groman or Kondrat'ev were in favour of an intervention themselves, still less that they formed an organisation for this purpose."*
>
> *Jasny (1972) p 74*

and believed the story regarding the foreign intervention was fiction, made up by the GPU (Soviet Secret Police) in 1930, in preparation for Groman's and the other Mensheviks' trial. Kondratieff reiterated his theory of long cycles (1928b) in an agricultural article. In 1928, and not 1930 as is generally reported, Kondratieff was removed from his position as Head of the Business Research Institute.

Stalin's intent to purge the kulaks, with whom Kondratieff was associated through his agricultural economic background, from the face of Soviet Russia was clearly indicated, at the meeting prior to the Party Conference in April 1929:

> *"In coming out against party measures to mobilise the poor and middle strata of the rural population for struggle against the kulaks' malicious concealment of, and speculation in, grain, the rightists are objectively assisting kulak attempts to thwart grain collections and the supply of grain to working class and poor peasants."*
>
> *CPSU (1974d) p 345*

The fate of leading Mensheviks and narodniks (the social democrats referred to as the "rightists" above) was sealed later that month (April 1929) at the XVIth Party Congress, particular mention of Bukharin was made:

> *"The party must devote attention to the most painstaking preparation for the purge..."*
>
> *CPSU (1974e) p 365*

and Stalin launched a major press campaign against the social democrats. The purge had commenced.

In December 1929, Kondratieff was subjected to some interrogation but he was still defiant enough to argue that agricultural reorganisation was possible without pressure, but he did concede:

> *"the development would be more rapid if it were simultaneously accompanied by pressure on the kulaks."*
>
> *Reported in speech by Mullins V S, interrogator,*
> *Kondrat'evshcina (1930) pp 105-7*

Stalin planned some show trials of the social democrat groups who were trying to protect the interests of their worker and agricultural worker groups against the collectivist planning. The biggest show trial, "The Trial of the Counter-Revolutionary Organisation of the Mensheviks", in Moscow was planned for March 1931 for the prosecution of the Mensheviks, to be immediately followed by the trial of the TKP's agricultural party. Chief defendants in the Menshevik trial were Groman and Sukhanov, with Kondratieff as a prosecution witness who was then due to appear as chief defendant along with Chayanov in the subsequent TKP trial. At the Menshevik 1931 trial, both Groman and Sukhanov received 10 year jail sentences. The planned TKP trial to follow was suddenly abandoned by Stalin. It is difficult to really say why with any certainty. Possibly because Stalin had 'nailed' all the "stars" anyway in the Menshevik trial, and anything following was an anti-climax. Also, Stalin could not make Kondratieff recant sufficiently to make him appear a broken man given his performance at the Menshevik trial. A small point, at the trial, the prosecutors were extemely discourteous to defendants, and addressed people only by their surnames. Jasny stated that Kondratieff was courteous, under pressure himself at the trial, but insisted on addressing people by their full titles and not surnames. Another reason to support why Stalin cancelled Kondratieff's TKP trial was found in Solzhenitsyn's (1974) writings, he said that Stalin was aware that soon (ie. 1930s) there would be many deaths anyway due to starvation.

Solzhenitsyn (1974) referred to Kondratieff's TKP public trial planned after the Mensheviks 1931 trial:

> *"The interrogation apparatus of the GPU was working flawlessly: thousands of defendants had already confessed their adherence to the TKP and participation in its criminal plans. And no less than two hundred thousand "members" altogether were promised by the GPU. Mentioned as "heading" the party were the agricultural economist Aleksandr V Chayanov; the future "Prime Minister" N D Kodratyev;"*
>
> *Solzhenitsyn (1974) p 50*

In piecing together the events between 1928-1930, the historical perspective helped to make sense of the nonsensical. Kondratieff disappeared in March 1931. One official (1937) source (which, if like the Party Conference notes, was notoriously unreliable) referred to his transportation to Siberia[10]. Solzhenitsyn (1974 footnote 24, p 50) referred to his placement in solitary confinement, where he became mentally ill and died.

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[10] Soviet Russian Encyclopaedia, (1937) second edn, Vol V, Moscow, pp 743-4.

However, Solzhenitsyn referred to the "whole TKP trial being called off" except for the leaders, and referred to Kondratieff being "hauled in". But Kondratieff, was an important witness in the Mensheviks trial, thus he was most likely to *already* have been in custody. The usual custom was to treat witnesses and defendants equally disdainfully, and to hold witnesses in jail for about 10-12 months before any trial. The implication was that Kondratieff was probably in custody before July 1930, and not the Autumn (Fall) as indicated by Garvy (1943 pp 204-5) as there were two waves of arrests, one around February/March and the other in July 1930.[11]

A suggestion is that Kondratieff was probably arrested not long after the December 1929 purge, possibly sometime after February but before July 1930. The reasoning behind this is that, the neo-narodniks were arrested *before* the Mensheviks, and Groman was not arrested until July 1930,[12], so again suggesting Kondratieff was already in custody. It was common for witnesses to be in jail for some time, and easily a year, in order to give them time to think and to break down their resistance. Kondratieff was scheduled to be called as a witness in March 1931, because he referred to having had time to think over (Stalin's) general line. Witnesses (there were only prosecution ones) and defendents were treated equally badly and he was classed as both. He probably was transported to Siberia. Possibly soon after March 1931 like many thousands, but unlike some narodniks (such as Makarov) he did not resurface following Stalin's death in 1953. There was nothing to suggest a lack of strength of character to indicate mental instability, just the opposite. It is possible he may have survived until about 1937 when he was one of those shot in one of Stalin's most massive purges, over 1936-8, the bloodiest period. The most likely time for this to have occurred was July to December 1937, when many thousands held in previous purges were shot. Getty (1985) referred to this period as being the worst and stated:

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[11] Reference to arrests in February-March 1930, page 115, 118 in Kondrat'evschina, but these notes are not always reliable.

[12] Jasny (1972) refers to Menshevik arrests then, including Groman's.

"former members of the opposition movements and officials working in economic-related fields were particularly exposed."

Getty (1985) p 174

Kondratieff's name is still identified with the theory of long cycles. He was not the first long theorist but was the first to provide:

"The most complete treatment of long cycles, as far as empirical content goes, ... who applies the modern methods of statistical technique"

Kuznets (1930) p 263

2.3 TRAILING KONDRATIEFF'S FORMULATION OF THE LONG CYCLE HYPOTHESIS

Kondratieff's initial hypothesis was formulated into a theory of long cycles in responses to official criticism in contemporary reviews of his work in Russia in the 1920s. Kondratieff was heavily criticised regarding any hint that capitalist systems passed through both decline and recovery phases. The politically correct view was that of decline only. His point in 1926 was a masterly understatement[13]:

"The idea of the existence of long cycles in economic conditions that I expressed in 1922 has encountered, in our country, a rather negative attitude in the literature."

Kondratieff (1928/26), (1984) p 31

Trotsky (1921, 1923) over the same early period, early 1920s, also formulated a long cycle view, a capitalist curve of 50 years. He identified 5 *historical* (as opposed to Kondratieff's *cyclical* ones) long periods (1781-1921) in capitalist society. He

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[13] Where he stated "in 1922" he was probably referring to "The World Economy and its Conjunctures During and After the War," Vologda, 1922.

characterised these as alternating periods of acceleration and retardation of growth. Whether the period was boom or decline was dependent upon *exogenous* conditions (and not *endogeous* as characterised by Kondratieff) centred around "superstructural" major crises, wars and revolutions, and the aquisition of new lands and new discoveries of resources.

Trotsky (1921) asserted:

> *"The war has destroyed capitalist equilibrium all over the world, thus creating conditions favouring the proletariat, which is the fundamental force of the revolution."*
>
> *Trotsky & Varga (1921) para 37, p 18*

Trotsky's fifth period, after the First World War, was the one he identified when capitalist systems were to be destroyed. Trotsky (1921), indirectly aimed at Kondratieff, as a social democratic bourgeoise:

> *"Social Democrats hinder the actual development of the revolution by rendering all possible assistance in the way of restoring the equilibrium of the bourgeois State, while the Communists, on the other hand, are trying to take advantage of all measures and methods for the purpose of overthrowing and destroying the capitalist government and establishing the dictatorship of the proletariat."*
>
> *Trotsky & Varga (1921) para 37, p 18*

In 1922, Kondratieff aged 30,[2] outlined the initial hypothesis on long cycles which he had formed over the short period 1919-21. As discussed earlier, this was done without the knowledge of the investigations of the Dutch socialists of De Wolff (1924) and van Gelderens (1913) and the striking similarities may well be attributed to the common influence of Tugan-Baranowsky. Kondratieff's hypothesis was propounded in a section

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[2] Jasny(1972) pp 158-78. Kondratieff's date of birth was given as 1892.

of economic conditions pre-and post-(First) World War stating:

> *"The dynamics [the movement] of the world conjuncture is rhythmical.... We have to distinguish two main kinds of cycles: a big cycle that covers about fifty years, and a short industrial cycle covering usually from eight to eleven years."*
>
> *Kondratieff (1922) p 242 reported in Kuznets (1930) p 262.*

and,

> *"We consider the long cycles in the capitalist economy only as probable"*
>
> *Kondratieff (1922) p 242 cited Kondratieff (1935/25) p 115*

Trotsky's (1923 p 273-80) subsequent long cycle formulation was particularly directed towards Kondratieff's work, building on the foundation of Marx's 10 year business cycle he asserted Kondratieff's extension of such cycles to long periods was a:

> *"symmetrically stylised construction...... [and an] obviously false generalisation* [and] *their character and duration are determined not by the internal interplay of capitalist sources but by those external conditions through whose channel capitalist development flows."*
>
> *Trotsky (1923) pp 276-7*

Varga argued (1924):

> *"Only the social democrats must see the future of capitalism in a rosy light, for their whole policy is built upon the continuance of capitalism."*
>
> *Varga (1924) p 56*

In 1924, Kondratieff studied the role of the cyclical process in economics, and later published (Kondratieff 1924) in a supplement to his regular Economic Bulletin of the Conjuncture Institute, the results of his statistical investigations. This was re-presented

(Kondratieff 1925) to become the basis of his best known paper (Kondratieff 1935/1925). Initially the 1925 paper was translated from Russian into German (Kondratieff 1926) and later summarised into English without all the actual tables, but with some graphs (Kondratieff 1935/1925). The 1935 publication in the West of Kondratieff's 1925 results became the best-known paper by him published outside of Russia. Garvy[3] published his translations from the Russian, of Kondratieff's other papers and some of the contemporary criticisms that Kondratieff faced. Garvy (1943 p 204) referred to the 1935 publication in English as Kondratieff's "first" paper, (Kondratieff 1935/1925) which built directly on his 1924 work, but there were also earlier papers and supplements published. Kondratieff's work reached a very receptive, Western audience but it was universally criticised by other Russian economists and colleagues at Moscow's Conjuncture Institute for not providing an explanation of "the origin and and dynamics" of long cycles.

Kondratieff identified 3 types of cycles: he was fully aware of Kitchin's (1923) "short" cycle of three and one half years' length and referred to an "intermediate" cycle of 7-11 years which also was of long-standing knowledge. However, Kondratieff proceeded to propound the existence of a fifty year "long" cycle. His first, second and third order equilibria, drew from Marshallian concepts and corresponded to varying spans of wavelike movements, with the third order equilibrium level representing the long cycles.

In 1926 Kondratieff's views were being expressed and clarified in forums of debate prior to the 1928 publication of the 1926 investigations (Kondratieff 1928/26), which Garvy referred to as the "second" paper, and which contained a criticism or rather, a

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[3] Garvy, George born in Riga, Russia in 1913 was educated at the Universities of Berlin, Paris and Columbia. He joined the National Bureau of Economic Research and later became Chief of Research at the Federal Reserve Bank of New York. He published his English translations of Kondratieff's work, at age 30 years, the same age as Kondratieff when he first published his long cycle views.

"counter-reply" by Oparin with others. Kondratieff (1984) is a translation of Kondratieff (1928/26) with additional material. Kondratieff (1928/26) reaffirmed his tentative explanation of long cycles making only minor changes and included extended statistical material to cover the postwar (First World War) period. Kondratieff was categorical:

> *"I certainly do not claim that I can now offer such a theory ..... What I intend to set forth briefly infra is merely a first attempt - a first hypothesis - to explain those cycles."*
>
> *Kondratieff (1928/26), (1984) p 89*

He reaffirmed it was the internal cyclical movements which generated the long swings, the endogenous variables were the consequences and not the external causes of long cycles as argued by Trotsky, Oparin and others, who Kondratieff said took an idealised point of view. Kondratieff (1928/26) was even more vehemently criticised in Russia, there was criticism over Kondratieff's choice of time series and the implied functional relationships. Indeed, Oparin, with the aid of nine assistants presented a paper to the Economic Institute a week later, disparaging Kondratieff's:

> *"sources, methods and conclusions"*
>
> *Oparin (1928) cited by Garvy (1943) pp 204-5*

Kondratieff (1928/26) did not accept that each long period was a unique historical one, as Trotsky argued. He asserted that some recurrences were cyclical. He pointed out that Trotsky:

> *"while not denying the existence of long waves in economic conditions, refused to recognize their patterned, cyclical character, and regards them as the result of adventitious (and, in that sense, random) circumstances of an economic and political*

nature."

Kondratieff (1984) p 31

He reminded Trotsky of one of his earlier publications[4] which Kondratieff asserted:

> *"gave grounds for thinking that he [Trotsky] recognized the existence of long cycles."*
>
> *Kondratieff (1984) p 31*

Kondratieff's final paper, (Kondratieff 1928b) on agricultural prices, (Kondratieff also advised at the Agricultural Academy) included the explanations on long cycles given in Kondratieff (1928/26) again. This was the last identifiable publication on long cycles by Kondratieff before he disappeared in March 1931, immediately after the Menshevik Trial.

The official Stalinist line (1929) regarding any hint that capitalist systems passed through both decline and recovery phases was summed thus:

> *"This theory is wrong and reactionary."*
>
> *Soviet Russian Encyclopaedia, Moscow (1929), vol IV, p 133*

But Motyleff (1923) stated:

> *"If there are Marxists who deny the cyclical character of the long cycles, this can only be imputed to their insufficiently profound analysis of the evolution of the capitalist society during the nineteenth century."*
>
> *Motyleff (1923), p 156-7 cited by Garvy (1943) p 212*

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[4] Kondratieff (1984) p 31, referred to Trotsky's article "Russia's New Economic Policy and the Prospects for World Revolution".

Schumpeter (1939) acknowledged Kondratieff's contribution to long cycles development and stated:

> *"It was N D Kondratieff, however, who brought the phenomenon fully before the scientific community and who systematically analysed all the material available to him on the assumption of the presence of a Long Wave, characteristic of the capitalist process."*
>
> *Schumpeter (1939a) p 164*

2.4 KONDRATIEFF'S METHODOLOGY AND STATISTICAL INVESTIGATIONS

The remaining sections in the chapter examine Kondratieff's methodology and statistical investigations, followed by a critique and summaries of long cycle tables, and the trend problem noted.

Kondratieff identified the presence of long cycles, from 47/48-60 years, 1.5 to 2.5 long cycles. Kondratieff formulated his theory of long cycles over two main papers and a number of supplements, bulletins, agricultural economic papers and in responses to contemporary criticisms where he clarified his earlier thinking. These writings provided clues regarding some of the conclusions drawn in his best-known (in the West) the 1935 paper of his 1925 results. The paper (Kondratieff 1935/25) was not completely forthcoming on all aspects of the investigations, probably because his environment was not receptive enough to offer much in the way of constructive comments to aid the development of the theory.

Kondratieff stated:

> *"the dynamics of economic life in the capitalistic social order is not of a simple*

and linear but rather of a complex and cyclical character"

Kondratieff (1935/25) p 105

and:

> *"It is clear to everyone that given the present state of our knowledge, the problem of explaining long cycles is extraordinarily difficult. ....[setting out a first hypothesis of long cycles]. ..... I shall be grateful for all criticisms directed against that hypothesis."*
>
> *Kondratieff (1928/26), (1984) p 89*

He had mainly British and French and some American data, available to him, grouped into value series such as interest rates, wages for agricultural and textile industries, bank deposits; series of a mixed nature of both value and physical factors, such as foreign trade; and physical series such as commodities like wheat, cotton, and production, like pig iron and coal. He drew on 8 British, 14/16 French and 7/8 US series,[5] some dated from the 1770s. Altogether, there was no more than 140 years in any one data series, and much less in some cases. The English data, although represented in fewer series, was the most complete and went back further, it is detailed in Table 2.2 later.

Kuznets (1930 p 263) found that Kondratieff was one of the first theorists to set about the establishment of the existence of long cycles by applying statistical techniques to empirical data on price, value and production series. Kondratieff identified data series in terms of containing trends and wave-like movements. His concern expressed over trend identification and elimination has remained unresolved by current long theorists. He found secular trends in "physical series" which had to be eliminated so he:

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[5] Kondratieff (1928/26) and (1984) provided clues to further data series. This also gave fuller tables than the English translation Kondratieff (1935/25) of the 1924 and 1925 investigations.

> *"divides the annual figures by the population, whenever this was logically possible, in order to allow for changes in territory. Then the secular trend was eliminated by the usual statistical methods"*
>
> *Kondratieff (1935/25) p 105*

So generally, Kondratieff's methodology was to divide most of the physical series by population figures, and used the (ordinary) least square method to fit a trend curve to all the (physical and price) data. Then, to eliminate the short- and medium-term cycles and any potential random fluctuations, the deviations from the secular trend was smoothed by a 9-year moving average. What remained was therefore the residual representing the long cycles. The Kondratieff's inferred Marshallian assumption being that the neighbourhood of equilibrium did not change significantly in capitalist societies, the third order equilbria indicative of long cycles.

The price data included the wholesale prices English data[6] based on the indices of Sauerbeck, Siberling and Jevons. The wholesale prices commodity data was indexed to a base decade of 1901-1910 at 100 and he found in the unsmoothed, untreated commodity prices index, 3 cycles.

The interest rate data was based on government interest-bearing bonds, that is, English consols and the French Rente. The data was found to contain secular trends and the deviations from the trend were again smoothed by a 9-year moving average. The rise in general business activity and the interest rate moved counter to the downward movement in bond quotations (the market price of bonds). Kondratieff found that the interest rate data shadowed the swings in the wholesale prices. Thus a fall in bond quotations (and rise in interest rates) was similar to the wholesale upswing, and the rise in the market price of bonds (and fall in interest rates) in the downswing. These interest rate cycles were confirmed by other English and French studies, MacDonald

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[6] The French, from the "Annuaire Statistique", Statistique Generale de la France, 1922 p 341 used the dollar-franc exchange rate on the gold basis.

(1912) and Lescure (1912).

Kondratieff examined the weekly wages[7] of workers in the English cotton-textile industry and in agriculture. He assigned the wages data, from 1789 to a gold basis and formed an index with 1892 as the base year. As with the interest rate, the wages were expressed as deviations from trend and smoothed with a 9-year moving average. He concluded that in the value group series:

> *"long waves are undoubtedly present in the movements of wages, the periods of which correspond fairly well with those in commodity prices and the interest rate."*
>
> *Kondratieff (1935/25) p 108*

In the mixed series, for foreign trade, he found less clear long cycles for England due to a number of peculiarities, such as the repeal of the Corn Laws and the occurrence of war with the Continent.

Kondratieff investigated the behaviour of physical series of production and commodities, such as the English production of coal, pig iron and lead, data based as before on Page (1919) and Statistical Abstracts for England. The figures were divided by the population figures (no source was mentioned for population). But in two whole-world series he did not explain why he failed to divide the series by the population, as previously. The deviations from the trend were smoothed by a 9-year moving average and then analysed. About 1.5 - 2 cycles appeared. The unsmoothed coal peak at 1873 conformed with the cycle upswing in the value series before its turn and the decline similarly troughing around 1890-94.

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[7] Kondratieff's data was based on G H Wood's "The History of Wages in the Cotton Trade" 1910 and the Abstract of Labour Statistics. Also, A Bowley's "The Statistics of Wages in the UK During the Last Hundred Years: Part IV, Agricultural Wages" Jrnl of Royal Statistical Society, LXII, 1899 and W Page's "Commerce & Industry" vol 2, 1919.

Based mainly on English data, Kondratieff concluded for the physical series, and which certainly held true for the production series, their periods coincided with the value series, so that 1.5 to 2 long cycles:

> *"stand out rather clearly."*
>
> *Kondratieff (1928/26), (1984) p 55*

However, the commodity series such as wheat, sugar, cotton and coffee did not display similar long cycles. Also, the commodity data was based on French and US sources which was not as complete as the English data. Combining all the known English data series across his publications, the findings were thus[8]:

Table 2.2 Kondratieff's English data series

ENGLAND	**First**	**Cycle**	**Second**	**Cycle**	**Third**	**Cycle**
	min	max	min	max	min	max
PRICES	1789	1814	1849	1873	1896	1920
INTEREST RATE	1790	1816	1844	1874	1897	1920*
WAGES-AGRIC	1790	1815~	1844	1875	1889	1921*
WAGES-TEXTILE		1810	1850+	1874	1890	1921*
FOREIGN TRADE		1810	1842+	1873	1894	1920*
COAL PRODN			1850	1873	1893	1914
PIG IRON PROD				1871#	1891	1918*
LEAD PRODN				1870	1892	1916*

min denotes the lower turning point, to commence the rise
max denotes the upper turning point, the start of the fall

---

[8] Kondratieff (1935/25), extract from Table 1, p 109, Kondratieff (1928/26), Garvy (1943), extract from Table I, p 206-7.

~	approximately 1812-17.
+	other min falls in 1835 (wages) indicated only in (1935/25) paper, 1837 and 1855 (trade).
#	other max falls in 1881.
*	denotes slightly different turning point of 1-2 years to the one given in the (1935/25 p 109) paper. Occurs in the max of the third cycle. Greatest change from 1914 for Foreign Trade, but still falls within Kondratieff's standard of error of 5-7 years.

To identify the turning points Kondratieff used the unsmoothed rather than smoothed data as probable approximations for the real turning points. To determine the minima and maxima, he observed, merited special consideration without offering anything more than the turning points were:

> *"only as the most probable and ..... closest approximations to the real ones."*
>
> *Kondratieff (1926), footnote 24 p 588*

The standard of error allowed 5-7 years in the turning point and gave the following dates:

Table 2.3 Kondratieff's long cycle turning points

up-swing	**down-swing**	**up-swing**	**down-swing**	**up-swing**	**down-swing**
1780-9	1810-17	1844-51	1870-75	1890-96	1914-20

Despite contemporary criticism (Oparin 1928) and Garvy (1943), later studies tended to support the turning point dates, which showed remarkable consistency, and all fell within the allowed standard of error. The studies included De Wolff (1929), von Ciriacy-Wantrup (1936), Schumpeter (1939), Clark (1944), Dupriez (1947, 1948 cited by van Duijn (1983)), Rostow (1978), Mandel (1973, 1980), van Duijn (1983) and Kleinknecht (1983, 1987). Mandel provided the closest fit to Kondratieff's original timings.

However, the most problematical date was the end of the Third Kondratieff and the beginning of the Fourth. Debate has ranged around broadly three dates, 1932, (supported by a Princeton study only, based heavily on USA data), 1939 and 1948. In summary, van Duijn is amongst those who support 1948, Mandel considered both 1939 and 1948 but Kleinknecht in a study on average rate of growth differences in long upswings and downswings, by Bieshaar & Kleinknecht (1983), found 1939 generally more suitable. In the classification of long cycles proposed and future later, Table 2.6, the end of the Third Kondratieff, start of the Fourth is estimated in the thesis at 1939.

2.5 CRITIQUE AND CONCLUSIONS TO KONDRATIEFF'S METHODOLOGY AND STATISTICAL FINDINGS

2.5.1 Kondratieff's methodology and statistical findings critiqued

Kondratieff hypothesised long cycles in economic life and illustrated long cycles of 48-60 years based on almost 140 years of data, equivalent to 2.5 cycles. Kondratieff's theory incorporated social, political and technological factors ranging from population, inventions to war, beyond straight economic ones. Kondratieff's findings were that long cycles occurred regularly, particularly in the price and value time series, albeit with some variation in length. Logically, he pointed out, "strict periodicity" in any case, did not occur in socio-political and economic factors. Kondratieff further found that differing series showed some similarity in fluctuations and there was some international correlation.

The timing of Kondratieff's turning points corresponded closely across the unsmoothed series, and allowed for 5-7 years standard deviation in the dates. However, there was some inconsistency in identification of cycles across the series types of physical and value, even so, they still fell within the allowable boundary set. Oparin asserted that adding more post-War data, 20-30 years, displaced Kondratieff's long turning points and cycle amplitude. His (1928) reworking of Kondratieff's statistics found different turning points, but others carried out a similar exercise and did not. Other and later evidence supported some of Kondratieff's turning points, for instance, Gayer, Rostow & Schwartz (1975a p346, 356) supoorted the 1848 one. However, Garvy (1943) accused Kondratieff of bias in the turning point dates in the price series data. The determination of turning points did tend to be dominated by the price rather than the production (physical) series. However, Schumpeter's (1939) contribution similarly relied more heavily on price and value series. As discussed earlier, in the Methodology and Statistical findings, the other studies given tended to support Kondratieff's cycle dates and the turning points showed remarkable consistency, within the allowed standard of error.

One of the other contemporary critics, Bogdanov (1928) accused Kondratieff of statistical manipulation and simply could not countenance Kondratieff's long cycle independence from short business cycles, he thought Kondratieff must have selectively included business cycles to achieve this end. Also, Bogdanov thought nonsensical the notion that the peak of a long cycle, for instance, occurred at the same time as a business cycle trough. This is dealt further under Swing Phases in the next section.

There was another common criticism laid against Kondratieff's finding of long cycles by Oparin and others (for instance, Granovsky 1929, Gerzstein 1928 and Garvy 1943). The criticism was that whilst Kondratieff was able to show long cycles within national time series, he was not able to do so globally, although there was some limited international similarity. The problem with this criticism is that the Russian Marxists appeared to have treated the capitalist societies as *one* entity, without allowing for differing accelerated or retarded growth rates nationally. The general perception was that if a long downswing was shown in a British time series then the timing and amplitude should be matched and not just similarly reflected in the USA and other capitalist societies.

Some series evidenced no long cycles: Kondratieff (1935/25) stated he found it impossible to establish long cycles in French wheat and cotton consumption, (also coffee and sugar) and in the US wool and sugar production. The inference was that of the 25 time series studied, there were 6 which produced negative results. However, it does seem there was some error or loss in translating Kondratieff's work from Russian (1925), to German (1926), to English (1935). Because at the time the paper was published in the original Russian in 1925, in Voprosy Conjunktury, the abstract in English there referred to 5 more physical series which evidenced no long cycles. The 1984 translation of (Kondratieff 1928/26) results provided a fuller picture of the time series investigated.

Garvy (1943) suggested:

> *"the evidence of long waves is certainly less convincing"*
>
> *Garvy (1943) p 208*

with the fuller inclusion to incorporate more negative results. Nonetheless, this does not necessarily make Kondratieff's theory of long waves less powerful for a number of reasons supplied after the table below. In any case, Kondratieff stated:

> *"I note, however, that we studied other data as well.... some of them did not exhibit them [long cycles] with as much clarity as the data examined above."*
>
> *Kondratieff (1984) p 58*

Drawing together from the known, available sources, Kondratieff (1935/25) results, (1928/26) and extracts from 1984 translation, the following summary is made:

Table 2.4 Summary of Kondratieff's known results

COUNTRY & SERIES	CLEARLY EXHIBITED LONG CYCLES	LESS CLARITY	NO LONG CYCLES	UNKNOWN
ENGLAND (8)				
VALUE (4)	4			
MIXED (1)		1		
PHYSICAL (3)	3			
FRANCE (14)				
VALUE (5)	2	2		1
MIXED (2)		2		
PHYSICAL (7)	1	1	5	
REST OF WORLD(10)				
VALUE (1)				1
MIXED (0)				
PHYSICAL (9)		9		
TOTALS (32)	***10***	***15***	***5***	***2***
VALUE (10)	6	2		2
MIXED (3)		3		
PHYSICAL (19)	4	10	5	

Notes: The Rest of the World refers to mainly USA (7), Germany (1) and Worldwide (2) series.

2.5.2 Concluding critique on Kondratieff's findings and summaries of long cycle tables

Generally, criticism was aimed at the variability to the length of Kondratieff's long cycles, which he concluded varied from 47/8-60 years. But gathering long data series for this thesis revealed very long periods in the data where there was little change in price and volume. Then periods of sudden spurts in changes. An explanation for the varied long cycle lengths is the rate of change. A period of faster change or growth *speeds up* the velocity of the cycle so more ground is covered in a shorter time space, giving a *shorter length* to the long cycle. Einstein's theory of relativity hypothesises the shortening in length with speed increase. Slower change impedes the cycle thrust, therefore producing a longer length to the long cycle. Even medieval society underwent periods of rapid change, to meet the demands of war, or a period of fast-growing population outstripping land availability. A different implication, is that long cycles could be getting shorter.

The fuller inclusion of negative results implied Kondratieff's conclusion regarding the existence of long cycles lacked rigour. He faced the common criticism that the production series did not display long waves. Also, once inflation was removed from the foreign trade series, they did not show long waves either; it was really only the price and interest rates (value series) which did.

However, the reasons for holding that fuller inclusion of non-cyclical exhibiting data series do not render Kondratieff's conclusion of long cycles less valid are these. Firstly, because it is not necessary for *every* data series to contain long cycles, there seems to be sufficient coincidences in movements. It is difficult to dismiss the existence of long cycles when 25 from 32 series (Table 2.4) display some clarity of long cycles, one third are value and two thirds are physical series. Secondly, all the English data Kondratieff investigated showed long cycles. Much of the long series data will have omissions, estimates and errors. The English data albeit with its shortcomings was more "accurate" than the US and French data and both countries underwent violent revolutions during the period, with moving terrritorial boundaries and population. Also, Kondratieff found secular trends in the "physical series" which had to be eliminated and so divided the annual figures by the population. It was particularly the physical series in these countries which displayed less clarity in long cycles. Forrester (1978) though identified via modelling that long cycles were visible in physical or rather, volume data particularly the increased volume demanded impacting on the capital equipment sector.

Kondratieff's data covered from 1.5 to 2.5 long cycles and he found similarity and simultaneity in the long movements, and between value and physical series. These possessed the characteristic of regularity in terms of:

> *"repetition in regular time intervals"*
>
> *Kondratieff (1935/25) p 112*

Van Duijn (1983) commented:

> *"The lengths of cycles vary considerably and so does their severity. Yet they are self-repeating,"*
>
> *van Duijn (1983) p 3*

Kondratieff did not conclusively assert the existence of long cycles but showed it was difficult to definitely assert that no such long cycles exist:

> *"On the basis of available data, it may be assumed that the existence of long cycles in economic conditions is very probable."*
>
> *Kondratieff (1928/26), (1984) p 89*

Other theorists commenting on Kondratieff, Kleinknecht (1987), acquiesed on it being called the "Kondratieff long wave" but referred to it as:

> *"the alleged 45-60 year cycle"*
>
> *Kleinknecht (1987) p 2*

Mandel (1980), offered a new-look Marxist interpretation of long cycles (waves):

> *"in capitalist development (which) can hardly be denied in the light of overwhelming evidence." [in terms of] the rate of profits determining, in the last analysis, quicker and slower long-term paces in capital accumulation (of economic growth and of expansion in the world market),"*
>
> *Mandel (1980) p vii,viii,2*

Solomou (1987) was dismissive of Kondratieffs and suggested:

> *"the existence of episodic disturbances rather than waves."*
>
> *Solomou (1987) p 170*

Kindleberger (1989) referred to Kondratieffs as:

> *"the more dubious and elusive ....cycle"*
>
> *Kindleberger (1989) p 17*

Such long cycles may be dated loosely. Clearly there is a problem with the lengths of Kondratieffs because even amongst those theorists that favour long cycles, there may be as much as 10 years difference in agreement at the start or end of a cycle.

Table 2.5 Long cycles dated - past consensus

ENGLAND	**First**	**Cycle**	**Second**	**Cycle**	**Third**	**Cycle**
	60	**Years**	**47**	**Years**	**43**	**Years**
INDUSTRIAL REVOLUTION	1789	1849				
AGE OF STEAM & STEEL			1849	1896		
ELECTRICITY, CHEMISTRY & M. VEHICLES					1896	1939

Given that the findings of long cycle theorists are generally inconclusive, and that there are problems with long dating agreement, the hypothesis for no Kondratieffs of 47/48-60 years but shorter long cycles is explored in the later sections.

Such long cycles are hypothesised thus, Kondratieff also anticipated the downswing of a depressionary/recessionary period at the end of the century:

Table 2.6 Long cycles dated - proposed and future

ENGLAND	**Fourth**	**Cycle**	**Fifth**	**Cycle**	**Sixth**	**Cycle**
	38	Years	29	Years	26	Years
AGE OF MASS PRODUCTION, NUCLEAR AGE	1939	1978				
MOBILITY IN INFORMATION & COMMUNI-CATION			1978	1997		
MOBILITY ADVANCES & OCEAN TECHNOLOGY					1997	2023

Notes: 1. Troughs are estimated 1932-37, 1966-72, 1986-94 and peaks, 1950-62.
2. The hypothesis for no Kondratieffs of 47/48-60 years but shorter long cycles are explored in the later sections.

2.6 THE TREND PROBLEM

Kondratieff was fully aware of the trend problem, which could either wipe out or cause long cycles to be visible. His method of breaking the time series data into trend and cyclical movements inferred independence of the varying fluctuations and was clearly in keeping with the accepted mathematical techniques of his day. Contemporary critics mistakenly referred to interdependence and could not uphold the view that a shorter (business) cycle rise could coincide with a longer cycle fall. But the leading mathematician, Cournot (1897) stated:

> *"it is necessary to recognise secular variations, which are independent of periodic variations"*
>
> *Cournot (1897) p 25*

However, regarding Kondratieff's methodology in de-trending and smoothing the data, the problem, with hindsight, regarding the choice of moving average period. Slutsky (1937) showed that the length of moving average selected in order to remove cycles of shorter duration impacted on the shape of the cycle. Jevons found this to his embarrassment some sixty years earlier, reviewed under the Harvest Theories section. Further, Slutsky was one of the first to particularly illustrate how cycles can emerge from sets of random numbers by manipulation of the moving average.

Kondratieff's de-trending choice and technique availability at the time, possibly contributed to his failure in some series to consistently identify long cycles, and is evaluated further. A number of other long theorists' methodology is drawn upon for some comparison.

Imbert (1959) used a similar trend process to Kondratieff, but the difference was that he suggested a log transformation before the trend was fitted. He also gave the criteria for selecting the basis for the trend specifications, and found the secular trend to be an S-shaped logistic curve, to be dealt with as follows: Reijnders (1990) citing Imbert directly:

> *"one must adapt the mathematical specification of the trend to be fitted to the shape of the logistic in the interval covered by the data. If the data series covers a part of the logistic curve which is close to the lower or upper asymptote, a hyperbolic function is adequate. Coverage of the convex or concave parts implies the choice of a parabolic function, whereas coverage of the central part around the inflection point*

suggests a straight line."

Imbert (1959) pp 86, 93 cited by Reijnders (1990) p 87

However, Reijnders reported that Imbert did not in fact adopt his own advice, finding it too laborious.

Van Duijn (1983 pp 20-44) argued that the trend in long cycles was not log linear and implied a constant growth. He suggested his S-shaped life cycle which could span more than 200 years should be applied in identifying long cycles. However, he found this supplied mixed results when applied to Kondratieff's first three cycles.

The adoption, as Kondratieff did, of the ordinary least square estimates of interval growth rates uses the average characteristics of the time series interval to provide an unbiassed, consistent estimate of the rate of growth. However, the existence of shorter cycles means that generalised least squares via a conformity test should be produced along with significance tests. Kleinknecht (1984, 1987) did just this although he maintained a non-committal stance on the existence of long cycles.

Other long cycle theorists continued to have problems in actually identifying the existence of long cycles. Reijnders (1990) was highly critical of the methodology of binary splits used by some long theorists, which he said was not suitable for coping with the problems of trends and was "no more than cosmetic" and more of a short-term approach to the trend problem. He suggested another approach. This approach confronted the idea of perspectivistic distortion. It required a standardisation procedure to correct for the distortion in the residuals of series of differing lengths and also to set up stationarity conditions to enable the application of spectral analysis.

Spectral analysis was applied with mixed results for the existence of Kondratieffs by a number of theorists: Kuczynski (1978), van Ewijk (1982), Haustin & Neuwirth (1982), Reijnders (1990). Metz (1984a,b), Gerster (1987) advocated filtering techniques in preference. The inconsistencies produced by spectral analysis were attributable to a number of factors. For instance, its particular sensitivity to the trend elimination process. Also, most of the later studies adopted aggregate data, which did not readily lend itself to the subtleties of a spectral approach. Aggregates do not have very long data series, 1.5 to 3 cycles at best. The thesis adopts non-aggregate data, preferring specific production data which can be identified historically over much longer periods. Spectral analysis, it was generally conceded, was a suitable method for testing waves if up to 10 cycles of data was available, (Kleinknecht 1987 pg 17, van Ewijk 1982 pg 476, Soper 1975 pg 575, Granger & Hatanaka 1964).

The trend elimination was problematical for Kondratieff and continues to be so for current long cycle theorists. No matter how sophisticated the modelling for the existence of long cycles, the method selected in trend elimination can potentially remove all traces of the long cycle. Reijnders overturned van Ewijk's findings of no Kondratieffs because of this. The use by later theorists of applications requiring standardisation procedures continue to face de-trending problems. Economic data has to be made stationary, but in doing so, the de-trending process can muddy the picture.

In conclusion, many long cycle theorists, as shown, were non-committal on Kondratieff long cycles. Reijnders stated, with some qualification though:

> *"the Kondratieff wave cannot be regarded as an illusion. There is substantial evidence to the contrary which demonstrates that long waves of the Kondratiff type do exist."*
>
> *Reijnders (1990) p 241*

Kondratieff's theory of long cycles propounded that major changes preceded the long upswing, that certain characteristics were identified endogenously. Kondratieff referred to this in terms of changes in inventions, gold production, colonialism and wars. Schumpeter (1939) built on Kondratieff's long cycle characteristics and stressed particularly the role of innovations, with the other features such as wars, gold discoveries and agricultural failures as *exogenous* rather than endogenous variables as postulated by Kondratieff. Such changes, "empirical patterns" generally occurred as prelude to the long upswing, except for wars which tended to occur in its sweeping rise. The validity of these characteristics are evaluated in more detail in the following section, particularly the characteristic of inventions which has been an enduring theme of current long cycle theorists in the 1980s.

CHAPTER 3

KONDRATIEFF'S CHARACTERISTICS OF LONG CYCLES

3.0 INTRODUCTION

This section examines the long cycle characteristics identified by Kondratieff. In particular, the long cycle characteristic of inventions. It is a feature which has proved to be an enduring theme with cyclical theorists, from the early 1900s to the 1990s.

Kondratieff hypothesised long cycles in economic life and showed the equivalent of 2.5 cycles, 48-60 years, based on almost 140 years of data. He found long patterns particularly in the price time series.

The essence of Kondratieff's theory of long cycles is summed thus: capitalist production was characteristic of *cyclical* long upswing and downswing phases, the long upswing was preceded by major changes in the *endogenous* factors of swing phases, inventions, wars, gold production and colonialism. Kondratieff's theory rested upon these endogenous factors as characteristically "passive manifestations" of long cycles not its causal factor. He empirically identified the characteristics of long cycles, but failed to describe the generators of the changes to those endogenous factors.

Schumpeter (1939) built on Kondratieff, and also located innovations as central to long cycle development. He, however, regarded the variables as exogenous, external, to the machinations of the capitalist system.

Forrester (1978) on innovations argued that since the 1800s:

> *"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."*
>
> *Forrester (1978) p 130*

3.1 CHARACTERISTIC STATISTIC OF INVENTIONS

Innovations, or inventions, as Kondratieff referred to them, have proved to be a more enduring theme than the other characteristics with long cycle theorists, thus innovations are considered in more detail than the other characteristics. Modern long cycle theorists are still debating the clustering or non-clustering of innovations.

Kondratieff (1928/1926) found in his empirically-derived long cycles, the rising phase [wave] of the cycle was:

> *"preceded by very great changes in the conditions of economic life, especially in the sphere of technics."*
>
> *Kondratieff (1928/26), (1984) p 67*

and that the "invigoration in the sphere of technical inventions" was observed:

> *"During roughly the first two decades before the beginning of the rising wave of a long cycle,"*
>
> *Kondratieff (1928/26), (1984) p 68*

Innovations continued to occupy the minds of modern long cycle theorists in the 1980s-1990s with the Dutch socialists identifying the importance of inventions in economic fluctuations as far back as 1913, with van Gelderen.

3.1.1 **Inventions as an endogenous occurrences**

Kondratieff found inventions and the development of new techniques occurred more frequently in the long downswing. However, they remained unexploited until the long upswing commenced. Kondratieff asserted such inventions formed part of the natural rhythm of the cycle, part of its economic fundamentals and could not easily be regarded as external (exogenous), random occurrences:

> *"First, I emphasize its [inventions] empirical character: as such, it is lacking in precision and certainly allows of exceptions. Second, in presenting it I am absolutely disinclined to believe that it offers any explanation of the causes of long cycles."*
>
> *Kondratieff (1928/26), (1984) p 69*

he asserted he characterised the *course* of long cycles. Another reason why innovations were endogenous to the cycle, was the frequency of the development of similar inventions in different countries at the same time.

Kondratieff believed that as inventions were endogenous, they must in effect "spring from economic necessities" (Kondratieff 1925). Further, that profit must be the prime motivator for their exploitation. In Kuznets' (1930) findings on long-intermediate swings, he similarly identified profit as being the main mover. Although Trotsky (1923) and Mandel (1980) had a different interpretation of the profit element. This was to move the long swing downwards as lower profits were generated, inferring no inherent recovery mechanism:

> *"endogenous factors alone cannot explain the upward turning point of the long waves."*
>
> *Mandel (1980) p 61*

Kondratieff (1935/1925) stated:

> *"Scientific-technical inventions in themselves, however, are insufficient to bring about a real change in the technique of production. They can remain ineffective so long as economic conditions favourable to their application are absent. This is shown by the example of the scientific-technical inventions of the seventeenth and eighteenth centuries which were used on a large scale only during the industrial revolution at the close of the eighteenth century."*
>
> *Kondratieff (1935/1925) p 112-3*

Thus differing economic conditions over the cycle favoured their greater or smaller pursuit and application. Discoveries were placed on "hold", until the time was right for exploitation. Kondratieff (1935/1925) argued:

> *"During the recession of the long waves, an especially large number of important discoveries and inventions are made, which, however, are usually applied on a large scale only at the beginning of the next long upswing."*
>
> *Kondratieff (1935/1925) p 111*

and in the rising long upswing:

> *"we observe the broad application of these inventions in the sphere of industrial practice due to the reorganisation of production relations."*
>
> *Kondratieff (1928/26), (1984) p 68*

Although inventions were made during the recessionary period of the long downswing, they were not applied until the next rise, and that different (cheaper) production methods were also required to ensure exploitation of inventions. The modern Marxist interpretation concurred with this view, and Kondratieff's cost cutting exercise, Mandel (1980):

> *"In order for innovation to follow invention, important reductions in costs (gains in productivity) must be accompanied by the possibility of mass production (i.e.,*

rapid diffusion of the innovating commodities). Therefore technical progress can appear to slow down when the passage from invention to innovation becomes more difficult (i.e. less profitable)"

Mandel (1980) p 88

Schumpeter (1939) similarly identified the role of innovations in long cycles. However, he located them as central, and exogenous to the long cycle. He found the *contours of economic evolution* were made by a process systematically producing the alternating phases of prosperity and recession. He found the duration of such phases as they pulled away from one neighbourhood of equilibrium towards another to be dependent on a "number of elements". The most important element he found to be innovations, particularly their nature. Innovation when defined in terms of a new production function, Schumpeter suggested that:

> *"This covers the case of a new commodity, as well as those of a new form of organization such as a merger, of the opening up of new markets,", [and] combines factors in a new way,"*
>
> *Schumpeter (1939a) p 87-88*

In terms of money cost:

> *"the old total or marginal cost curve is destroyed and a new one put in its place each time there is an innovation."*
>
> *Schumpeter (1939a) p 89*

He was applying the Marshallian concept that a more rational division of labour or better organisation of factors can also be innovatory and not necessarily connected with a cost cutting exercise. Kondratieff's observation on the application of inventions similarly drew on Marshall and was:

> *"due to the reorganization of production relations."*
>
> *Kondratieff (1928/26), (1984) p 68*

The most striking proposition of Schumpeter's theory was that major innovations led to the rise of new "leading sectors". New factories, new businesses emerged and there were expanded order books on the basis of indefinite continuance of the rates of change. Speculation anticipated the prosperity to come by staging a boom. New borrowings were made by all, producers and consumers; and there was a presumption of rising prices.

Schumpeter found it hard to identify any *single* innovation to spark the ignition of the long cycle mechanism. Kondratieff did not comment either on the relative sigificance of inventions. Rather, Schumpeter identified, via historical references like Kondratieff, broad periods of innovation gathered under one umbrella, such as the railways boom. This fitted with Kondratieff's major capital investment programs and his third order equilibrium (third level equating to long cycle movements). Schumpeter allowed for a lengthy span in order for the innovations to be "up-and-running" and their subsequent impact on factors like the location of industry and population.

Schumpeter expanded on some unique features which were generally held about the different cycle phases. For instance, he asserted that during a recession phase, more errors (of judgement) were likely to occur because more innovatory untried methods were being applied. But later, he quoted a popular saying of the day:

> *" "there is more brain in business" at large during recession than there is during prosperity."*
>
> *Schumpeter (1939a) p 143*

Earlier, van Gelderen (1913), independently reached similar conclusions to

Kondratieff, innovation in fast-growing sectors pushed the long upswing, with leakage spilling over into affiliated sectors. Thus in Kondratieff's second cycle, the Age of Steam and Steel, the fast-growing railway construction sector spilled over into the steel and coal industries.

Kondratieff did not comment on the relative significance of inventions appearing more concerned with the frequency of occurrence, particularly their clustering. This is evaluated in the next section.

3.1.2 Inventions : clustering or continuous occurrences?

The debate surrounding the clustering or not of inventions is central to the interests of current long cycle theorists and so is evaluated in more depth than the other elements. Kondratieff (1928/26)'s long cycle theory was further propounded in terms of the *application* of inventions in the long upswing: The application of inventions led to the *expansion of capital goods,* which was not a continous process, it:

> *"does not take place smoothly but in spurts, and the long waves in economic conditions are another expression of that."*
>
> *Kondratieff (1928/26) p 60, (1984) p 93*

Briefly, the roots to this hypothesis originate in Marx's periodic reinvestment of fixed capital driving the intermediate (10 year) business cycles. However Kondratieff's argument was, this *reinvestment is not a continuous process* so for the large expansions to take place there must be *capital available in the upswing.*

The assertion of non-continuous reinvestment attracted contemporary criticism, the general opinion expressed typically by Gerzstein (1928) was that capital equipment was a continuous, if irregular, process and did not occur in spurts. Oparin's (1928) contemporary analysis on the clustering of inventions asserted that it also occurred in the long downswing, particularly in the period of the shorter business cycle upswing.

A modern Marxist interpretation, however, fits in more closely with Kondratieff's non-continuous, *endogenous* hypothesis. Mandel (1980) in the long upswing clearly followed Trotsky's exogenous factors line of argument, but in the downswing there seemed to be *implicit endogeneity.* Mandel (1980) drawing on Mensch (1975)'s frequency of basic innovations from 1740 to 1960, asserted:

> *"Economic history, in turn, confirms that the investment outlays for the first massive applications of these basic innovations generally occurred ten years later, after the turn from the depressive long wave to the expansionist long wave had already taken place."*
>
> *Mandel (1980) p 40*

and basic innovation occurred in "the depressive long wave", because there was:

> *"Accelerated research for new labor-saving and rationalization inventions."*
>
> *Mandel (1980) p 57*

This was more widely applied along with radical innovations in the "expansionary long wave" due to the higher profits and growth expectations:

> *"Rationalization investments (second phase of technological revolution, vulgarization of innovations, ..)"*
>
> *Mandel (1980) p 59*

Mandel expanded further:

> *"a beginning technological revolution, the start of new branches of industry, which guarantee huge technological rents (superprofits) for leading firms, slowly peter out when the technological revolution begins to be generalized. Generally, the turn*

from an expansionist long wave to a stagnating long wave is coupled, in the history of capitalism, with such turns from revolutionary introduction to general vulgarization of new techniques. Technological rents begin to become scarce. Prices of typical "new" products begin to fall under the impact of massive output and a return to competition. The computer industry is an excellent example of that trend."

Mandel (1980) p 85

Concerning the *decline* in the rate and impact of innovations, there was a non-continuous process because of the "key role" of profitability and economic growth. Kondratieff said:

"In the matter of technical inventions it is essential to distinguish between the time of their appearance and the time when they were applied in practice."

Kondratieff (1928/26),(1984) p 65

Mandel, like Kondratieff and Schumpeter allowed for spillage of innovations to leak over into other industries but Mandel's shortcoming must be his concentration on output, a supply-side theory, not giving due to attention to the demand for technological products and the impact on the decline in the rate of profits and growth.

Schumpeter (1939a) argued that:

"if innovations are at the root of cyclical fluctuations, these cannot be expected to form a single wavelike movement, because the periods of gestation and of absorption of effects by the economic system will not in general, be equal for all the innovations that are undertaken at any time."

Schumpeter (1939a) pp 166-7

At any one time there will be long span innovations, and other innovations undertaken on the back of the long cycle which run their course within shorter time periods.

Schumpeter argued that, once one innovation had broken through any resistance to its adoption, it became easier for subsequent innovations to get on board. The implication was for a clustering or "swarming" of innovations breaking through at specific points, rather than some sort of evenly spread, continuous cycle of them. He asserted that innovations following on, were more likely to appear in similar fields rather than breaking out in brand new areas, pointing out that major innovations hardly ever emerged in their complete form. Further, a clustering of innovations superimposed on each other bring about a fundamental change in the economic and social organisation, as in the Industrial Revolution.

Kuznets (1940) contradicted Schumpeter and argued for a continuous flow of innovations without any clustering:

> *"the application of entrepreneurial ability will flow in a continuous stream which is magnified in a constant proportion by the efforts of imitators."*
>
> *Kuznets (1940) p 263*

That entrepreneurs innovate in new areas, in other industries, in order to keep ahead of the emulators. Modern theorists were also split regarding the clustering versus the non-clustering arguments in the long cycle. Kuznets came up with another suggestion regarding Schumpeter's swarming. The line of argument here was that, discontinous distribution of innovations was due to discontinuous opportunity, that new major inventions were not exploited until the old one had been completely exhausted. Kuznets (1974) expanded on the threads of innovatory life cycles made 34 years earlier, he referred to:

> *"a systematic succession of distinct phases, in which the emergence of one phase constitutes the life cycle of an innovation;"*
>
> *Kuznets (1974) p 60*

Mensch's (1979, Chapter 4) addressed the cyclicality of innovations. Central to his argument was the "metamorphosis model" of product life cycles. Mensch's (1979) investigation of 127 innovations between the period 1740-1955 proved to be influential. Mensch's (1979) "metamorphosis model" was structured in terms of long periods of economic growth and overlapping product life cycles, giving S-shape curves. The bottom of the S-shape of the next stage started before the top part of the preceding one was completed.

Thus, like Kondratieff and Schumpeter, Mensch found clustering in the long downswing depression phases, and like Mandel, he especially found them to be basic or radical innovations . In particular, he found cluster periods of 1813-27, 1871-85 and 1926-38 which by creating new growth sectors brought the economy out of depression, indeed a "depression trigger". The clustering of innovations generally occurred in stagnating industries so innovatory ideas came to the fore as entrepreneurs were looking for alternative investments.

Mensch identified basic innovations as "great deeds in technology", which like Schumpeter's new leading sectors laid down the foundation for new industries or revitalised stagnant ones. He separated the major innovations in terms of basic innovations: product and process. Kleinknecht (1987) referred to product innovations such as penicillin, television, helicopters and process as catalytic petrol cracking, oxygen steel making.

Mensch further identified minor innovations in terms of improvement innovations, which improved on the major basic product and process ones introduced. Then came pseudo-innovations, improvements on the improvements which were illusory in substance.

Mensch decided to date his basic innovations thus: an invention occurred in the year in which it was either formulated as a practical application or discovered, which predated the commercial introduction of the innovation from that invention. The distribution of basic inventions and innovations were found by Mensch to have a random distribution. However, he arrived at his bunching of innovations argument via his "stalemate in technology" hypothesis. This was that as long as the economy was prosperous, firms were generating profits without having to take any risks such as committing themselves to expenditure in radical R & D. Thus there was no need to do more than make improvements in innovations. However, a stage was reached where no more cosmetic or psuedo improvements could really be justified. Stagnation set in, which deepened into recession. Like Mandel, there were new technological breakthroughs backed up in the economic system which were not being adopted through lack of risk capital. Entrepreneurs and/or investors were looking for alternatives and were more likely to be induced to invest risk capital in the long downswing phase of the cycle. Thus Mensch the basic innovations clustered around the *troughs* of the long cycles, in the periods 1813-27, 1871-85 and 1926-38.

Mensch has since been criticised on a number of fronts. One is not readily resolvable, and that is the timing of inventions and innovations, how long should a gestation period be? Kleinknecht (1987) cited Brockhoff (1972)'s French bicycle invention as illustration, this gave potentially 9 different results for the time-span between invention-innovation of the bicycle. Mensch, defined invention as the date where something is perceived as a "new way of using" it, ie. the bicycle wheel. This was followed by improvements, and other basic innovations to make the original workable. It became an innovation only when it was successful commercially, which in this case, resulted in the creation of the subsequent bicycle boom. Altogether a time-span of 67 years.

Mensch was also criticised for not distinguishing as Baker (1976) had, when examining British patents 1691-1971, between the master, the key and the simple patents. Mensch failed to distinguish between basic innovations like the simple ballpoint pen and the car. Clark, Freeman & Soete (1981-1983) used Baker's patent data and definitions, and did make distinctions; they identified the master to be:

> *"the first to be economically viable"*
>
> *Baker (1976) p 15*

[and the key patent to]

> *"refer to the most important patents in relation to each specific subject"*
>
> *Clark, Freeman & Soete (1981-1983) p 65*

and thereby they found a clustering of innovations to occur.

Clark, Freeman & Soete (1981-83) found the evolution of the number of master and key patents as "very similar", and non-linear clustering of basic inventions thus:

> *"it seems possible to identify a clustering of major inventions in various phases of the long wave, including depressions (clusters in periods 1874-89 and 1928-36), prosperity phases (clusters in periods 1897-1903 and 1956-1961) and war (1806-1815). There does not therefore appear to be clear prima facie evidence that the observed clustering is unambiguously related to particular economic circumstances, whether favourable or adverse. ..[it shows].... the importance of examining data on significant inventions rather than merely aggregate data."*
>
> *Clark, Freeman & Soete (1981-1983) p 66*

Thus Mensch's findings that there was clustering of innovations in deep depressions and that entrepreneurs were induced to take a risk and invest; with time-spans between invention-innovation being compressed due to economic conditions, generally did not find much support. Clark, Freeman & Soete (1981-83) suggested that clustering was more likely during revival and boom periods when entrepreneurs were more likely to invest. Also, that during a depression phase, the time-span for inventions-innovations was likely to be longer and not shorter as indicated by Mensch (1979).

Solomou (1987) similarly identified omissions in Mensch's data. Mensch drew incompletely and with some inconsistency from Jewkes's database[1] which in itself had a number of shortcomings for the purpose. Solomou also raised the problem of comparability, with differing relationships between inventions-innovations over the study period. The later period from the 1930s covered more defence research and development.

Solomou (1987) criticised Mensch and argued that:

> *"a weighting structure for these innovations is needed - some are going to be more basic than others..... It is only ex post that some innovations can be said to have had a greater impact than others."*
>
> *Solomou (1987) p 92*

Solomou, like Clark et al found that in Mensch's sampling procedure, he:

> *"has an arbitrary selection procedure from an unknown population"*
>
> *Solomou (1987) p 93*

Clark, Freeman & Soete (1981-83) similarly concurred with Schumpeter's swarming theory, that related innovations were likely to occur together and further, rather than being depression-induced, in fact were demand-led, particularly in boom and war periods. New product launches were delayed by firms until the revival or recovery phase of the cycle. Their argument that the social tensions, conflicts and mass unemployment in a depression phase caused more radical or basic innovations to cluster, can be traced firmly back to the hypothesis of Kondratieff and Mandel (1980): that more radical changes were made in a depression phase.

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[1] Mensch's data wass based on 1st edition of Jewkes J, Sawers & Stillerman's "The Sources of Invention" (1958) Macmillan, revised 1969.

In another study, Freeman, Clark & Soete (1982) investigated 200 British innovations 1920-1980 and their important conclusion was that innovation was the engine of the long cycle movement. However, they found no clustering, but a random distribution, and that the interconnectedness of innovations could cause a long Kondratieff cycle.

Solomou (1987), similarly Kleinknecht (1984) was critical of Freeman et al's conclusion arguing that over the pre-1913 period:

> *"Given the American domination of innovation trends the Kondratieff wave needs to be studied in terms of its relevance to this economy. The trends analysed (earlier) suggest the American economic growth has not moved along a long wave"*
>
> *Solomou (1987) p 98*

pointing out it was misleading to use only British data.

However, the American economy did not progress along a long-intermediate Kuznets cycle. Also, Solomou (1987) over-emphasised the role of American domination in innovations. Van Duijn (1983) found that half the Nobel Prizes for Science awarded to Europeans went to British scientists:

> *"on a per capita basis it wins more Nobel Prizes than the USA. But Britons apparently lack the ability to turn their inventions into innovations."*
>
> *van Duijn (1983) p 185*

Kleinknecht (1981) found support for some of Mensch's conclusions. Based on Mahdavi's (1972)[2] data he found:

> *"a strong clustering of radical product innovations in the period of relatively*

---

[2] Kleinknecht's (1981) study is based on Mahdavi's (1972) technological innovation efficiency investigation.

unstable growth [depression phase] ...... in sharp contrast to the periods of relative prosperity .... which were obviously poor in initiating (but not in the diffusion of) radical product innovations."

Kleinknecht (1981) p 58

In the distribution of them, product innovations mainly occurred in new sectors, whilst the older ones (like railways) tended toward more improvement and process innovations:

"often exploiting technical progress achieved in new industries.... [eg.] the electric railway."

Kleinknecht (1981) p 58-9

Kleinknecht's (1981) product innovations clustering in depressions compared to Clark, Freeman & Soete's (1981-83) delay in new product launch was not readily reconcilable. Although Kleinknecht referred to the possibility of the "rationalisation" of R & D programs: longer term projects coming to the fore at the same time that new launches were delayed until after the worst of the recession.

However, in further support of Kondratieff's and Mensch's hypothesis that depressions triggered innovations, Kleinknecht suggested and found support in Mahdavi's ICI's polythene 1932 illustration that:

"during prosperous times, some half-finished innovation projects will be stored up and, in periods of prolonged crises, it may become interesting to resume work on such projects, because short-term alternatives are unattractive."

Kleinknecht (1981) p 59

Forrester (1978) found support for long cycles and also found a clustering of innovations:

> *"the 50-year repeating rise and fall of economic activity.... Kondratieff cycle. .... There seems to be an alternating tide in economic affairs, spanning some 45 to 60 years, that determines the climate for innovation.".... [typically] "a decade of depression, 30 years of technical innovation and active capital investment, and finally, ten years of economic uncertainty,"*
>
> *Forrester (1978) p 127*

Van Duijn (1983) similar to Freeman et al (1982) found for long cycles but not for innovation clustering. However, unlike Freeman's British only data, van Duijn investigated 160 international innovations over the period 1871-1960, of which 75 were American, 25 British, 27 German, 11 French and 33 in other countries.

Van Duijn found that:

> *"only war and armament-related innovations have statistically significant peaks during and around World Wars I and II. Unlike Kleinknecht (1981:301) we thus do not find 'strong support for the existence of a depression-trigger effect'."*
>
> *van Duijn (1983) p 181*

In fact, he found that over the period of the Kondratieff long downswing from the start of World War I to the 1929 stock market crash, there was a lack of innovations. Those that did occur were either mainly in consumer goods or continuations of major ones introduced earlier:

> *"innovative activity will be lowest during the long-wave recession periods due to the fact that the need for firms to innovate will then be low."*
>
> *van Duijn (1983) p 181-3*

Van Duijn noted the affect of the depression phase was to postpone innovations and conversely:

> *"There is no doubt that the long-wave recovery phase is characterised by a high propensity to innovate."*
>
> *van Duijn (1983) p 183*

A necessary condition for the increase in innovation must be market demand, regardless of whether it is consumer led or government led. Kondratieff referred to economic conditions being favourable for their exploitation and that inventions that must in fact:

> *"spring from economic necessities"*
>
> *Kondratieff (1935/1925) p 112-3*

Van Duijn cited Schmookler (1966) that invention and innovation followed demand increases. Sectors, including new ones, exploiting earlier-introduced innovations grew and even introduced further product innovations in the long depression and recession phases. However, no one was likely to embark on any brand-new radical ideas until the following recovery phase.

Solomou (1987) was dismissive of innovation clusters, mainly because of their lack of regularity. He was not able to identify, in retesting others' data, a regular Kondratieff cycle path for clusters. Why he was looking for a "regular" cycle was not clear. Where he did find a "structural change" he accounted for this in terms of:

> *"the effects of war and the development of an R & D sector rather than an underlying long-wave mechanism."*
>
> *Solomou (1987) p 96*

Although he did concede support for Mensch's depression trigger for product innovation. Solomou (1987) suggested the existence of episodic disturbances rather than long Kondratieff cycles. He referred to these as G-waves, episodic shocks which were not cyclical or endogenous or exogenous but acted on such variables to remove the cyclical nature. For instance, he found long swings to be episodic rather than endogenous:

> *"climatic variations are important in explaining the long swings in agricultural production but the structural change in the economy filtered out many of the cycle-generating effects of climatic change."*
>
> *Solomou (1987) p 171*

Solomou found the American innovation data failed to follow a long cycle path and used this to support his dismissal of the existence of long cycles. However, he over-emphasised the role of the Americans in basic or radical innovations as opposed to supportive key innovations. He observed long swings in data such as aggregate output, productivity, investment, profitibility, migration, money supply, climatic variations, agricultural production and construction. He dismissed the wave in prices as inflationary bias. He found the British swings "were the most marked".

3.1.3 In conclusion of the clustering or non-clustering of inventions debate

The debate regarding clustering or non-clustering was not resolved. Clearly, there needed to be careful analysis and *agreement* regarding what were the basic or radical innovations. A two-tier league, the premier league with weights attached to the basic innovations, aids distinctions among the simple, key supportive and the major breakthroughs. The other innovations, improvements and illusory or psuedo are best tackled in a second tier. The premier league comprising the basic or radical innovations where characteristics in long cycles to be identified or dismissed.

Another observation, is that there *were* clustering of innovations both in the long downswing and in the upswing, but for different reasons. This argument reconciles

Kondratieff's, Schumpeter's, Mandel's and Mensch's references to more radical solutions being tried out in the downswing because of the depression. It was where entrepreneurs had a freer hand in the organisation of industrial structures and more desperate measures were required.

The clustering in upswings were indicative of key supportive innovations to carry forward the radical inventions introduced in the downswing. Thus, more capital was available from entrepreneurs (the risk being lower) and was poured into supportive innovations. This pushed forward the radical inventions as firms competed to be first with a major breakthrough to produce a successful and commercially applied product, thus creating/fuelling a boom in the upswing.

3.1.4 Application of inventions leading to expansion of capital investment

Kuznets (1930) believed Kondratieff's (1928/26) results to be:

> *"essentially cycles of expansion and contraction in the growth of the basic capital equipment of a country"*
>
> *Kuznets (1930) p 266*

Garvy (1943) stated:

> *"Consequently, long cycles appear to be pure reinvestment cycles."*
>
> *Garvy (1943) p 216*

Solomou (1987) and van Duijn (1983) on Kondratieff's long cycle drew an analogy with De Wolff's (1924) endogenous replacement cycle of capital goods, average lifespan of 38 years, the long cycle being an echo-replacement wave. Tugan-Baranowsky (1913) referred to free loanable funds which Kondratieff called on for his non-continuous reinvestment assertion for the funding of capital production goods.

For the upswing to proceed, Kondratieff (1928/26 results) asserted that there must be

1. "an intensity to save" by those whose incomes and wealth increased as inflation fell,
2. a low rate of inflation which was necessary to allow people to save,
3. the accumulation of funds, available at low rates of interest
4. the existence of large entrepreneurial groups.

The low of rate of inflation encouraged "long term capital investment" (Kondratieff 1928b p 38).

In an economic environment aimed at even wealth distribution Kondratieff's assertions were bound to attract criticism. The implication was that a more even distribution of wealth led to less funds freely available for investment in capital goods. Also, the link between a low inflation rate which led to more savings, was not empirically provided by Kondratieff. This was a difficult one, in a class-less environment was he assuming those equivalent to the "middle-class" and above were more likely to save than spend as greater income became available with falling inflation. And the "working class" continued to spend up to their income? No mention was made of firms utilising savings but then again were firms likely to have surplus funds in depression and recession phases?

An omission in Kondratieff's scheme not readily explained is that, of failing to allow credit for reinvestment. Rostow (1980) found sufficient discretion for the creation of credit over the timescale of Kondratieff's data series. As with a monetary overinvestment theory (Spiethoff 1925), over-expansion and over-capacity led to falling profits. Capital shortages and higher interest rates brought about the upper turning point as the economy slowed down and firms ceased to invest, and the downswing ensued. During the downswing phase, prices fell and investors started saving again, and there were lower interest rates.

The lower turning point was not interpreted by Kondratieff but neither was it by other long theorists. Depletion occurred either as the wear and tear on excess capital goods or as obsolescence or war damage in the depression phase. Such depletion allowed room for re-building in the next long upswing. However something else was needed: demand. Investors who saved their income did not induce demand, the precautionary motive to save not spend remained pyschologically strong given recent memory of the depression. Only when investors felt their future income-generating ability (particularly by employment) was safe were they induced to spend and demand goods.

As referred to in Chapter 1 on long-intermediate cycles, Forrester's (1978) MIT System Dynamics National Model modelled the interactions of the economy so as to reflect changes in demand and the time response it took for industry to gear up production (labour, inventory, capital equipment ordering) in order to meet the demand for goods. Forrester's experiments with lags in the fixed investment (capital equipment) sector between the ordering and supply of the capital equipment required to meet the demand of producers satisfying consumers needs, led to variations in his cycle, ranging 15-25 years. Forrester identified his experiments with the variation in lags in the fixed investment (capital sector), particularly the variation in the "feedback loop" in effect produced long waves. This is in keeping with what Kuznets had hypothesised fifty years earlier and later reiterated by Schumpeter. The expansion of the capital investment sector to meet its own demand entailed diverting production back into the sector to gear it up to produce more machinery to meet the demand by the manufacturers of consumer durables in turn to enable them to have more production equipment to produce goods for the final consumer market. The longer time it took between the ordering of equipment, diversion of production back into the sector and the needs of producers being supplied to enable them to satisfy the final consumers, the longer the wave from 50-60 years.

Other theorists also explained the long upswing in terms of over- and under-investment of capital. Forrester, Graham, Senge & Sterman (1983) add:

> *"In order to expand capacity, producers .... must order additional plant and equipment from each other. .... Self ordering is therefore a sufficient cause of long waves"*
>
> *Forrester, Graham, Senge & Sterman (1983) p 5*

3.2 CHARACTERISTIC STATISTICS OF SWING PHASES AND AGRICULTURE

3.2.1 The pattern of phases in the long swings

Kondratieff found a predominance of prosperous years in the long upswing with shorter depressions and sharper rises. However, in the long downswing there were more frequent and longer depression years in the down phases. Further, that the underlying long cycle phases sharpened the phases of any shorter cycles, so the coincidence of an upswing in the trade cycle or Marx's intermediate (10 year business) cycle was intensified and lengthened in the long upswing phase but restrained and shortened in the long downswing. Conversely:

> *"the intermediate cycles occurring during the downward period of a long cycle must be characterized by depressions that are especially long and deep, and by upturns that are brief and weak."*
>
> *Kondratieff (1928/26), (1984) p 79*

Kondratieff's rising and falling phases were summed up thus:

Table 3.1 SPIETHOFF'S LONG WAVE PHASES

WAVE PHASE	**FIRST CYCLE**	**SECOND CYCLE**	**THIRD CYCLE**
RISING	1789-	1849-	1896-
RISING WAVE (YEARS)	*25*	*24*	*24*
FALLING	1814-	1873-	1920-
FALLING WAVE (YEARS)	*35*	*23*	
(YEARS)	60	47	

Spiethoff (1925) concurred with the view of predominance of prosperity periods in the long upswing etc, as did Oparin (1928), but he asserted that this phenomenon was explained in terms of inflation (price level changes) without the need of a long cycle hypothesis. Kondratieff cited Spiethoff:

> *"he did not allow the first downward wave its full scope. Nonetheless, Spiethoff's periods are very close to mine, and I consider it feasible to be satisfied with his description."*
>
> *Kondratieff (1928/26), (1984) p 138*

The following phase pattern was illustrated by Kondratieff, based on Spiethoff's data (Kondratieff 1984 p 80). It showed that in the rising wave of the long cycle, *upswing* years predominated and in the falling (downward) years, that *downswings* predominated:

Table 3.2 KONDRATIEFF'S SWING PHASES

WAVE PHASE	**FIRST CYCLE**	**SECOND CYCLE**	**THIRD CYCLE**
	UP + DOWN SWING SWING	*UP + DOWN SWING SWING*	*UP + DOWN SWING SWING*
RISING		1843-	1895-
RISING WAVE (YEARS)		*21 + 10*	*15 + 12*
FALLING	1822-	1874-	1912-
FALLING WAVE (YEARS)	*9 + 12*	*6 + 15*	
(YEARS)	60	47	

Schumpeter (1939a) referred to:

> *"the impact of external factors would of itself account for wavelike alternation of states of prosperity and of depression, both because some disturbances occur at almost regular intervals"*
>
> *Schumpeter (1939a) p 11*

and that the *"process of economic change or evolution"* (Schumpeter 1939a p 138) was an unstabilising cyclical process generating booms or slumps as the cycle phase swung from one "neighbourhood of equilibrium" to another. Schumpeter toyed with the idea that within the economic system, there were some forms of speculation which were susceptible to swings and therefore seemed wave-like. Areas such as stock market or property speculation were likely to be subject to swings in optimism and pessimism according to psychology theorists such as Pigou (1927) whereas:

> *"Industry and trade are much less given to being swayed by moods."*
>
> *Schumpeter (1939a) p 141*

A contemporary critic of Kondratieff's, Bogdanov (1928) thought nonsensical the notion that the peak of a long cycle, for instance, could occur at the same time as a business cycle trough.

Later, Keynes (1936) was clear that underlying long trends impacted on shorter (trade) cycles in terms of their magnitude and length. Also Schumpeter (1939a), referred to the:

> *"presence of many fluctuations, of different span and intensity, which seem to be superimposed on each other."*
>
> *Schumpeter (1939a) p 162*

Modern practitioners also operated on the assumption of coincidence of cycles where the short order cycles were affected by the underlying long waves. Shearer (1994) referred to the trough years of the trade (short) cycle being more badly affected when the long wave depression phase coincided, thus destocking by firms would be heaviest over such a phase period.

3.2.2 Consideration of growth and on the swing phases

The contemporary, generally politically correct opinion opposed Kondratieff's long cycles, this was that long cycles did not exist but there were *long swings* instead. The argument was that if long swings did exist they were caused by unique, non-periodic phases of accelerated or retarded growth in certain economic activities. Such fluctuations were determined by exogenous factors which gave capitalist societies their structure. Trotsky's (1923) historical exogeneity view was of non-periodic, basic linear trends of differing lengths and slopes with recurring elements. Kondratieff said about Trotsky's idealised view, he:

> *"refused to recognise their patterned, cyclical character"*
>
> *Kondratieff (1928/26), (1984) p 31*

and Trotsky referred to the:

> *"capitalist curve of development (fifty years) which Professor Kondrati'ev incautiously proposes to designate as cycles..... such major facts of "superstructural" order as wars and revolutions, determine the character and the replacement of ascending, stagnating, or declining epochs of capitalist development."*
>
> *Trotsky (1923) p 277*

This was in contrast to the inherent, rolling cyclical characteristics of capitalist societies inferred by Kondratieff, with new long cycles periodically unfolding.

Schumpeter (1939) embraced Kondratieff's long cycle hypothesis and referred to the impact of external factors causing a wavelike pattern as the economic states moved between boom and slump. Each disturbance occurred at somewhat regular intervals and induced adaptations in the system. The *rate of change* of prices after a time lag was more revealing of the wave than the absolute magnitude of the change. However, Schumpeter was suspicious though of reliance on statistics for such understanding. He stated, the

> *"economic machine ... never truly works to design,"*
>
> *Schumpeter (1939a) "Introductory"*

The implication was that contour lines drawn from the past did not hold up in the same way in the future, particularly due to the contributive factor of behaviour changes which varied with shifts in the current understanding. Changes to the general pattern occurred anyway due to interpretation of "semeiology", the common-sense linking of symptoms or facts that were observed in economic life. Schumpeter found these to be profits/expected, consumer demand and producer demand. Over 60 years later, the same concerns were being expressed. An intimate understanding of the whole system enabled such common-sense linkages to be made and to arrive at a reasonable diagnosis and prognosis.

In analysing the long cycle phases, Kondratieff referred to a "mobile equilibrium" because the capitalist system was an evolving and changing system, with:

> *"each given moment having its own equilibrium level."*
>
> *Kondratieff (1928/26), (1984) p 90*

He drew on Marshall's periods of time, with the long period called the "third order equilibria" as:

> *"an equilibrium in the distribution of the changing fund of basic capitalist goods."*
>
> *Kondratieff (1928/26), (1984) p 92*

Schumpeter coined the term "neighbourhoods of equilibrium", to allow for a range of movements and statistical normals, in modelling the contours of the economic system. He assumed economic evolution through the phase units of the cycle, each phase separated from each other by the pull of the neighbourhoods, being pulled away from one whilst being pulled towards another equilibrium. The evolution progression was an unstabilising, cyclical process, producing booms and slumps.

In Schumpeter's identification of the "contours of economic evolution" he found the contours were made by a process systematically producing these alternating phases of prosperity and recession. Such phases, he asserted were due to the working of a definite mechanism, triggered by a definite force or cause. He found the duration however, of such phases, as they pulled away from one neighbourhood of equilibrium towards another, to be dependent on a "number of elements". These elements were summarised as

1. innovations, particularly the nature of them,
2. the structure of the responding industrial organisations, and
3. the financial conditions and conventions prevalent in the business community.

Schumpeter stated that in a 2-phase or 4-phase cycle, (prosperity, recovery, depression, recession) the principles were the same in that:

> *"What we get is hence, never a trend resulting from or produced by the cyclical process alone, but by the cyclical process as distorted by external factors."*
>
> *Schumpeter (1939a) p 207*

Also, it was not necessary for all 4 phases in the cycle to occur. The depression phase need not develop, it depended upon the mood of the business community and whether it kept its nerves. A scare could cause values to drop sharply:

> *"the mentality and temper of the business community and the public, ...[the way] in which credit is handled in prosperity, ... [public opinion regarding] ... beliefs in phrases about prosperity plateaus and the wonders of monetary management."*
>
> *Schumpeter (1939a) p 150*

The contours of the cycle moved from one phase to another, with consequent changes in the neighbourhoods of equilibrium. Theoretically, prices rose in the phases of prosperity and recovery, fell in depression and recession. However the neighbourhood of equilibrium was not midway, but could be any place between the peaks and troughs. Further, regardless of any dependence between cycles of varying lengths, the longer span (he referred to the "higher unit") influenced the lower in that:

> *"the sweep of each longer wave supplies neighbourhoods of equilibrium for the wave of the next lower order."*
>
> *Schumpeter (1939a) p 173*

Corresponding phases which coincided for all cycles would produce "unusual intensity", especially in prosperity and depression phases. An implication for time series evaluation in identifying cycles, is that the peaks and troughs should not be counted from trough to trough or peak to peak. Counting from the trough cut off the revival phase from the end of the cycle and attached it to the next one. A cycle ended at the revival phase, and started at the prosperity one. There was a difficulty in distinguishing between the revival and prosperity phases as they were both positive, but with differing forces acting in each.

The central role of innovations identified by Schumpeter in long cycles was reviewed earlier. Innovations led to the rise of new "leading sectors". New factories, new businesses emerged and order books expanded on the basis of indefinite continuance of the rates of change. Speculation anticipated the prosperity to come by staging a boom. New borrowings were made by all, producers and consumers; and there was a presumption of rising prices. Prosperity phases, for instance, required firms to restructure, if they did not adapt they were eliminated when obsolescence set in. When the contour of the cycle headed towards a point below equilibrium in its neighbourhood, it was heading towards abnormal liquidation, which wiped out those firms without adequate financial support. The depression which may or may not have followed, but on bottoming out, the contour moved towards a new neighbourhood of equilibrium, that of revival/recovery.

Van Duijn (1983) referred to the upswing and downswing phases of a long cycle and its underlying trend of the long cycle thus:

> *"determined relative to trend, i.e. the underlying long-run tendency in economic*

> *activity. ...... is not a log-linear trend (with a constant rate of growth) as many people believe. Rather, it is what has been called the "life cycle of economic development": an S-shaped curve stretching over a period of more than a century."*
>
> *van Duijn (1983) p 8, 54*

Kleinknecht (1987) addressed long cycles worldwide (he referred to as waves) in terms of successions of long periods of accelerated and decelerated growth. He called the long accelerated periods, upswings or A-periods with higher average rates of growth, the other as downswings or B-periods with lower average rates. In an earlier study, Bieshaar & Kleinknecht (1983):

> *"If the long wave hypothesis is relevant, it should be possible to demonstrate that the alleged A-periods of the long wave have average growth rates that are significantly higher than the average growth rates of the preceding and the following B-periods and vice-versa."*
>
> *Bieshaar & Kleinknecht (1983) cited in Kleinknecht (1987) p 19*

The data, cross-country, was based on industrial production and GNP, and used Mandel's dating of long cycles. The methodology to estimate the average growth rates for the long A- and B-periods was to compute log-linear trends on the original data series and impose constraints in such a way as to produce a continuous zig zag pattern. They added a factor $\ddot{\imath}_t$ to allow for auto-correlation of medium-term cycles which existed, without this they argued their test was biassed. Their auto-regressive modelling involved estimating ordinary least squares (OLS) to give the residuals. They applied their auto-regressive formula to the residuals to identify the auto-regressive pattern. This pattern was then compared with that derived from generalised least squares (GLS). The iteration process continued until the two patterns match. To test whether the growth rates of two successive periods were consistent with long cycles, they applied a significance one sided t-test. They presumed foreknowledge of the start and end of the cycle, a weakness in the study because of the problematic dating. Even with recent long cycles, the dating shifted: the end of the Third and start of the Fourth Kondratieff was taken as 1939 and not 1948 as in other studies. Overall, Bieshaar & Kleinknecht found that there was weak evidence for long cycles in the British data, and also a world market "hegemonial" long cycle which dominated the First & Second British Kondratieffs. From the end of the Third Kondratieff onwards:

> *"there is a British growth pattern consistent with the Kondratieff long wave hypothesis."*
>
> *Kleinknecht (1987) p 31*

Globally, their cross country findings were inconsistent for long cycles before 1890 ie. the First & Second Kondratieffs. Smaller domestic economies like Belgium, Sweden and Italy did exhibit them, but the larger France, Germany, UK and USA did not. Also the A-periods compared with B-periods did not consistently show higher average rates of growth. However, this could have been connected with another important long cycle characteristic, that of inventions/innovations: developed in the long downswing but not exploited and applied until the long upswing for reasons previously considered.

In the Bieshaar & Kleinknecht study, the infant industries failed to attract much attention in statistical data gathering/reporting until they came into view as new leading sectors. This weakness in the data underestimated the average growth rates in the long upswing, the A-periods. A further problem with the data was the concentration on aggregate data rather than specific price and production data, thus any weak long cycles were not consistently detected or dismissed. Other speculative arguments regarding the inconsistent cross country findings for long cycles: longer, long cycles dominated a country's economy and led to differing timings for long upswings. Bieshaar & Kleinknecht concluded that more historical research should be carried out on the data, especially pre-1890.

Modern practitioners continue to refer to long wave phases as a matter of course, not only commodity advisors operating in the commodity markets but also practitioners in long-term strategic planning. Shearer (1994) in reference to forecasting and planning:

> *"a rough knowledge of the long-wave clock, together with acknowledgement of the phasing of the construction [18 years] cycle, can be used to anticipate business developments in long-term forecasting. It is important, however, to use this information as an environmental backcloth upon which we can paint a more detailed picture."*
>
> *Shearer (1994) p 109*

3.2.3 Agriculture

Kondratieff found agriculture less adaptable than industry to changing economic, technological and social conditions. He observed that

> *"the downward wave of those [long] cycles are accompanied by a long depression in agriculture."*
>
> *Kondratieff (1928/26), (1984) p 75*

However, at the end of the rising wave, compared to industry, agriculture:

> *"is less subject to the destructive social and military upheavals ....[but] ..... agriculture experiences a deeper depression, at any rate during the first period of a long downward wave: there is a drop in the prices of agricultural commodities and their purchasing power declines accordingly."*
>
> *Kondratieff (1928/26), (1984) p 97*

and initially resources switched from agriculture to industry. As depression deepened in recession, then industry was also badly affected by dwindling investment. He examined movements in important agricultural prices (not included in his Tables of Basic Statistical Material) of wheat, flax and wool. He found the absolute level of prices fell sharply and purchasing power declined, even with protective import duties being imposed (on wheat). There was also an impact on the rent of agricultural land which also declined.[1] For confirmation of the occurrence of depression in agriculture he pointed to the setting up by the British Parliament of several commissions to examine the matter.

Ernle (1922) also found that agriculture was particularly susceptible to depression in the recessionary phase of the long cycle, for example, the period after the Napoleanic Wars, the 1870s and the 1920s. Schumpeter (1939) similarly identified the feature of harvest failures, but exogenously to the cycle. Chance variations in crops due to weather conditions exerted a differing influence on general business conditions. The differing influence varied in importance over time and over countries:

> *"In Germany, for instance, precipitation and temperature which are bad for wheat are good for potatoes ..... while regional catastrophe might be sufficient to affect the general situation." It may mitigate or accentuate depressions or prosperities and perhaps trigger a turning point. Such cycles however, do not explain the cyclical character of the economic process."*
>
> *Schumpeter (1939a) footnote 1, p 177*

Schumpeter's approach differed from Beveridge's (1921) regarding the effect on values and income of weather conditions causing crop variations, and in the light of contemporary Russian experience:

> *"If it sells for more or less, there will be a shift in incomes and expenditures, but in an isolated country prosperity or depression does not necessarily follow. For the*

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[1] Kondratieff (1928/26), and (1984) p 76 cited Thomson's (1907) inquiry into the rent of agricultural land in England and Wales.

prosperity or depression of the agrarian sector which does follow is compensated by conditions of opposite complexion in other sectors."

Schumpeter (1939a) p 177

Schumpeter held little faith in a view that a good harvest meant better business conditions because he said there was an increase in the value of exports:

"Expecting bigger receipts, farmers will borrow and spend promptly, beyond the requirements of harvesting .....we observe.... increased banking activity .... This then may enliven business all round."

Schumpeter (1939a) p 178

Also, industries prepared to meet the expected increase in demand by borrowing for the expansion. Schumpeter asserted all this happened before there was a compensating fall in demand from the other sectors. So overall, no variability was seen and agriculture displayed its own natural cycles which superimposed themselves on the economic process, but "not additively".

Sirol (1942), like Kondratieff, also found a lack of flexibility in agriculture led to long lags in production which provided long cyclical movements. In the long upswing phase, the supply of agricultural produce failed to keep up with demand. When, after a period, supply increased it was such that it was more than the market demanded, the glut caused a price fall and commenced the long downswing. This view of long cycles has less relevance in the Third and subsequent Kondratieff Cycles because the lagging effect which caused the swing phases was reduced (and even eradicated) in capitalist societies. There was more flexibility in-built into agricultural cycles due to the prevalence of some central purchasing of gluts in order to maintain prices and production of certain produce, for instance, the European Union's Agricultural Policy.

Tinbergen (1981) commented on de Wolff's (1929) work and said that in a more agrarian society, years of large and small crops resulted in low and high prices for cereals:

> *"These waves were probably influenced by the periodicty of sunspots. Although many questions about these cosmic influences on crops have remained unanswered,"*
>
> *Tinbergen (1981) p 15*

3.3 CHARACTERISTIC STATISTIC OF WARS

This thesis tests war data for long cycles via regression analysis and spectral modelling. War data is thus further explored in the Chapter 6 "The Data" and this section is confined to Kondratieff's assessment of war as a characteristic feature of long cycles. Kondratieff's arguments were summed thus: the rhythmic elements such as wars and revolutions arose from economic conditions and followed long cycle upswings. Such upswings marked high economic tensions where pressure was on sources of supply, and on markets which led to greater susceptibility to social upset. Revolution was a symptom not a cause in the long wave.

Kondratieff asserted that the regularity of wars and major revolutions was endogenous, as a product not an explanation of the cause of the long cycle:

> *"As a rule, the periods of rising waves of long cycles are considerably richer in big social upheavals and radical changes in the life of society (revolutions, wars) than are the periods of downward waves."*
>
> *Kondratieff (1928/26), (1984) p 70*

There was pressure on economic resources in the expansionary phase of the long upswing, accessing markets or targetting resources:

> *"The upward movement in business conditions, and the growth of productive*

forces, cause a sharpening of the struggle for new markets - in particular, raw materials markets."

Kondratieff (1928/26), (1984) p 95

Goldstein (1988) similarly found:

"much more severe wars occur during the upswing phases than downswings."

Goldstein (1988) p 15

Further, that there was concern regarding fair apportionment of the benefits which accrued from the expansion phase in the long upswing. Thus with the pressure, social upsets more easily came to the fore:

"it makes for an aggravation of international political relations, an increase in the occasions for military conflicts,"

Kondratieff (1928/26), (1984) p 95

The impact of the war changed the momentum within the long cycle; in the rising long upswing there was an increase in demand for capital as consumption increased effectively using up capital investment. This brought about the turning point, ie. the downturn to the long swing:

"This engenders a trend toward raising the price of capital and the interest on it.... Its cause lies in the development of upheavals: military outside the country, and social within it. These upheavals, once they take place, increase nonproductive consumption (wars), cause direct destruction, and slow the rate of accumulation,"

Kondratieff (1928/26), (1984) p 96

Kondratieff examined the sequences of historical events which he said had "no pretensions to completeness" (1984 p 70) and characteristically identified that in the long upswing:

> *"the most disastrous and extensive wars and revolutions occur"*
>
> *Kondratieff (1928/26), (1984) p 111*

Oparin's view of Kondratieff's statistical characteristic that wars occurred more frequently in the long upswing differred in that he found a "clustering around the turning points". He allowed for Kondratieff's standard deviation of 5-7 years, and found that for major and minor wars and revolutions there was an even distribution over the long up- and downswing. Other criticisms were to do with the completeness and weightings of Kondratieff's data. Omissions were identified, (for example, the British-American war, 1812), without any analysis of the significance of omissions in the overall hypothesis. Also the weightings attracted notice in that, for instance, there was one example, interestingly, given the current events in the former-Yugoslavia (1993/4) where Kondratieff attached the same weight to:

> *"11. The Civil War in the United States of North America (1861-65)*
> *12. The Herzegovina uprising of 1861."*
>
> *Kondratieff (1928/26), (1984) p 72*

Other theorists have developed a business cycle theory which linked population changes and the occurrence of war. Juglar (1889) referred to his early population study (1851-52) and identified a cyclical movement in the rate of marriages, births and deaths. There seemed to be variations in the rates between those years of abundance of harvest and those of scarcity. War decimated the size of the working population by requiring people for the armed forces and support, diverting people to war work, and the subsequent loss of life as a direct result of the war. Extending the theory, birthrates increased when war ended; a generation later economic pressure built up as demand by the growing population increased. Governments attempted to release pressure by extending their national boundaries and staked claims on another's natural resources, thereby igniting another war. So the cycle rolled on. This theory was held to be particularly relevant to the German experience.

Another war theorist, von Ciriacy-Wantrup (1936)[2] found that the long periods of good times, *Aufschwungsspannen* came about as war preparations and the event itself incurred enormous government expenditure which stimulated economic expansion. At the same time, changes in the way of doing things or changes brought about by inventions were more speedily adopted. Conversely, the bad times, *Stockungsspannen* were the winding down of war costs, and adjustments made for peacetime. This was found to be particularly appropriate in Kondratieff's First Wave and the Napoleonic Wars.

During World War II, a number of theorists linked war as an exogenous, causal factor to long cycles, Bernstein (1940), Rose (1941), Silbering (1943) found long upswings more indicative of major wars than in the downswings. Further, that economic expansion was war induced, and non-war production fell, consumption increased and higher prices resulted. The economy succumbed to a slowdown as the shortages caused bottlenecks in the system: raw material, labour, capital equipment diverted to the war effort and/or not replaced, and exacerbated by the lack of foreign trade. Silbering particularly noted that war, an exogenous, causal factor to the long cycle, based on US experience, was a price wave. However, a similar argument was identified by Kuznets (1940) in order to dismiss wars as a theory of long cycles. Silberling (1943) found war to be inflationary in the long upswing as demand outstripped supply. Post-war depression in the long downswing occurred due to lack of economic growth. The inflation and war connection was identified by other theorists (Akerman 1932 (1979), 1944, Tinbergen, 1950) who found inflation spiralled during or shortly after major wars, Akerman found long upswings:

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[2] von Ciriacy-Wantrup, S "Agrarkrisen und Stockungsspannen" (1936), Paul Parey. Cited by Hansen A (1951) p 65.

"culminated in general inflation during a war period"

Akerman (1932,1979) p 87-8

and that crisis occurred in credit organisations in the long downswing as prices fell. Silberling summed the war-inflation connection thus:

"The Government enters the market supplied with virtually unlimited funds and bids against the private consumer or business firm; the result is naturally a swift and more or less cumulative spiral of price advances"

Silberling (1943) p 59

Hansen (1951) on wars and long cycles placed the importance of wars, at times, on equal terms as the role of innovations, but never higher than:

"Each reinforced the other, and it is difficult to disentangle the relative potency of each factor."

Hansen (1951) p 66

Overall he placed more emphasis on the domination of innovations in the long cycles, but which can be reinforced by the preparation for war and the subsequent wind down in peacetime:

"readjustments flowing from the war played an important role, though it may well be that the adaptation of the economic structure to the innovational developments of the preceding period was of equal importance."

Hansen (1951) p 66

Imbert (1956), according to Goldstein (1988 p 36-39) provided a "hybrid" theory integrating the innovation-war theories of long cycles. Also, Imbert's findings based on war data from the thirteenth century fitted with Kondratieff's hypothesis. Imbert's assertion translated by Goldstein might well have been written by Kondratieff 30 years earlier:

> *"The rise in economic activity, the strain on markets, the boom fever, the needs of the capitalist economies for raw materials, leads the economically dominant countries to a political and colonial expansion..... The unfolding of the rising phase creates an increasing competition between the capitalist countries which dispute the zones of colonial influence.... Finally the general tension provokes a war between the economically dominant countries"*
>
> *Imbert (1956) cited by Goldstein (1988) p 37*

Imbert's five causal links between the war period and the following stagnation of the downswing for a country were summed thus, that during the war:

1. Paper money was greatly increased with the diminution of (metal) reserves. Currency depreciated, prices rose and gold fled to neutral countries.
2. Production faced disruption caused by sudden rises in demand and war loss. After a short post-war boom, stagnation set in.
3. Production was straitjacketed by the state bureaucracy which directed the economy.
4. The population: particularly reminiscent of Juglar (1889) in that war decimated the size of the working population by requiring people for the armed forces and support, diverted people to war work, and the subsequent loss of life as a direct result of the war. Birthrates increased when war ended, so there were more children and war casualities to be supported by a smaller working population.
5. The prevailing atmosphere in the stagnation downswing was moulded by the war generation who were keen to preserve peace and there was a rise in conservatism and order.

Goldstein (1988) found that Imbert's last point did not hold up well over the period of the Fourth Kondratieff where he identified an expansion phase beginning with a major war (World War II). This was not surprising, given that a generation later (or two, given current events in the former-Yugoslavia) economic pressure built up as demand by the growing population increased. Governments attempted to release pressure by extending their national boundaries and staked claims on another's natural resources, thereby igniting *another* war. Goldstein (1988) concluded that:

> *"More attention should be paid to the role of war than most long wave theories have given it."*
>
> *Goldstein (1988) p 278*

3.4 CHARACTERISTIC STATISTIC OF GOLD PRODUCTION AND COLONIALISM

An brief overview only of these characteristics is given because of the reduced relevance in long cycles theory in the 1990s. The past significance of gold production had its roots in the monetarist theory of long cycles. This was where total money circulation was dependent on a country's gold reserves, and the value of those reserves. This was linked to price levels, to the discovery of new goldfields and whether it was worth extracting given the price of so doing.

Kondratieff dismissed random discoveries of gold and increased gold production as outside causal factors in the long cycle. The increased search or exploitation of gold was not deemed an outside or random factor. It was dependent upon its cost of production, making gold more or less profitable and therefore more or less valuable.

Typical general perception and evidence (Beveridge 1920 p 181-4) showed gold had its highest value and its highest production volume when the costs of producing it were lowest. So the costs of production, that is, prices generally were normally at their lowest towards the end of a long cycle thus making gold more profitable to mine. The level of gold production generally increased at the end of the depression (long downswing) and start of the long upswing. The impact of new discoveries or technical improvements caused an earlier increase in gold production, which occurred part way down the downswing (depression phase), rather than at the lower end. Ultimately, an increase in gold production led to a generally accelerated economic pace.

When the relative value of gold fell, there was pressure to bring down its cost and so improve its profitability. When the long wave passed its peak, then gold mining reached its peak, during the middle of the long downswing. For illustration: after the 1870s (trough), important technical innovations were made in the 1880s, and gold discoveries were made in Alaska 1881, Transvaal 1884, West Australia 1887, Colorado 1890, Mexico 1894, Klondike 1896. Improved techniques and discoveries increased gold production before the end of the long downswing. The long upswing began once the relative purchasing power of gold reached its peak.

To sum up on gold: the relative value of gold compared with other commodities was at its highest when commodity prices were at their lowest, which occurred towards the end of a long wave. Gold production became more profitable as its cost of production fell (its costs were akin to the prices of other commodities). Thus even poor lode mines were worth exploiting. Gold production was favoured when the general price level was low and so the purchasing power of gold was relatively high. Improvements in the technique of gold production or discoveries of new lodes also acted to cause a fall in the costs of gold production.

Kondratieff referred to the "opening-up of new countries for the world economy", and to colonial links seeking out resources and markets in other continents. In the latter half of the twentieth century, it was no longer the colonial links acting as the motivator within the cycle, but there was an analogy with the flow and character of direct foreign investment. The long upswing was driving the search for new markets, new sources and the nature of the direct foreign investment itself is seen to be characteristic of the country's life cycle, stage of maturity, newly-industrialising, etc. This has been widely noted in the direct foreign investment literature, for example, Hymer (1960,1976), Kindleberger (1969), Caves (1966,1971), Buckley & Cassons (1976-92), Vernon (1966, 1979), Rugman (1980, 1988), Ozawa (1984), Kojima (1979-1992) and Dunning (1977-1992). The searching out of resources and markets was all part of the continuous motion of the cycle, and not randomly or externally and occurred particularly in the early period of a rising phase.

As part of the cyclic rhythm, the less developed countries and newly industrialising ones were opened up as the pressure from the other newly industrialising countries and the old colonial and mature ones sought new markets or new materials. A new upswing accelerated the rate of growth of economic development and made exploitation of new areas of the world possible and worthwhile.

3.5 GENERAL CONCLUSION

Kondratieff's theory of long cycles propounded that major changes preceded the long upswing, that certain characteristics were identified endogenously. Kondratieff referred to this in terms of changes in inventions, swing phases, agriculture, wars, gold production and colonialism. Such changes, "empirical patterns" were "passive manifestations" and generally occurred as a prelude to the long upswing, except for wars which tended to occur in its sweeping rise. The validity of these characteristics continue to be evaluated by long theorists.

Earlier theorists' criticisms of Kondratieff were being overtaken by the event of more long research being undertaken. Such later findings whilst not tending to dismiss the existence of Kondratieff long cycles were still somewhat split, particularly within the innovations characteristic school as discussed earlier. Kondratieff's identification of the role of inventions and the coincidence of long upswings with investment in major capital goods production (the Industrial Revolution, the Railways, the Motor Vehicle, etc) was probably his most important contribution to the long cycle hypothesis. The fact he attempted to identify long cycles on mainly price data should not be held to his detriment. Many other long theorists relied on price data whether formulating a view on wars or innovations.

The problem of the trend was discussed earlier. It was problematical for Kondratieff and it is still for current long theorists. No matter how sophisticated the modelling for the existence of long cycles, or to which theoretical school the researcher adheres, the method selected in trend elimination can potentially instigate or remove all traces of the long cycle. Kondratieff had little opportunity in the prevailing political climate to obtain constructive feedback on what was in effect, simply a series of working papers produced over a short period, hypothesising long cycles. He certainly identified some important ingredients, and in a more conducive atmosphere and given more time, he could have produced a richer hypothesis. Kondratieff concluded:

> *"on the basis of the available data, the existence of long cycles (waves) of cyclical character is very probable."*
>
> *Kondratieff (1935/1925) p 115*

Reijnders (1990) qualified:

> *"the Kondrateiff wave cannot be regarded as an illusion. There is substantial evidence to the contrary which demonstrates that long waves of the Kondratiff type do exist."*
>
> *Reijnders (1990) 241*

However, there was general inconclusiveness in the literature regarding the existence of Kondratieff long cycles. There was inconsistency in identifying the lengths of the third and fourth cycles particularly; problematic for those theorists whose studies involved pre-judging the length of the cycle period. The hypothesis for the remaining part of the thesis is that long cycle Kondratieffs of 47/48 - 60 years *in length* do not exist. That there are *shorter* long cycles, where Kondratieffs move faster to cover shorter long periods. The remaining part of the thesis concentrates on methodology and modelling non-Kondratieff data, data which is non-price and has much longer, consistent runs to the time series.

CHAPTER 4

RESEARCH METHODOLOGY

4.1 INTRODUCTION

4.1.1 General introduction

The intention in the general introduction to research methodology is to identify and evaluate various methodologies to aid the formulation of the hypothesis, modelling and interpretation of the long data used in the thesis. A particular problem identified in the literature review of long cycles was the inconclusiveness regarding the existence of Kondratieff cycles. Thus some thought must be given to the way in which theory is formulated and tested, that is, tested via the modelling of the represention of reality in the interpretation of the long cycle analysis of the data. Generally, the approach of long cycle theorists was to either hypothesise or theorise the existence or not of long cycles, test the hypothesis by objectively subjecting the observations to various statistical techniques and reach an objective conclusion. And thus the conflict arose.

4.1.2 Problems with long cycle methodology

Some brief examples of inconclusiveness in long cycle findings are given. For instance, as identified earlier, central to Mensch's (1979) theory of long cycles was a metamorphosis model of S-shape life curves. Mensch truly believed he identified clustering of radical innovations which he found occurred in the long cycle downswing. Solomou (1987) was equally convinced that there was no such finding in Mensch's data, he dismissed innovation clusters, and found no regular Kondratieff cycle path. Interpretation of regularity seemingly the lynchpin to Solomou's long cycle hypothesis. Two other theorists applied spectral analysis to long data in the investigation of the existence of Kondratieffs. Van Ewijk (1982) could find no trace, but Reijnders (1990 p 239) said that, that was "an unfortunate mistake".

Generally, those long theorists who followed an empirical methodology found that observations of the data or "facts" that were collected, confirmed their own particular view of the theory. However, there was difficulty in arriving at any broad agreement in the literature on whether Kondratieff long cycles actually existed or not, let alone any agreement on conclusive proof.

A more philosophical approach provides more food for thought for long cycle theorists by highlighting the shortcomings to the rational and scientific methodologies applied in the long cycle investigations. An extreme philosophical view of rational scientific theory was almost anarchic in its criticism. The argument was that such theory was perceived as being irrationally founded, based on the subjective values of the individual theorist, (Feyerabend (1975)). Further, Feyerabend placed scientific theory on the same level as mythic, religious knowledge such as Voodoo.

Some philosophical approaches are reviewed in this section, subjectively selected it, in order to illuminate the problem of methodology choice. Methodology and loose interpretation could have been a contributory factor to the lack of consistent conclusive proof/dismissal of Kondratieffs in the literature. Broadly, the empiricist methodology drew heavily on observed knowledge, and such theorists can be traced back to Bacon, and earlier. This school provided the roots for the positivists and the logicality of induction (Carnap, Fiegl), that is, of induced observation statements. Positivism further led into instrumentalism in realism, with the acceptance of convenient fictions. Realists asserted a mind-independent reality in the setting of objectives, that is, not coloured by personal beliefs or ideology. The falsificationists (Popper), still strongly instrumental and theory-laden, tried to improve on the empiricist and positivist methodologies. The idealists (Kant) recognised knowledge was created by the perceiving mind and provided some basis for the post-empiricists (Hanson, Lakatos, Kuhn and Feyerabend) who drew heavily on relativism (Papineau) and applied rational criteria to make empirically true propositions, whilst acknowledging interpretation was influenced by a subjective pre-disposed stance, theoretically and culturally coloured.

4.2 INDUCTIVISM

Inductivism as a research methodology was initially proposed as a methodological approach to science by the seventeenth century philosopher, Francis Bacon. This was summed up by Chalmers (1982) as:

> *"the collecting of facts through organised observation and deriving theories from them."*
>
> *Chalmers (1982) p xvii*

From this developed inductive reasoning and logical positivism schools as methodologies for the derivation of scientific theories. The inductivist observed and recorded facts, and made (induced) observation statements which then formed the basis for the theory. The inductivist assumed the observer was objective, impartial, without any preconceptions or prejudice, like a blank sheet of paper. Thus anyone observing the facts could make the same observation statement because of the logicality of the process of inductive reasoning. The application of theories derived from the observed facts provided predictions of future behaviour via deduced reasoning.

The obvious shortcoming to the inductive methodology was the assumption that the observation statements induced from the observed facts were unassailable, to be totally relied upon. Further, that false conclusions could be made based on the induced observation statements which had been legitimately inferred. The premise of the observation statements may have been satisfied, but the conclusion wrong. For illustration, the town centre backstreet on which I live is littered with small garages, and I observe the mechanics' hands to be always marked with oil and grease. The induced observation statement made is that over the past six to seven years under varying conditions, come rain or shine, I note that all the mechanics I see have oily hands, conclusion: "all mechanics have oily hands". This inference is based on *observed experience. It lacks logicality however.* There is no guarantee that the next mechanic I observe does not have clean hands.

The problem with inductive methodology was that its justification was circular, it was based on the premise that experience had shown it was correct for this or that scenario so induction reasoning must always be correct. Further, no matter *how many* observations the inductivist recorded in making inferred statements on which to base the theory, it was no safety net. One *single* observation of the Loch Ness Monster would wipe out the theory that its existence was simply a myth.

However, the usefulness of past experience allowed the inference of some general theories which reasonably predicted the probability of behaviour. For instance, the general law of gravity predicts that spills from an oil-can will fall to the ground.

Hume (1939) concluded that science cannot be rationally justified, that:

> *"beliefs in laws and theories are nothing more than psychological habits that we acquire as a result of repetitions of the relevant observations."*
>
> *Hume D's "Treatise on Human Nature" (1939),*
> *cited by Chalmers (1982) p 19*

A further problem was that of semantics, the theoretical terms suffered over- or underdefinition, with overdefinition being the more serious problem. Papineau (1979) referred to:

> *"theoretical terms [which] are overdefined by illegitimate multiple definitions."*
>
> *Papineau (1979) p 8*

To reduce the problem of overdefinition, the operationalists suggested fixing the meaning of each term, but Papineau argued:

> *"This would fragment into a multitude of distinct generalizations,"*
>
> *Papineau (1979) p 9*

Carnap (1956) found that theoretical terms were interpreted in an indirect way and the source of the definition varied from a theory of a different (older) conceptual system or from an observation language (newer) simply because, such terms were popularly:

> *"used by a certain language community as a means of communication"*
>
> *Carnap (1956) in Fiegl & Scriven (1956) p 40*

Feyerabend (1970 p 225) believed that such loose definition was crude beyond belief and worse than the old method of translating difficult points into Latin. Latin with so many distinctive definitions was held to be more precise and clear for scientific writing. Similarly, observation language was as problematical as the theoretical language terms. Papineau (1979) cast doubt on the generally-held perception that observational expressions were:

> *"authoritative descriptions of observable features of reality."*
>
> *Papineau (1979) p 18*

Along with Hanson (1969) who referred to the act of scientific-seeing, Papineau commented on observers holding general hypotheses which predisposed them to see things in a certain way, depending on their intellectual background. What seemed illogical to one culture at one particular time, became logical to the same culture at a different time, for instance, the notion that the earth was flat. The implication was that judgements about observation statements were not really based solely on observed reality but also on the observer's knowledge of the theoretical background which perceived or interpreted the observed. The conclusion was that all judgements or statements on observations were in fact "theory-dependent.". This conclusion helps throw light regarding the inconsistency in the conclusiveness in the literature by theorists (inductivists) on Kondratieff long cycle findings.

4.3 FALSIFICATIONIST OR POPPERIAN SCHOOL

The Falsificationist or Popperian school advanced inductivism as a research methodology by the construction of some speculative theories for trying out. The Popperians (1959, 1980) attempted to explain some behaviour not adequately addressed by current theory, thus *"science starts with problems"* rather than with observations (inductivism). Advancements were made by not just studying facts only but in finding order where there was *"some difficulty"* in a practical or theoretical situation; where delving into the facts produced some explanation. Hanson (1958, 1961) examined discovery patterns and referred to:

> *"a continual conceptual struggle to fit each new observation of phenomena into a pattern of explanation. Often the pattern precedes the recognition of the phenomenon."*
>
> *Hanson (1961) p 61*

Hanson (1969) particularly addressed the problem of the:

> *"unsettled conceptual situation"*
>
> *Hanson (1969) p 62*

the same problem facing long cycle theorists, where one set of findings was disputed by another. Hanson attempted to look for a more useful approach to scientific inquiry. Hanson used as illustration, thirteenth and twentieth century astronomers; he posed the question, "Do they both see the same thing?", on looking at the eastern sky. They may see the same things, but:

> *"they may **interpret** what they see differently,"*
>
> *Hanson (1969) p 65*

but this is too naive an interpretation, and:

> *"There is more to seeing than meets the eye."*
>
> *Hanson (1969) p 69*

Hanson showed the "sense-datum theory" or "phenomenalism" required an essential ingredient, *awareness*. A penny, placed on a table some distance away was known to be a round penny, by past experience, even though only a copperish oval shape could really be seen. Equally, if sitting deep in thought, the presence of the penny on the table would be overlooked completely. *The observer would be wrong* to insist that an oval penny can be seen, *but correct* to insist that an oval copperish shape can be observed even though it does not fit in with what was commonly known. The role of the intellect is not to be underestimated. In making sense of observations, we draw on not only physical sensations (and hear the physical sound of the telephone ringing) but also the intellectual senses, the inferences, intuition, memory, conjecture, habit, imagination and association which leads us to believe that we know we hear the telephone and that it is not tinnitus. However, mistakes can be made in the application of sense-experience as indicated by an observer's insistence of the existence of something fictitious like an oval penny. Hanson (1969) argued that sense-datum theory was:

> *"a misapprehension of the force of a familiar range of statements about how common objects are sometimes found to look. ..* [and attempted] *.. to make the concepts of sensation do the work of the concepts of observation."*
>
> *Hanson (1969) p 84*

If interpretation was essential in sense-datum theory this happened only in terms of seeing rather than thinking. For illustration, a figure (Hanson (1969) p 90) with a variable aspect seemed to some observers either as a picture of a young woman, or an old one. Another picture was perceived either as a duck or a rabbit. So for scientific inquiry, a matter of organisation was important. It became a matter of what one expected to see. As Wittgenstein (1953) stated:

> *"I see that it has not changed, and yet I see it differently"*
>
> *Wittgenstein (1953) p 193*

The context allowed the setting of what was placed before the observer to be seen in a meaningful way. An intellectual context built up by intuition, experience and reasoning varied the conceptual organisation, so different observers saw things in different ways. Goethe said we see only what we know, Wittgenstein:

> *"You only see the duck and rabbit aspects if you are already conversant with the shapes of those two animal"*
>
> *Wittgenstein (1953) p 207*

So the implications for long cycle theory is that there is a need to view data neutrally, without any definite or preconceived ideas about it.

However, sense-datum or phenomenal "seeing" was not the only way that observers saw data, the more usual was Goethe's and Wittgenstein's "seeing" in terms of the observer's knowledge. Hanson (1969), as referred to earlier, summed this position up in terms of "seeing" as a "theory-laden" operation:

> *"It is a seeing which gets its cast and its hue from our already established knowedge ..... we see through spectacles made of our past experience, our knowledge.."*
>
> *Hanson (1969) p 149*

Regarding whether facts can be seen, Hanson argued:

> *"We can perceive only what we can express, or can say to some extent express. ... Nor is it any wonder that our statements so often fit the facts. They were made for each other."*
>
> *Hanson (1969) p 185*

Facts may be states of affairs or sets of circumstances or events or true statements, Hanson disagreed and referred to facts as "that-clauses" (*that* they have a ....). A that-clause was not a statement, nor was it true or false. Facts of a science he found to be "wrapping-paper", and chameleon-like which changed as perceptions of the world became modified, but were indispensable to the advancement of science:

> *"The facts are what our hypotheses call to our attention."*
>
> *Hanson (1969) p 198, 217*

With reference to the adage of letting the facts speak for themselves, anyone who does so Hanson stated:

> *"will either be enveloped in silence or be deafened with the noise."*
>
> *Hanson (1969) p 220*

Advancements in knowledge were made not by just studying facts but in finding order where there was *"some difficulty"* in a practical or theoretical situation where delving into the facts produced some explanation. There was dissatisfaction with the established knowledge, in the search for an explanation, in the search for order. The theories the falsificationist school or Popperians conjected, tried to explain that behaviour so far not adequately addressed by current theory, thus "science starts with problems". Theories were tried and tested, and honed until there was some "best fit". There was no expectation that hypotheses will ever truly be verifiable, or rather, corroborated beyond all doubt. The essence of the falsification school, was that the basis for the theory was falsifiable. The assertion was true or false, the point was, the assertion was constructed in such a way that it could be shown to be false because it was making a definite claim, there was an inconsistent statement which feasibly existed which contradicted the assertion. For example,

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"It always rains on Saturdays."
"It may or may not rain on Saturdays."
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The first assertion, on testing, can be found to be false; it is falsifiable because it is making a definite assertion that can be refuted should there be one clear Saturday. The second assertion is not falsifiable; this cannot be refuted in terms of a logical contradiction because it must always hold true for Saturdays regardless of the weather. Chalmers summed up Popper's falsificationist theory:

> *"If a theory is to have informative content, it must run the risk of being falsified .... it makes definite claims about the world."*
>
> *Chalmers (1982) p 42*

Otherwise, there would have been such vague theories which tried to explain everything, and thereby explained nothing so that any observations could always be interpreted as fitting in with the theory. Thus no advancement in scientific theory was made because the Popperians starting point was that science started with problems, rather than the inductivist, science started with observations.

Hanson argued the need for a hypothesis, in order for inquiry to begin, and referred to its essential methodological function thus:

> *"a well-constructed hypothesis can give our research maximum clarity and direction, and eliminate muddling ambiguities in the form of our question. .... Facts*

must be selected for study on the basis of a hypothesis."

Hanson (1969) p 225

rather than undirected observation which would not show up which facts were required to move a theory forward. The hypothesis should direct the inquiry regarding what facts were or were not relevant. This was on the basis of previous knowledge of the world so:

> *"Hypotheses are theory-loaded conjectures."*
>
> *Hanson (1969) p 227*

but balanced with what was about to be learned. Chalmers (1982) referred to the fallibility of theory-laden objective statements and that hypotheses which turned out to be false still advanced science by directing attention to previously unnoted phenomena or to new fields. In any case:

> *"Random observations uncontrolled by hypotheses never resulted in a science. Letting the facts speak for themselves can only result in a deafening confusion or a primordial silence."*
>
> *Hanson (1969) p 227*

Hanson's account of William Harvey's hypothesis in 1628 of the circulatory system of blood in animals was a fine illustration of hypothesis formulation and refinement, in advancing science. The falsificationist school whereby science progressed with the newer, speculative hypotheses being more falsifiable than the ones they superseded; the intention was however that the hypotheses would not be contradicted. They were tentatively accepted until shown at some later date to be incorrect (falsifiable), nothing was held sacred. Cajori (1930) on Newton's formulation of hypotheses stated:

> *"Newton gave his scientific imagination free scope and made very extensive use*

of hypotheses. But hypotheses were always scrupulously dethroned whenever they were found to be in irreconcilable conflict with experimental fact. In his publications Newton frequently avoided full statement of his hypotheses, hoping thereby to escape much-dreaded controversies."

Cajori (1930) pp 627-680 in Newton's Principia (1947 edn) p 676

Causality was an issue and Kant asserted that the law of causality was summarised by: "everything that happens (begins to be) presupposes something upon which it follows according to some rule". But on the other hand, the physicist Eddington argued that:

"In recent times some of the greatest triumphs of physical prediction have been furnished by admittedly statistical laws which do not rest upon a basis of causality."

Eddington (1930) p 298

The illustration on the solar system below sums the position up: Copernicus's (1543) contribution on the solar system theorised planetary motion in terms of planets orbiting the sun, which was stationary, and that the earth rotated its axis daily. This was a maverick approach in the day. Galileo's distinction between velocity and acceleration conjected that objects falling do so at a constant acceleration rate independent of the weight, landing a distance proportional to the square of the fall. Galileo (1604) asserted:

"The principle is this: that the velocity of a freely falling body increases in proportion to the distance it has fallen from its starting point"

Galileo (1604) from 1953, vol x, p 115

but Galileo's theory about the terms of distances required exponential functioning to express it, a technique then unknown. Galileo (1604) did not know then, as Leonardo da Vinci had, that velocity increased in proportion to the timespace not distance. He generally conceded the mathematical fiction of his work, and did not detect flaws in his law of falling bodies until many years later, 1638. Kepler's theories on planetary motion hypothesised the planetary positions relative to the sun at particular times. Kepler's laws on planetary motion:

> *"were brilliant discoveries, but they did not satisfy the requirements of causality. It was Newton who showed that the 3 apparently independent laws were the logical consequence of one fundamental law of Nature."*
>
> *Cajori (1930) pp 627-680 in Newton's Principia (1947 edn) p 676*

Newton in his Book III - The System of the World showed that:

> *"there are centripetal forces actually directed (either accurately or without considerable error) to the centres of the earth, of Jupiter, of Saturn, and of the sun. In Mercury, Mars and Venus, and the lesser planets, where experiments are wanting, the arguments from analogy must be allowed in their place."*
>
> *Newton (1686, 1713, 1726), 1947 edn, pp 554-5*

Newton, in the Principia, drew on his third law of motion in Book I, and proceeded:

> *"[20.] .... "all action is mutual, and (pp 13, 26, by the third Law of Motion) makes the bodies approach one to the other,.....*
> *[21.] ... the attractive force is found in both. ..... we are to conceive one single action to be exerted between two planets arising from the conspiring natures of both;".*
>
> *Newton (1947 edn) pp 568-9*

Thus Newton's assertion that pairs' of planetary bodies attraction was inverse to the square of their separation pinpointed planetary positions at specific times. This conjecture led to the seeking out of a conjectured planet paired to Uranus (1781 by William Herschel) and the eventual discovery of Neptune (1846). Newton's bold hypotheses were conjectures which built on Kepler and Galileo (1609, 1638) and

Copernicus (1543). However, when Newton published his theory of motion in Principia it was regarded as abstract and mathematical, like a formula:

> *"Soon it ceased being a merely mathematical aid to prediction of how bodies behave and became a system, the system of mechanics,"*
>
> *Hanson (1961) p 91*

Newton admitted the "eccentric motion" of the planet Mercury, that is, the phenomena of Mercury's anomalous behaviour could not be explained in Newtonian methodology. Indeed this could not be explained until Einstein's (1915) theory of general relativity on gravitational pull and the impact on planetary motion.

Chalmers (1982) reiterated the shortcoming of the progression of science by the falsification school. The bold conjectures that were shown to be falsifiable and the cautious ones which were not, were uninformative:

> *"all that is learnt is that yet another crazy idea has been proved wrong. ... Such confirmations merely indicate that some theory that was well established and regarded as unproblematic has been succesfully applied once again."*
>
> *Chalmers (1982) p 55*

Science progressed when bold conjectures were confirmed and cautious ones (based on the then-established knowledge) were falsified. However, novel conjectures which were still in their infancy could be rejected because the observation statements had not been framed correctly. Falsificationism was rather a nomadic approach to scientific inquiry, the ground covered was constantly shifting, there was no firm base to build on or return to.

Lakatos referred to the modest scientific honesty of the dogmatic (naturalistic) falsificationism where all theory was fallible and that:

> *"empirical* ***counterevidence*** *is the* ***one and only*** *arbiter which may judge a theory. .... all theories are equally conjectural. Science cannot* ***prove*** *any theory. .... it can* ***disprove****: it "can perform with complete logical certainty the repudiation of what is false" [Medawar 1967 pg 144], that is, there is an absolutely firm empirical basis of facts which can be used to disprove theories."*
>
> *Lakatos (1974, 1978) p 96*

However, Lakatos found the dogmatist views "untenable" for a number of reasons, one being the criteria that a theory was scientific if it was empirically based, that is, observations available to potentially disprove it. Logic did not allow factual statements or propositions to be proved by experience or experiment, propositions were derived from other propositions not facts and thus were fallible. For long cycle theorists, this meant there were inconsistencies rather than falsifications with subjectivity in the formulation of theories. Like Popper, he asserted, they could neither be proved or disproved:

> *"The demarcation between the soft, unproven "theories" and the hard proven "empirical basis" is non-existent:* ***all*** *propositions of science are theoretical and, incurably, fallible."*
>
> *Lakatos (1974, 1978) p 100*

However, Popper (1980 revision) returned to the usage of the term "corroboration" of a theory which earlier in his work had been translated to mean verification or confirmation.

> *"I wanted a neutral term to describe the degree to which a hypothesis has stood up to severe tests and thus "proved its mettle". By "neutral" I mean a term not prejudging the the issue whether, by standing up to tests, the hypothesis becomes "more probable", in the sense of the probability calculus."*
>
> *Popper (1980) p 251, footnote 1.*

In assessing the degree of corroboration of a theory, the degree of falsifiability was given due regard, and the objective probability of the event. Of course, the assertion or hypothesis should not be not so vague or imprecise that the logical probability of it being correct was very high. Popper's rule was that:

> *"Its degree of corroboration will increase with the number of its corroborating instances. Here we usually accord to the first corroborating instances far greater importance than to later ones:.... [unless the later] new instances are very different from the earlier ones, that is if they corroborate the theory in a new field of application. In this case, they may increase the degree of corroboration very considerably."*
>
> *Popper (1980) p 269*

However, Popper's argument proceeded that there was an inverse relationship between logical probability and the degree of corroborability of a theory:

> *"if you value high probability, you must say very little or better still, nothing at all"*
>
> *Popper (1980) p 270, footnote3*

However, he concluded:

> *"Bold ideas, unjustified anticipations, and speculative thought, are only means for interpreting nature .... Those among us who are unwilling to expose their ideas to the hazard of refutation do not take part in the scientific game. ....* [and referred to the old scientific ideal] *- of absolutely certain, demonstrable knowledge - has proved to be an idol... every scientific statement must remain tentative for ever. .... We can never rationally justify a theory, ...* [and] *... We can sometimes rationally justify the preference for a theory .... [in] assessing their nearness to the truth"*
>
> *Popper (1980) p 280-1*

in the plausibility of the theory rather than an abolute yes to its corroboration.

4.4 LAKATOS'S HEURISTIC APPROACH

Lakatos's heuristic methodology for scientific research attempted to improve on Popper's falsification school where there was tentative acceptance of theories with nothing held sacred, "conjectures which have more empirical content than their predecessors.". He was dissatisfied with others' approaches:

> *"one cannot simply water down the ideal of proven truth - as some logical empiricists do- to the ideal of "probable truth"* or .. to "truth by [changing] consensus".** "*
>
> ** meaning Carnap ** meaning Kuhn*
>
> *Lakatos (1974, 1978) p 92*

The Lakatos approach tried to provide some sort of structure to guide future research by laying down some hard core, base foundations which could not be dug up and re-examined. This was known as the negative heuristic. This seemed to be similar to Kuhn's (1970) single paradigm which contained the general theory and laws which "normal scientists" applied in their "puzzle-solving" activities. In the Lakatos methodology, there was a protective layer, groundsheets (my term) on top of the cold, bare foundations. This was known as the positive heuristic, a protective belt of auxiliary hypotheses and observation statements. So any threat to the hard core was warded off by changing the protective ground sheets, that is, by changing the refutable auxiliaries or observation statements. However, Kuhn's normal science continued to prevail until a new paradigm emerged as a result of crisis and revolution because the old paradigm no longer satisfied.

Lakatos on the positive heuristic stated:

> *"It is this protective belt of auxiliary hypotheses which has to bear the brunt of tests and get adjusted and re-adjusted, or even completely replaced, to defend the thus-hardened core. . [thus] .. The negative heuristic specifies the "hard core" of the programme which is "irrefutable".... the positive heuristic consists of a partially articulated set of suggestions or hints on how to change, develop, the "refutable variants" of the research programme, how to modify, sophisticate, the "refutable" protective belt."*
>
> *Lakatos(1974, 1978) pp 133-5*

Modelling proceeded without any data as observations were made much further along the research path, predictions being made for subsequent confirmation. The model was a set of initial conditions which were to be replaced with better understanding which enabled production of more complex modelling of the scenario. Lakatos viewed observations rather as verifications, which confirmed the theory not the proof of it. There was provisional acceptance of theories which stood up to independent testing, rejection of those that did not. The problem with the Lakatos approach was that a degenerating programme, one which made few novel or bold predictions successfully was overtaken by a more progressive one. However, the time scale could be centuries long, astronomy is an example, requiring the development of new techniques (telescopes) for any prediction to be verified. Also, there was no place for mavericks in the Lakatos system, his was an ordered system not amenable to deviations.

4.5 OTHER APPROACHES

An anarchic view of research methodology was Feyerabend (1975) who argued:

> *"All methodologies have their limitations and the only "rule" that survives is "anything goes"."*
>
> *Feyerabend (1975) p 296*

Feyerabend (1970,1978) on Kuhn's single paradigm ideology stated:

> *"It would tend to inhibit the advancement of knowledge."*
>
> *Feyerabend (1970, 1978) p 197*

The methodology for Feyerabend had its roots in the principle of tenacity. Tenacity led to the development and improvement of theories which at some stage managed to reconcile those problems which initially remained unexplained. This was similar to Popper's corroboration degree. In fact, Feyerabend was suspicious of evidence which supported a single theory:

> *"Different experimenters are liable to make different errors and it usually needs considerable time before all experiments are brought to a common denominator."*
>
> *Feyerabend (1970) p 204*

More importantly, basic theories and auxiliary statements were often "out of phase":

> *"As a result we obtain refuting instances which do not indicate that a new theory is doomed to failure, but only that it does not fit in at present with the rest of science. .... we can no longer use recalcitrant facts for removing a theory"*
>
> *Feyerabend (1970) p 205*

A methodology should take on board other theories, other competing alternatives which he referred to as a "principle of proliferation". Otherwise, he found it difficult to perceive how changes in paradigms, advancements or revolutions could occur. It seemed naive to assume there was support and pursuit of a single paradigm which was suddenly abandoned as normal when frustration with it became too great.

Advances in knowledge were made through the:

"active interplay of various tenaciously held views. ... [and] the invention of new ideas ..[which] goes on all the time."

Feyerabend (1970) p 209

Feyerabend was dimissive of Popper's, Kuhn's and Lakatos's methodologies:

"There is only one task we can legitimately demand of a theory and it is that it should give us a correct account of the world."

Feyerabend (1970) p 227

It should not be hampered by inadequate concepts of other ideologies which constrained new ways of looking at old problems. Indeed, Feyerabend asserted that the incommensurability of theories such as Newtownian mechanics and Einstein's general relativity made for different meanings in observation statements. The implication was that it was illogical to try and compare competing theories because the basic foundations were so dissimilar. Feyerabend (1975):

"The new conceptual system arises (within relativity theory) does not just **deny** *the existence of classical states of affairs, it does not even permit us to formulate* **statements** *expressing such states of affairs. It does not, and cannot, share a single statement with its predessor"*

Feyerabend (1975) pp 275-6

Earlier, he outlined an ideal methodological view as something:

"that tries to develop our ideas and that uses rational means for the elimination of even the most fundamental conjectures must use a principle of tenacity together with a principle of proliferation. It must be allowed to retain ideas in the face of difficulties; and it must be allowed to introduce new ideas even if the popular views

should appear to be fully justified and without blemish."

Feyerabend (1970) p 210

Where there was conflict between competing theories, he concluded:

> *"What remains are aesthetic judgements, judgements of taste, and our own subjective wishes."*
>
> *Feyerabend (1970) pp 228-9 and (1975) p 285*

Feyerabend's comment that "anything goes" referred to earlier had a response from Krige that those with the knowledge base (power) kept it, (1980):

> *"anything goes ... means that, in practice, everything stays."*
>
> *Krige (1980) p 142*

In general conclusion on research methodology, having reviewed subjectively it appears, some of the philosphical approaches to research methodology, the next section considers a methodological framework for modelling long cycles bearing in mind the issues the philosophers have raised, particularly drawing on Lakatos's heuristic approach.

CHAPTER 5

A METHODOLOGY FOR MODELLING LONG DATA

5.1 INTRODUCTION

5.1.1 General introduction

The intention in this section is to introduce a methodology for the evaluation of long cycles. The aim is to address the general problems that were identified from the literature review on long cycles regarding the inconsistency in Kondratieff findings, whether they do or do not exist, and from the research methodologies reviewed, the problem of scientific seeing and investigation.

The methodology for modelling long cycles in the thesis initially draws broadly from Lakatos's (1974) approach of heuristic modelling. The thesis approach is that the core assumptions are the model's negative heuristics, assumptions central to the model which are fundamental and not to be shifted or changed over the course of the empirical study. The positive heuristics are auxiliary assumptions which can undergo adjustment over the testing of the data. The thesis methodology is developed by drawing on the other research methodologies such as Papineau's (1979) in constructing the assumptions base for the model. This is further evaluated in the later section in this chapter on the model's heuristics.

5.1.2 The methodological problems to be addressed

The general problem of inconsistency in Kondratieff findings in the literature is to be tackled by addressing the following specific problem areas. The problems to be faced are the clarity of hypothesis setting, data efficacy, the trend elimination in the long data to produce residuals for further modelling in the investigation of long cycles, and the scientific-seeing, that is, the represention of a reality on which to base the long cycle interpretation and the potential inconclusiveness of results. The empirical modelling needs to be sufficiently flexible in identifying long cycle length because of the perceived large variability to a standard Kondratieff length, should such a cycle exist.

5.2 THE MODEL'S HEURISTICS

5.2.1 The negative and positive heuristics

The hypothesis for the thesis is that Kondratieffs, 48-60 year long cycles, do not exist; and an induced observation is that long cycles do exist but are shorter than an average 50-year Kondratieff. Both these statements are falsifiable, satisfying Popper's falsificationist theory. These represent the core assumptions or the model's negative heuristic. They are not to be adjusted until the end of the study.

At the end of the empirical study, inductivism as an ending methodology may induce an observation statement regarding the existence of long cycles and their length, for subsequent testing in any further research on long cycles.

The data efficacy is tackled in a number of ways. The actual data and sources are discussed in more detail in the next section. The model's negative heuristic for the data is to reduce subjectivity; it is to be sourced from other than Kondratieff and his sources, the data is to be collected by other than long cycle theorists, for instance, by economic historians. The data is to be drawn from consistent runs or reportage, and consecutive runs are to be strung together, any errors in estimates will be consistent for one place whereas averages cause further problems by being spread over regions potentially containing further, unknown errors. Also for this reason, specific data and not aggregate indices are to be used. The length of the time series is to cover 10 potential long cycles. The positive heuristic is to only allow adjustment to the long data to plug small gaps, in order to facilitate the consecutiveness of long runs to allow modelling to take place.

The representation of reality on which to base the long cycle interpretation acknowledges Hanson's (1969) scientific-seeing and Papineau's (1979) approach in addressing the problem of theoretical terms' over- and under-defmitions. Therefore the negative heuristic for the model is to *confine* its description of cyclical reality and interpret and evaluate the empirical cyclical findings in terms only of:

Powerfully strong (P),
Strong (S),
Medium (M),
Weak (W),
very weak (v) and,
Zero (0) for no findings.

Bearing in mind Hanson's comment on the problem of letting the facts speak for themselves, resulting in the investigator being enveloped in silence or deafened with the noise: the positive heuristic of the model is to allow the strengths of the cyclical descriptions given above to vary across the different time series data. The reason for this is to ensure consistency of descriptive terms within a single data series and then to allow comparability across them. Thus, a cyclical finding which is evaluated and described as Medium in say, the tin data, is a finding relative to any other cyclical finding within that same individual time series of tin. Then a cycle evaluated as Medium within the tin data can be compared to another Medium finding, interpreted relatively as medium within another data series, say population.

Building on the approach to scientific-seeing via Hanson and Papineau, the problem of inconclusiveness of results is tackled by making the thesis hypothesis falsifiable and applying Popperian language to evaluate the empirical results by adopting broad bands for the cycle years. The model's negative heuristic is to have the same banding of years across all the data series. Without some banding of empirical findings, say a banding of 26-30 years, there would be some difficulty in interpreting the detail found. As this is part of the model's heuristic, the danger that Hanson 's (1969) sense-datum identifies particularly is that the evaluation is clouded by the intellect, so the same results would be interpreted differently by another researcher, for instance, because of the choice of empirical banding. But the advantage of the empirical banding allowing scientific-seeing is thought to overcome the drawback of sense-datum clouding.

In assessing the degree of corroboration of the hypothesis when evaluating the results, it is to increase with the number of corroborating instances. It is not necessary to verify the hypothesis of no Kondratieff cycles across all the data. The conclusion does not have to be proved without any shadow of a doubt. The band for the Kondratieff cycles at 48-60 years is sufficiently broad to be classed as a long movement for any findings to be found or dismissed. In line with Lakatos, the results are verifications confirming the hypothesis, not its proof. Feyerband (1975)'s approach that "anything goes" is taken on board in that the model holds on to the tenacious view that Kondratieffs do not exist but if there are other cycles, they will show up if the trend elimination technique is sufficiently robust.

5.2.2 The methodology for the trend elimination: the First Stage Modelling

There is a tendency for economic time series to show trends with data observations ever-moving upwards, that is, there is an underlying increase over time. Kondratieff himself expressed concern over underlying trends and so he sought to eliminate them in case they concealed long cycles. However, mis-specifying the trend affects the curve in the residuals by introducing distortions or eliminating cyclical affects. Such subjectivity in the selection of trend elimination has thrown doubt on the long cycle findings in the literature. Kondratieff himself was not consistent in his approach (for instance, in the world time series) but if time series are substantially different in length, then the trends to be eliminated may well be different.

Therefore, the model's negative heuristic for the trend elimination is to apply regression analysis to all the time series. The methodology specifically is to subject the raw data to log transformation, then to transpose the independent variable x of time and the dependent variable y, the logged data. Subject them to regression analysis. Identifiy the *x coefficient* which is the slope for the independent variable x and the *constant* which is the intercept for the y-axis, the dependent logged data variable. Recast them to produce an estimate for the trend, deduct from the logged data, leaving the residual for the second stage modelling of spectral analysis. The positive heuristic is to allow time series to be regressed in steps over the data, the length of steps to be judged from the raw data. (Chatterjee & Price 1977, Chatfield 1989, 1992, Granger & Hatanaka 1971, and Granger & Newbold 1986). This is further explained later, Chapter 7, the section on "First Stage Modelling".

The advantage of regression analysis is that it provides an unbiassed, consistent estimate of the rate of growth. The drawback to the exponential functioning in regression analysis is that it assumes an average growth rate and constant amplitude. Therefore the positive heuristic in the model, as a way to reduce the problem is to allow steps in the data. The stepping of the data allows regression over a very long time series rather than the whole data series to help mitigate the drawback of average rate of change. The heteroscedasticity problem of the error variance not being constant over all observations is mitigated rather than reduced via a stepped model in the regression of the trend. The empirical results are reported though for *all* the basic regression and heteroscedastic reduced (stepped) models, should the choice of steps in the data be incorrect.

An alternative choice to the regression approach, for instance, a high degree polynomial model would not require regularity in the rate of change in the data to be assumed. But this is judged to be too flexible in the choice of degrees allowable in the least squares fitting of the polynomial model. The reason is because such a flexible approach could potentially no longer be falsifiable, and could possibly face the accusation that the results produced are those one intended to see. Indeed, Kondratieff in generalising his trends used different degrees for different interval lengths, and then faced accusations of having engineered long cycles.

Other alternatives, such as Mensch's S-shaped logistic curve requires a pre-conception regarding long cycles, which does not fit with the model's framework as proposed in the thesis. A linear filtering to smooth out fluctuations involving some form of moving averaging is not used because of the potential to introduce cycles where there are none in the series (Slutsky-Yule). Also, in a linear filter there is some bias regarding the weights, (Chatfield 1989,1992) and the impact on medium-term cycles like Juglars, potentially would be eliminated. The model's framework is such that in Feyerband's words, anything goes. So the potential to identify any other long cycles when investigating for Kondratieffs would otherwise be lost.

Other trend fittings were evaluated and dismissed, they all seemed no better or worse overall, each had advantages and drawbacks, but particularly the drawback of the loss of medium-term cycles. Filters such as Spencer's 15-point moving average, weights of 1/320, points from -7 to +7, or a convolution filter, which over 3 stages adds successive observations together and then divides them.

However, because of the problem of the trend elimination procedure, no matter what choice is made, the second stage modelling tests not only the de-trended residuals for the existence of long cycles, *but also* the raw data and its log for comparison to the cycles found in the residuals.

5.2.3 The methodology for cyclical investigation: the Second Stage Modelling

The model's negative heuristic for the investigation of cycles in the second stage of the modelling procedure is to apply spectral analysis. Since the selection of data is confined to very long time series, then the full benefit of spectral analysis can be obtained as the recommendation for spectral application, is for data covering 10 (potential) cycles being needed (Kleinknecht 1987, Granger & Hatanaka 1964) for any sensible conclusions to be drawn regarding cycles and their lengths.

The spectral modelling, in summary, estimates the spectral densities of the time series by using a finite Fourier transform (breaking the data down into sine and cosine waves) to give the periodogram. The ordinates in the periodogram can then be smoothed via various kernel windows. The detail is discussed further later in Chapter 7, the section on "Second Stage Modelling".

Fourier analysis is an appropriate method in the thesis for modelling to identify long-term characteristics in time series data. The Fourier function describes a series in terms of a constant, a basic or fundamental frequency and harmonic parts. However, there is a sinusoid assumption, that the curve description is a sine wave of constant amplitude. Thus a regular model is being used to describe irregular data fluctuations. However, some simplicity to assumptions is necessary for modelling in order for scientific-seeing. The most significant drawback to Fourier analysis is that described as "leakage" identified in the 1960s by Granger (1964) and Jenkins & Watts (1968). It is to do with lack of synchronicity between the Fourier sequence components and the actual periodic components sequence in a data series. Bloomfield (1976), as Reijnders (1990), adjusted the Fourier technique by not requiring specification in advance of the (unknown as yet) periodical characteristics of the data. Thus these "hidden periodicities" for such as amplitudes and periods were all estimated at the same time through least squares, with only the number of periodical components being specified in advance. This flexibility allows for differing amplitudes in differing data series, yet still meeting the confines of a generalised modelling procedure.

However, in the thesis, in the First Stage Modelling there is to some extent, standardisation in the residuals and stationarity conditions introduced pre-sprectral, in order for the application of the spectral analysis to be sensibly made. Also it is not necessary to attribute particular periodicities at the start in the model used, the model used is finite Fourier transform which is also (kernel) window based, so a choice of the size of the kernel window can be made and modelled. This is discussed further later in Chapter 7, the section on "Second Stage Modelling".

CHAPTER 6

THE DATA

6.1 INTRODUCTION

The intention of this section is to provide some background to the data used in the thesis for the modelling in the investigation of long cycles. Further, to identify some common characteristics of the data, the reasons for the choice of data, the sources and the shortcomings to the data. The data chosen is tin production (white ore), population and war (battle fatalities). Also, sunspot data is used to test the spectral modelling applied.

6.2 THE DATA

6.2.1 Common characteristics of the heuristic approach

The model's framework requires specific data characteristics based on the heuristic approach identified earlier in Chapter 5, "A Methodology for Modelling Long Data". The main points are reiterated here. One of the common characteristics in the data's negative heuristic is that the data is to be sourced from other than Kondratieff's sources. The intention of this is to reduce any subjectivity, should there be any, of any bias towards long cyclicality in the data. Further, the data is to be drawn from other than long cycle theorists, preferably collected by economic historians, accustomed to disciplined reporting of data.

Another feature is that the data is to be drawn from consistent runs, also, any consecutive runs from different sources are to be strung together to produce a single time series. The aim is to reduce variation in errors, any errors in estimates will be consistent for one place and more readily identifiable. Average figures based on data gathered from many places may well contain further errors, not readily ascertainable. The positive heuristic is to allow adjustments to the data in order to facilitate the consecutiveness of the long runs and thereby permit the modelling of the data.

The negative heuristic is that specific data rather than aggregates or indices are to be preferred. Aggregates, by the averaging process do not readily lend themselves to cyclical investigation. The specific data is to be other than price or value data which are prone to cyclicality anyway. The length of the time series should potentially cover 10 cycles to permit a reasonable time span over which to investigate long cyclicality.

6.2.2 The reasons for the data choice

All the time series, particularly the tin, are believed to be a reflection of the changing economic and social environment and as such should be a reasonable test for the existence or otherwise of Kondratieff cycles. The arguments are developed in the individual data sections following. The data choice is thus:

Table 6.1 Data Summary

Data type	Data range	Number of years
Tin production (white ore)	1156-1992	837 years
Population	1541-1992	452 years
War (battle fatalities)	1495-1992	495 years
and		
Sunspot density (for testing)	1700-1993	273 years

In all the time series data used, there were some problems of total reliability and accuracy. However, other time series of longevity were examined and dismissed because there were some readily identifiable problems of efficacy of the data, for instance, data found to have deliberate omissions, due to medieval fraud and tax evasion such as in candle production. Other series were carelessly reported, in that production measures were not accurately reported in the volumed studies on agriculture and prices, and work and wages, where the detail provided suggested care and reliability (Thorold Rogers (1886)) on the part of the collectors. Later economic historians re-examining the methodology in reporting found inaccuracies, for example, Beveridge (1939) identified differences in measuring a "standard" bushel of grain and coal locally which was undetected by Thorold Rogers.

The time series selected in the thesis for the modelling, all display longevity and meet the requirement of 10 potential cycles. Sunspot density data is used to test out the spectral modelling and spectral windows used in the thesis because it has a generally well-known result, a cyclicality of 11 years.

6.3 SUNSPOT DATA

The sunspot data (1700-1993) gathered for testing the spectral modelling is particularly chosen because it has a generally regarded cyclical fluctuation of about 11 years, so to a certain extent, the outcome of the fluctuation is known in advance. The data gathered is about 90 years longer than that used by Granger (1971, 1986) incorporating new data. Sunspots density (activity) is defined in terms of astro-physics: sunspots are areas of very strong magnetic fields on the surface of the sun, which sometimes, are so intense, as to be clearly seen on the sun's disk. The intense activity is a small but exceedingly cold area on the sun's surface which emits violent magnetic energy. Thus, sunspots are dark focussed regions which can last up to 2-3 weeks and are generally found in groups of 2 or more, and where very large spots can cover an area of 240,000 km across, the average is about 37,000 km. Very little is known why sunspot activity occurs but the impact causes a "burst of radiation" which disrupts radio communication on earth. The radiation reaches earth about 8.5 minutes later and the charged particles form a "spiral path" and arrive 1-2 days later. This manifests as auroras, magnetic storms and more radio interference, (Michelson (1990 p198), Moore (1989), BBC (1988), Cambridge (1985)). As an aside, some background social economic reading revealed that E W Maunders (1900) noted zero sunspot activity over the the period 1645-1715, this coincided with the occurrence of the most severest weather. Over many consecutive winters, severe winters were reported and with the 1680s period reputedly being the harshest; the diarist Samuel Pepys records fairs being held on the Thames, it being frozen hard over a number of successive winters.

Sunspot cycles are irregular in behaviour and can only be studied in retrospect, it is difficult to anticipate the next exact point in the cycle. On average, the sunspot cycle is approximately 11 years but with some variation, (Michelson 1990 p 198) from 8.5-14 for minima years and 7.3-17 years between successive maxima years. However, 11.1 years (Stamper 1994, McKinnon 1987) is the most commonly accepted sunspot length.

Sunspots have supposedly been sighted since AD300, by Chinese astronomers who presumably could only report the very large groups or spots. An astronomer, Fabricus (1611) is credited with the first printed report of observations. However, Wolf's[1] sunspot R number is the standard measure for sunspot density, which he derived in 1848 from the published observations of Schwabe (1844). The Wolf R number for sunspots is defined (Michelson 1990, p 198) as:

$$R=k\,(10g+f) \tag{1.}$$

where the sunspot data R is measured by a number of astronomical observatories and reconciled (k) by taking daily observations of the total number (f) of sunspots on the sun's surface and counting them regardless of size, also counting the number of spot groups (g) which has a weighting of 10 applied to it.

The sunspot data gathered in the thesis runs from 1700-1993 and is the annual mean of

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[1] Rudolph Wolf, Director of the Astronomical Observatory in Zurich, Switzerland, where sunspot data continues to be regularly gathered and reported.

Wolf's sunspot R number. To calculate the annual mean, daily observations have been taken since 1848 to produce the monthly mean with the annual mean based on the average of the 12 monthly means until 1944. Since 1945, the daily observations have been used to calculate the yearly mean of the sunspot number. For the period 1700-1988 Michelson's (1990) data is used and which is derived from the Zurich Astronomical Observatory and World Data Center, Boulder Colorado. For the period 1989-1993, Stamper (1994)'s data[2] is used.

Sunspot data is deemed to be a suitable series with its generally accepted cycle of 11.1 years to test the spectral modelling and spectral windows to be used. The expectation is that the spectral modelling produces peaks in the power spectrum of the sunspot data, equivalent to an approximate 11 year cycle, over various kernel windows.

6.4 TIN PRODUCTION DATA

6.4.1 Introduction

Tin production is a useful series to include in long cycle analysis as it has undergone major changes reflecting the varying social and economic conditions of the day. Production falling in times of declining population, and the longevity of tin production is due to the changing utilisation it has undergone, tin was used in different and new ways for domestic consumption and war.

In England, tin production can be traced to at least Roman times, from diluvial ores (stream-tin) and from veins mined near the earth's surface, (Carne 1839). Hatcher (1973) asserted tin utilisation by people "for more than 4,000 years". The choice of

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[2] Stamper,R of Rutherford Appleton Laboratory, Solar Terrestrial Physics (1994), via internet e-mail response.

tin production as a data series further satisfies the criteria of the negative heuristic of the model, it is a not a series used by Kondratieff , he used pig iron and lead series in his analysis, and tin production is a non-price series, another criteria of the model's heuristic.

Importantly for the efficacy of (medieval) data collection, tin production was fairly localised with Cornwall by far the most important medieval producer of tin, and for a short period pre-1200, Devon, so in terms of the metal ore content for white tin, very long consecutive runs have been recorded for it. Current mineral statistics now published by the Central Statistical Office in its Annual Abstract still (1994) record the white tin consistent with the reported Cornish production dating back to the 1150s.

6.4.2 The detail on the sources and adjustments to the tin data

The thesis draws together material from Lewis (1903) and Carne (1839) and on the extensive but meandering tome by Hatcher (1973). Also the Mineral Statistics (1853-1938) (Non-ferrous Metals), metal content of ore relating to white tin, the Annual Abstract of Statistics published by the Central Statistical Office sourced from the Deparment of Trade & Industry (1939-1993), Table for Non-ferrous Metals - Tin Ore (Metal Contents) Production, white tin. The Newport Central Statistical Office kindly provided the updated 1991, and the 1992 figures. All sources are therefore independent of long cycle theorists.

Tin production is the longest data series used, dating back to 1156 and so particularly satisfies the model's negative heuristic of longevity and 10 potential cycles to ensure an adequate time-scale for the modelling. The gaps in the 1200s are estimated in line with the model's positive heuristic approach, detailed below. The original sources for tin production can be broadly categorised over 1198-1837, as the output of tin for England and over 1156-1549, as the tin presented for coinage in Devon & Cornwall, and 1156-1549 where the tin output is based on tax paid as coinage duty. Although tax evasion was prevalent, which potentially could be detrimental to the data as reported, Hatcher stated that the tax evasion:

> *"should not be overestimated"*
>
> *Hatcher (1973) p 152*

and Lewis referred to coinage administration being:

> *"extremely efficient"*

so most tin production was

> *"presented for coinage each year"*
>
> *Lewis (1903) pp 149-56*

The following detailed adjustments are consistent with the model's postive heuristic and are made to ensure consistency in the time series and to permit modelling of the data material. Judgement regarding the change (increase, decrease, no change) in the tin production in filling in gaps in the data is also made with reference to the economic and social historians' commentaries on the period, Ashton (1955,1959,1966), Coleman (1978), Ernle (1961), Fisher (1965), Floud & McCloskey (1981), (Holmes 1970), Kershaw (1973), Loyn (1977), Miller & Hatcher (1978), Postan (1959,1972), Taylor (1814,1837), Russell (1948, 1961), Wrigley & Schofield (1981) and others.

Detailed adjustments:

Tin production prior to 1301 is deemed to occur in Cornwall which was much the major producer over Devon, however until late 1100s Devon was the more important producer.

The thousandweight mwt differs from 1000lbs in Cornwall to 1200 lbs in Devon, difference in weight from 1198-1214 data is adjusted in the data.

Table XIV p 153 Hatcher for 1156-94 :

A midpoint figure is taken from the output range.

Blank years filled by previous year's figure.

Devon most important producer to late 1100s so mwt thousandweight converted at 1200 lbs up to 1197.

Table XV p 154 Hatcher for 1198-1214 :

Devon declined as Cornwall increased in importance, in 1220 there is an example in Lewis (1903).

Lewis[3], from the tax on tin the production is in the ratio is 1:5. Mwt is converted at 16.7% 1200 lbs and 83.3% at 1000 lbs from 1198-1214 to allow for differing thousandweight between Devon and Cornwall respectively.

Table XV1 p 155-160 Hatcher for 1243-1549 :

No figures from 1215-1242, so 1209-10 figure held constant to 1230 and 1243 held back to 1231.

No figures for 1244-1287, so 1243 figure held constant to 1265 and 1288 held back to 1266.

Figures for 1243 and 1288-1300 for Devon only: So estimate Cornwall to be included at 4 times Devon's 1243 figure and 6 times the figures from 1288, 8 times from 1294 to acknowledge and allow for Cornwall's increasing importance, given the proportions in 1301 and 1303 of 7.5 to 8.5 times the size of Devon's tin output.

For 1302, 1304-1368, 1375-78: to estimate missing Devon figures, Cornwall's are increased by one-eighth.

For 1371 and 1382 Devon only, missing Cornwall estimated at 8 times (as for 1294).

No Figures for 1318-1323: Coincides with severe Agrarian Crisis of 1315-22, (Kershaw 1973) so 1317 figure held constant.

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[3] Lewis (1903) p.136: annual farm is 200 marks on Devon stannaries compared to Cornwall's 1000 marks in 1220.

No figures 1325-31:assumed even annual growth from 1324 to 1332.
No figures 1343-50: Use 1343 fig to 1345, popn at peak (Russell 1948, 1961),
(Miller & Hatcher 1978). Epidemics from 1347, Black Death '48-9
so use 1351 fig back to 1346. Through 1350s-70s for odd missed
year, use nearest having regard to major epidemic year.
Missing years: nearest year held constant.
From 1550s: in tons not mwt or lbs, so divide by 1000 only.

To sum up, generally, missing years are filled in by the nearest appropriate year rather than by any averaging process to avoid implying a cyclical affect. Appropriateness is independently sought from non-long cycle sources. For example, economic historians' accounts of conditions, expanding or declining population, land utilisation etc. Thus an imputed figure for a missing year is not an increased one in a generally acknowleged period of decline.

In the Mineral Statistics and Annual Abstract of Statistics, the table for the metal content of ore figures relates to white tin, consistent with the early Cornish production. The figures for southern Ireland are excluded after 1921, without any significant impact on the data.

6.4.3 The reliability of data

The medieval data is the most problematic from 1150s-1350s and so it is mainly this which is addressed here. The source of much of the tin deposits was located in Cornwall and Devon, well-known for smuggling of goods in order to avoid any taxes and thus throws suspicion on data drawn from customs records. However, the medieval customs duty was only about 5% of the selling price. The bigger problem was the tax on production, which amounted to about 15-20% of the price. Unlike cloth and wool, the tin exports were not separately recorded in the Enrolled Customs

Accounts in the early Middle Ages, instead tin records were based on receipts from tax on production, with more precise quantitative evidence recorded from 1400s.

Many people were involved in smuggling, not just merchants but burgesses and clergy (who may have also been part mine-owners or usurers). However, the Crown stood to benefit more from coinage revenues than from custom dues, the Close Roll[4] in 1400 implicitly acknowledged this fact. It recorded 3 merchants' protest at the seizure of their tin at Calais, they had declared that they had in fact paid coinage dues, with no mention made of the unpaid customs duty.

Hatcher's (1973 p 18) medieval figures, which drew on the Pipe Rolls (begun in 1155) where there were enrolled the "receipts of the farm of the tax on tin output" and thereby provided some consistent medieval data. From the receipts, the amount of tin presented for coinage was estimated and led Hatcher (1973 p 67) to uphold the coinage accounts as being "accurate lists". Hatcher's estimates were probably a minimum figure with no account taken of early evasion but did recognise that most production was then located in Devon rather than Cornwall. The significance of the locale is that there are differential duties between the two and also in their measurement of a thousandweight. Thus Hatcher differed in his early estimates from Lewis (1903) due to locale and second smelting affect. Lewis's data misinterpreted coinage accounts by believing them to be lists of *all* the producers, whereas in fact, they represented people from *groups* of the working tinners.

From 1198, more accurate estimates can be made due to improvements brought about by the appointment of a royal warden, William de Wrotham. The new tax he then imposed is recorded in the Pipe Rolls. By 1200, Cornwall had reverted to being the major producer again. Data for tin was very thin in the 1200s because it did not have to go through the Winchester Assize of Customs, being exempt, as it was already

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[4] Close Roll 1399-1402 (Public Record Office), p 148.

subject to a new tax. However, French documentation supported English tin trade there (Bayonne and La Rochelle) and the industry must have been flourishing in the 1200s because money was loaned to the Crown by both the French and the Cornish (merchants and mineowners respectively). The links were so close that the French were informed of any changes to Cornish tin production and sale. However, the Particulars of Customs provided data on overseas trade by port in less detail. Even so, Hatcher (1973) stated that although:

> *"evasion of duty was prevalent throughout the period..... tin coinage records..... reflect the major fluctuations in output, although they consistently tend to understate its magnitude. Furthermore, the extent of evasion should not be overestimated,"*
>
> *Hatcher (1973) p 152*

Lewis (1903 pp 149-56) referred to the efficiency of the stannary administration in monitoring the movement of tin from the mines to the coinage process. In 1241, Matthew Paris referred to abundant tin being discovered in Germany which may have caused English tin prices to fall. Even so, by the end of the 1200s, Hatcher (1973) clearly stated:

> *"England was scarcely troubled by competitors in her position of supplier of tin to the known world."*
>
> *Hatcher (1973) p 26*

6.4.4 The general background to show tin's relevance due to its changing utilisation

Cornwall, was by far the most important medieval producer of tin, and for a short period pre-1200, Devon. The quality of English tin production meant it dominated the European and Middle Eastern markets, from about 1250s until the 1600s, Rich &

Wilson (1967 p 424). Indeed, there was counterfeiting of English pewter on the Continent, particularly in Germany, Hedges (1964 pp 16, 87-8.) and German laws specified which manufacturing processes required the use of English tin. Hatcher (1973 pp 2, 9) referred to tin export as "the oldest export.", dating from "about 500 B.C." and where there was much supporting evidence of tin's export to France (Marseille) and onwards.

Tin production is a useful series to include because of its early widespread utilisation, (archaeological evidence corroborates the documentary data), thus evidence of widespread use: for household utensils during the Middle Ages; tin, when combined 4:1 with lead, forms pewter, popular from 1300s-1700s; and in buildings, arts (jewellery, decoration and effigies) and of course, warfare.

The medieval Church was a heavy tin user, not only for vessels etc but also for organs, bells and construction. The building industry used tin for soldering in plumbing, guttering and roofing and as glaze for windows and for decorative tinning on iron doors and grilles. Also for cranes, Edward I (1272-1307) used them at Westminster. From late 1300s, the demand for cast bronze artillery like cannons, which had a short life anyway, increased during wartimes, such as over 1500s. Ordnance manufacture pushed up English tin prices.

Tin production reflected prevailing economic conditions by keeping its costs down due to the flexibility in tin operations which must have contributed to the longevity of tin-mining. The flexible mine-working kept down the expense of operating costs and working capital, to the owners. Indeed, Price (1891), an Oxford political economist suggested that the Cornish tin mines' unique labour structure of "tributers" and "tutworkers" subcontracts may be attributed to the Romans, who employed Britons to work the tin. Under the system, miners had to bid against each other for pitches, the miners provided their own tools and were always paid in arrears. Since the miners[1] were paid according to the value of ore brought up, when productivity of a mine declined, lower wage bills were offset against profits. Even the fixed costs were minimised because of the normal practice of hiring machinery with probably no charge for test periods, hire charge based on usage not time. Resources could be switched to more profitable mines at very short notice, with minimal shut-down costs being incurred to the owners. Such practices endured to the end of 1800s/early 1900s.

Again, tin's approximation to prevailing economic conditions is illustrated with its link to usury. Hatcher (1973) is quite adamant that since the 1300s there existed waged labour in tinning and wealthy capitalists since the late 1200s. At least since 1198, credit or usury was an implicit link all along the chain, with the tin being sold only twice a year. Thus labouring tinners sold to merchant tinners, who sold to dealers (in London). Carey (1769 p 15 in "Survey of Cornwall") referred to dealers commonly charging the merchant tinners interest rates of between 40-60% per annum. Loans may have been needed at short notice, required perhaps for a period of only 6 months, due to sudden subsidence or flooding, but very high interest rates were a common feature of the industry.

6.4.5 The patterns in the data series: possible explanations

Most long theorists have relied on data of about 150 - 250 years in length or just re-worked Kondratieff's data because the major drawback to the investigation for long cycles is identifying efficacious data of at least 10 long cycles in length. Many series

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[1] There were always two classes of mine workers, summed up in the report of the Mines Commission (1864 p xix), "called tutworkers and tributers". The tutworkers contracted at so much a fathom, to drive the levels, sink shafts, and put in rises and winzes. The tributers were employed to extract the ore from the levels, which had been ventilated and partially explored by tut-men. The tributers were paid so much in the pound, on the market value of the ore, which they brought to the surface, when sold.

other than tin, as discussed, were evaluated and dismissed, due to problems with length and efficacy. This section illustrates tin's continuous new usage and flexibility which ensured production *longevity and volume* thereby lending itself to being an *approximation only* of the coincidence of change in the general economic environment. The length of the tin series covers 837 years, from the subsistence level living in the Middle Ages to modern times, with the coincidence of peaks and troughs in tin examined via economic historical phases. The significant troughs and peaks in the tin data were found to be only somewhat reflective of the prevailing general economic phase with the comparative economic historical phasing becoming weaker post-1850.

The patterns or steps in the time series for tin production were quite marked and led to the decision to add variations to the modelling in 300-year and 150-year steps over the 837 years of the time series. The tin series was investigated by examining ***historically*** the conditions reported in social and economic literature to ensure that the patterns in the tin data were valid and not accidents in the recording. A summary is provided below of the main peaks and troughs, with the fuller explanations following.

Table 6.2 SUMMARY OF MAIN TROUGHS/PEAKS IN THE RAW TIN DATA AND THE FIT WITH THE GENERAL HISTORIC ECONOMIC PHASE

Period	Tin Data Trough/Peak	Summarised changes and fit with general economic phase
1350s	Trough	Tin trough coincides with economic pressure as illustrated via pressure on land causing rent rises, population at limit of cultivable land, landholdings smaller, yields lower, subsistence level living, vulnerability to harvest dearths. Occurrence of wet summers, poor harvests and epidemics and the vulnerable population almost halved.

1450s	Trough	Depression occurred in England. End of Hundred Years' War, demand for armaments fell. Other exports: wool, cloth aswell as tin declined.
1500-50s	Peaks	A generally prosperous period in England. Trade in England recovered. There was a series of good harvests ensuring a higher standard of living generally, allowing grain for animal husbandry and thereby extra income. Population growing. English shipping booming. Exporting of goods. The reflection in peaks in tin data is illustrated via new usages for tin, production expanding: printing, bronze, although pewter (tin-based) still popular.
1650s	Trough	Changeover period in technologies in England with the economy in general recession, facing high costs and lower production, by traditional methods, that is, until the new methods emerged. First air furnaces emerged 1680.
1690s-1790s	Peaks	Overseas trade boomed and the economy was buoyant over much of the period, benefitting from England's lead in innovatory manufacturing methods. This coincides with innovation in tin and peaks in the tin data via new usages: tin-plating. The demand for tin increased and production costs benefitted from new technologies (air furnaces 1680s onwards, Newcomen's engine 1740) and the use of shipping, via sea/rivers, of new raw material such as coal, an essential substitute for wood charcoal in manufacturing, including tin production.
1801	Trough	The tin trough is attributable to the fact that earthenware was replacing pewter. Also, the domestic tin industry was facing overseas competition (Dutch East Indies, India) for cheaper tin imports. The trough in tin exactly coincides with a minor recession in England (Deane &

		Cole p 171)*[2].
1800-70s	Peaks	Expansion of tin-plating works and tin exports over the period approximates only to the general economic prosperity over the period, and with some differences in the troughs indicated in the following.
except 1828-34	Trough	Tin trough phase precedes general recessionary period, centred 1831* and 1841*.
1850-1870 *except* 1861	Peaks mild Trough	Rising tin phase approximates only to a period generalised as a prosperity period, with uneven prosperity referred to (*Deane & Cole p 171). The 1861 tin trough timing coincides with economic trough. Rising tin phase approximates to the start of Kondratieff Second wave (Spiethoff, Table 3.1), 1849.
1870-80s	Trough	Tin trough phase approximates to falling economic phase, (Spiethoff 1873, Kondratieff 1874, Tables 3.1, 3.2). Coinciding with the tin trough and economic recession is a downward trend in population as the census reports[3] a one-third reduction in the Cornish mining population 1871 to 1881. This is due to the high level of emigration of unemployed miners/families to the Americas.

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[2] *Deane & Cole's "British Economic Growth" (p 171) provides extracts from Thorp's "Business Annals" for England (W L Thorp pp 162-173) for benchmark years, "A convenient characterisation of the cyclical circumstances of industrial years" over the period 1800-1901.

[3] "Census of England & Wales",1881, vol iv, General Report, pp 8, 48. Also the emigration of miners is addressed in the Royal Commission on the Housing of the Working Classes in 1884 and contemporary reports in Daily News, 14/1/1879 and 21/9/1885, pp 6.19-6.20, this chapter.

1880s	Sharp peaks/troughs	Period of speculation in England in commodity markets. England becomes centre for metal trading in 1869, and 1877 LMEC established (detailed on p 6.20). Actions of French speculators particularly prevalent in copper and tin markets.
1889-98	Trough	Trough in tin production approximates to generally acknowledged recessionary period. But tin precedes it by 2 years, as 1891* is described as industrial recession phase to 1896-8. 1896 is thought to be the turning point for end of the recession phase of the Kondratieff Second long wave and the rising of the Third, (Spiethoff, Table 3.1). A major long turning point.
1897-1914:	*Mixture*	Period of mix of mild tin troughs and peaks with only loose approximation to the economic historical phasing of peak/trough, as indicated in the following.
1904	Trough	Mild depression is described for 1901 (Deane & Cole p 171) as general economic condition, approximates to the tin data.
1914+	Falling	Tin production starts falling from World War 1, until bottom of trough, 1922.
1922	Trough	Tin postdates by 2 years the falling economic phase in the Third Cycle (Spiethoff, Table 3.1), given as 1920.
1923-1929	Rising	Tin's production continues rising until 1929, when the fall approximates to the stock market crash and the onset of the 1930s depression.
1931	Trough	Deepest trough for tin production in the twentieth century. 1930-32 are generally acknowledged as the deep recession years, eg. Deane & Cole (Appendix 3,

		p 331), with a general economic recession to 1937.
1930s-52	Falling	Tin production on gradual decline. Approximates to economic decline over depression, war and post-war depression years, for example, 1931-1948 (Brown & Hopkins (1981) Table 2 pp 129-30).
1953-1990s *except* 1979, 1987, 1991-2	Rising	Tin production on gradual and steady increase. May be due to a combination of factors: tin's continuous new usages, in such varied processes from car manufacture to drinks cans; increase in consumer demand and increase in disposable income. Tin's production profile (Table 2.6) approximates to the general prosperity periods over 1950-62. Particularly, tin's (rising) profile 1966-72 does not fit that general recessionary period, but a mild trough in 1969 tin production does coincide with an economic one. The general recessionary period 1986-94 (Table 2.6) matches tin's production profile. At the height of the 1980s boom, tin's highest peak, since the end of World War One, in 1985 reflects the mid-boom period. The general stock market crash of 1987 is reflected in tin's only trough since 1979, occurring in 1987.

Overall, the historical summary shows that tin production can really only be a useful approximation of the changing general economic environment. It is unlikely that any time series will be a consistent economic reflector over such a very long period. It is worth restating that a better statistical justification, other than by historical phasing would require data comparable to this thesis, which is just not available over the 837 years of the tin study. More detailed analysis of the tin data patterns and economic phasing is given in the remaining part of the section.

The original data showed relatively deep troughs every 300 years: 1350s, 1650s and 1950s. The depression in tin production in 1350s coincided with other economic and social conditions and may be partly explained by a number of factors. In the very early 1300s the tin increase may have been due to the opening up of the Mediterranean markets for the ongoing transportation of English tin within the Med or to the Middle East. Generally, living conditions in the 1300s were lower than in the 1200s due to a number of coinciding factors. Pressure on land caused unabated rent increases as opportunities to the growing population slackened with medieval towns at their growth limit and villages at the frontiers of cultivable land, (Searle (1974), Brandon (1971), Miller & Hatcher (1978)). Landholdings were smaller and yields lower, more people were living at subsistence level, leaving them vulnerable to dearths. Mortality peaked following wet summers causing poor harvests, with the Agrarian Crisis 1315-22 affecting both people and animal via epidemics (Postan & Titow (1959), Postan (1972), Kershaw (1973)). Population declined from 1340s for the next 30-40 years (Black Death occurred in 1349) due to epidemics and the poverty of existence. Profit margins fell as prices rose in real wages, and grain prices fell and there was lower demand with a falling population, a bullion shortage may have also contributed to falling prices. (Baker (1966), Miskimin (1964), Holmes (1970), Rees (1972), Coleman (1978), Kershaw (1973), Miller & Hatcher (1978)). All these may have been contributory factors to the plunge in tin production in the 1350s.

The first sharp increase over the late 1100s can be attributed by Hatcher's (1973 p 18) reference to the "easy shovelling of rich alluvial deposits". Tin production rose in the early 1200s and exceeded those levels later obtained in the 1300-1400s when home demand fell. Data for tin was very thin in the 1200s because it did not have to go through the Winchester Assize of Customs, being exempt so data was drawn from the Pipe Rolls as discussed earlier. Trade must have been flourishing in the 1200s because

merchants and mineowners were lending money to the Crown. However, from 1240s, in 1241, Matthew Paris referred to abundant tin being discovered in Germany which may have caused English tin prices and production to fall. But by the end of the 1200s, Hatcher (1973) clearly stated England was the unparalled supplier of tin to the known world.

Over the 1300s, in agriculture, the average size of smallholdings decreased probably due to population growth and landlord pressure (Postan (1973), Hatcher & Miller (1978)). Waged labour saw real increases in rates and increased bargaining positions mid-1300s as mortality increased. Tin miners also benefitted from shortage of their labour. Tin holdings from the early 1300s similarly showed a levelling off with a much larger spread of holdings, which continued well into the 1500s, Hatcher (1973):

> *"The immensely rich tin merchants of the early fourteenth [1300s] had no counter-part in the mid-fifteenth century [mid-1400s]"*
>
> *Hatcher (1973) p 69*

A less significant trough in tin production occurs in the log transformed original data in 1450s. The Hundred Wars' Year ended (Holmes (1970)) and so probably the demand for armaments by the Crown. Again, around 1450s, depression occurred in England. Exports declined in raw wool, cloth and tin. Tin production was dropping steadily. Coleman (1978):

> *"the Customs figures .... may exaggerate the depth, though not the reality, of the depression."*
>
> *Coleman (1978) p 49*

As trade in England recovered from 1460s to 1550s, tin production increased steadily over the period so tin prices did not increase significantly despite general inflation. Demand for tin increased for its usual products, pewter was still popular and bronze artillery replacing iron in other European wars, and new usages found for it, such as printing (Caxton printed the first book in 1477). The population started growing again, there was a series of good harvests, trade recovered with the boom in Europe centred around London (Coleman (1978, Hatcher (1973), Holmes (1970)) and English shipping did particularly well at exporting, although Henry VII's seizure of Venetian galleys at Southampton for troopships (as in 1492) may also have had an affect (Ruddock (1951), Ramsay (1957), Rees (1972)). Credit was more easily available and from more sources than previously, Hatcher (1973).

Until the late 1600s, tin (metal) mining was a relatively small-scale activity. However, two major technological changes occurred which led to large-scale development during the late 1600s/early 1700s: gunpowder-blasting and the invention of pumping engines. The decline in wood availability in the 1600s in Cornwall necessary for the charcoal for the blast-furnaces led to an increased cost in smelting tin. Alternative means of smelting therefore was sought, Carne (1839) referred to the first air furnaces being erected in 1680, and the use of coal. The impact on tin ore production in the mid-1600s prior to this alternative being found, may have been to cause a lower production rate due to its higher cost which may partly explain the drop in tin production around the 1650s.

In 1690, the manufacture of tin-plate was introduced although the main industrial use for tin was still the production of pewter, Deane & Cole (1969 p 56, footnote 1). Over the 1700s, the link between tin production and the well-being of overseas trade is clearly illustrated. Not only for the transportation by sea of the smelted tin to London but also for the incoming supply of coal (now necessary over wood) for the smelting process. The log transformed original data shows tin production generally rising over the 1700s with a significant drop in the early 1800s. Tin production slumped in the very early 1700s with the outbreak of the War of the Spanish Succession, but recovered and peaked in 1710, Ashton (1959 pp 69-70). Cornish tin production expanded in two other war periods when foreign supplies were cut off: War of the

Austrian Succession and the Seven Years War. However, with the loss of overseas markets by the American and French Wars towards the end of the 1700s/early 1800s, depression in tin production resulted.

In the 1740s, an advance in Cornish mines was brought by the application of Newcomen's engine. Also, the start of the decline of tin for pewter and the "rapid growth", Deane & Cole (1969) of tin for tin-plating. However, increased tin production from the late 1780s found a new market in the East Indies, India and China, which was doubly attractive given the relatively low domestic price of Cornish tin in the face of cheap Dutch imports of Banca tin. This combination of increased tin supply caused prices to drop from 72s to 58s per cwt in 1788.

Domestic *consumption* increased four-fold over the period from 1780s-1830s, much more than production due to cheaper foreign, imports (via Holland), Carne (1839). There were two general mild recessive periods, 1781-4 and 1786-9 followed by a growth period, and tin prices rose 13% from 1790-92, a lower increase than other commodities. In a letter from Penzance, Ashton (1959):

> *"every mine is going back to work and we are all Mining Mad."*
> *Ashton (1959) p 167 citing John Dennis of Penzance in 1792*

There was a temporary decline in tin consumption from the end of the 1790s as earthenware gradually replaced pewter, Deane & Cole (1969). The price of tin in the domestic market was kept artifically high to aid the low price of tin for export paid by the East India Company from about 1790-1820, when exports ceased until the price paid increased. At one point, in 1810:

> *"the Cornish refused to sell any more unless the price was advanced."*
> *Carne (1839) p 263*

The expansion of tin-plating works and tin exports continued into the early 1800s which may well acount for the general rise in tin production, Deane & Cole (1969). Cornish tin production continued unabated because the East India Company, Carne (1839):

> *"entered into arrangements with the tinners of Cornwall for an annual supply"*
> *Carne (1839) pp 262-3*

The industry was again particularly hard-hit in the 1830s, the price of Cornish tin was very low and in 1837 application was made by the miners for the abolition of the duty paid to the Duke of Cornwall. The rights of working the tin, and privileges such as separate courts for Cornish matters and a separate parliament were vested in the Norman kings as Earls of Cornwall. They conceded these rights to the Cornish people for the duty payment on tin. It is not known whether the *level* of production *declared* by the Cornish tin mines was affected by the duty. The payment of duty by tin miners to the Earl (now Duke) of Cornwall which persisted up until 1838 of 4s per cwt (120 lbs) was confirmed in a charter in the 33rd year of Edward I[6]; fees to officers were estimated at a further 1s (Carne 1839). The duty certainly caused hardship, and was finally abolished in 1838 when the Cornish mines were suffering particularly badly. From the 1860s-1875, the rising canning industry increased consumption of tin and foreign imports.

A link is made between emigration and the decline in tin production. Tin production peaked in the 1860s/70s, gradually declining from late 1870s onwards. The population census from 1871 to 1881 showed a one-third reduction in the mining population in Cornwall according to the Registrar-General[7]. The link is made between emigration

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[6] Stephen's "Commentaries on the Laws of England", 10th edit, vol iii, book v, chap iv, sec 7.

[7] "Census of England & Wales", 1881, vol iv, General Report, pp 8, 48.

and the decline in tin production by other corroborative evidence, to the Royal Commission on the Housing of the Working Classes in 1884 and reported in the Daily News:

> *"These emigrants, who apparently make the Canadian and American mines their chief destination, are continually returning to take out their wives, their families, and their friends; and indeed this is one of the most pleasing traits in the miner's character."*
>
> *Daily News, 14th January 1879 and 21st September 1885*

By the 1870s and up until World War II, London was the central clearing house for British tin and more than half of that produced elsewhere (Rees (1972 p 342). Metal trading commenced in 1869 on the Lombard Exchange and Newsroom and grew to become the London Metal Exchange Company in 1877. Price (1891, Ch.VII, 9th page) referred to the periodic speculation in tin prices, of the "most unaccountable transactions in the market". Particularly, to the manipulation of both tin and copper prices by a French syndicate in 1887 which:

> *"was conspicuously successful in raising prices of those two metals"*
>
> *Price (1891) Ch. VII, 9th page*

Tin's price subsequently halved suddenly over a one-month period. Cornish banking failures, notably Tweedy's in 1879 held mining overdrafts. Although an implicit intention of the LME was one of levelling out metal (tin) prices by absorbing surpluses so that prices would not overly fall or rise during shortages.

In the 1900s, war disrupted tin by changing its supply and production with the loss of German and French smelting and Australian supply, leading to the US becoming a major tin producer along with some growth in British capacity. Tin prices became subject to government control (1918). Over 1926-7 were boom years for tin, the Tin

Producers' Association formed in 1929 was concerned about surplus capacity and attempted, unsuccessfully, to restrict tin output. Throughout the 1930s, restrictions on output and "buffer pools" tried to stabilise tin prices over a recession period when prices had started to fall after 1930. During World War II, tin trade was taken over in 1940-1 by the Ministry of Supply which purchased it all and distributed it on. From November 1949, tin, unlike other non-ferrous metals was a sterling area commodity thus the export of English tin was allowed. However, the paucity of tin supply had a detrimental affect on tin prices. The impact of the Korean War caused tin prices in 1950 to rise from £ 600/ton to a peak of £ 1615 in 1951 and so the Americans ceased stockpiling, thus tin prices fell back to normal levels. The UN's International Tin Agreement from 1956 specified too low a buffer stock and so did not curtail tin prices very well to demand, particularly in the 1960s with the Russian demand and Vietnam War. The US Government's periodic disposals from its massive stockpile of tin has had a particularly significant on prices, and along with Germany was not party to the International Tin Agreement. (Rees 1972). These factors may have contributed to the 1950s fall in tin production in England, displayed in the time series for tin.

6.5 THE POPULATION DATA

6.5.1 Introduction

The population time series as a choice (1541-1992, 452 years) is made because there is a generally held generational effect on population. Variously attributed to: bad/good harvests impacting on later/earlier marriages and birthrates, land reclamation allowing expansion of separate family units, wars arising when one region's boundary expansion impinges on another's. The population data used is for England and Wales.

6.5.2 The detail of the sources and reliability of the population data

The sources actually used for the data are:

1541-1871 : Wrigley & Schofield (1981)
1871-1992 : Registrar General's Statistical Review of England & Wales, Registrar-General's Decennial Reports on the Census, Office of Population Censuses & Surveys

Other sources were explored and not used because the intermittent reporting of population would have required substantial guess work which would have been at odds with the positive heuristic approach to the data. This allowed only adjustments necessary in order to facilitate and not replace the modelling of the data. An illustration of the discrepancies in early population estimates: in 1086, The Domesday population figure recorded the number of tenants at 275,000 and varying estimates of the population were subsequently produced by applying a multiplier. Russell (1948 pp 34-54) applied an estimated multiplier of 3.5 people per household and arrived at an estimated total figure of 1.1m. However, later scholars, Miller & Hatcher (1978 p 29) allowed for a multiplier of 4.5-5 and made more generous allowances for the unrecorded populate such as landless people, sub-tenants etc. Miller & Hatcher thereby estimated a population somewhere between 1.75 to 2.25m, much higher than Russell's 1.1m. Researching the literature, the next population survey did not occur until 1377, and following 30 years of major epidemics the population was halved. This survey was for poll tax returns for those over the age of 14, regardless of status, and the estimated population figure was recorded as 1,386,196 for England. However, Miller & Hatcher (1978) make generous provision for fraud, evasion, exemptions and under-enumeration and thereby estimated a population of 2.5 to 3m compared with Russell's (1948) estimate of 2.2 m. An interim estimate made by Hatcher & Miller (1978 p 29) of population in 1345 was 5.5m. Other in-between estimates of population referred to manorial records, for example, local data on the Bishop of Winchester's manor at Taunton: a continuous 100-year record of a "fine" at the rate of one penny per annum extracted from every male over 12 years, showed a population growth rate of 0.85% per annum from 1209-1311. Overall, due to the discrepancies regarding early population figures and also the gaps between surveys and estimates, it was held to be too inaccurate a part of the series for cyclical analysis.

Thus, data for the thesis does not commence until 1541, drawn from Wrigley & Schofield's (1981) groundbreaking population study which swept aside some of the assumptions and misconceptions of earlier studies. Wrigley & Schofield's study incorporated data from a sample of 404 parish registers on monthly baptisms, marriages and burials collected by hundreds of local historians, to produce a *national* demographic picture. They developed a technique referred to as "back projection" in order to estimate a population. Back projection involved estimating some rates overlooked in earlier studies, for example, net migration (1541: 1.3%). It also included estimates for age structure (pp 528-30): (1541: for 0-4 yrs 13.25%, 5-14 yrs 21.24%, 15-24 yrs 17.96%, 25-59 yrs 39.09%, 60+ yrs 8.47%)[8], fertility rates, age at marriage, expectation of life (1541: 34.64 years), dependency ratio (under 15s and over 60s) aswell as mortality rates.

Since 1837, population figures have been published by the Registrar-General in the Annual Reports, even so, Wrigley & Schofield found necessary to make some corrections to the official figures, for instance, due to exaggerated claims by the officers collecting the data. Although official census figures were available from 1801, Wrigley & Schofield's were preferred from 1801 to 1871 for several reasons. Using Wrigley & Schofield's data is in line with the model's negative heuristic, that of adopting a longer and more consistent run of data. Also, their data may well be more accurate, because they refer to exaggerated figures in the official census compared with the parish registers of the time. Indeed, the differences between Wrigley & Schofield's 1801 figures and the official census is about 168,000 people, and in 1871, 1,288,000 people. Wrigley & Schofield themselves admitted to some reservation in their data, and referred to it as no more than "tolerably reliable".

The Official figures since 1871 were further defined for England and Wales as the Home population + HM forces overseas - other armed forces serving temporarily.

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[8] Wrigley & Scholfield (1981), Table A3.1, page 528.

6.5.3 The relevance and patterns in the data series: possible explanations

Social economic historians have put forward explanations regarding population changes over the centuries, their comments also throw further light on particularly, the troughs in the tin production series. For example, a trough in the tin series around about the 1350s following a boom period. The literature is in general agreement regarding a peak in the population around 1345, prior to a major decline caused by four major epidemics over the next 30 years. This effectively halved the population including in 1349 the catastrophic Black Death, bubonic plague carried by black rats, and 1361 when the Black Death plague returned, which Holmes (1970 p 137) referred to as the Second Pestilence or Pestilence of the Children. This again mirrored the dips in tin production with the shortage of labour. In fact, because of the pressure of population shortage, real wages increased and so were forcibly constrained in 1351, (Holmes (1970), Coleman (1978)).

Falling patterns in the population in general terms appear to be linked with harvest failures: living conditions in the medieval environment were particularly precarious due to the impact of the vagaries of the weather on the quality and quantity of the harvest. A poor harvest not only meant less food available for people but also for animals and affected the whole economy. It entailed buying in food, where possible, killing animals that could not be sold off so as to reduce the need for grain, buying sub-standard food at high prices, leaving little or no income for non-essentials thereby reducing the income of the suppliers of same. A series of poor harvests may or may not, in themselves, have resulted directly in deaths, but the subsequent widespread malnutrition and food poisoning did. It made people more prone to diseases like influenza which then became life-threatening, in addition to the periodic epidemics of such as, measles, smallpox etc. The whole community was affected from labourers, peasant farmers, craftsmen, professionals through to merchants.

Further patterns can be identified in terms of innovation and change of land utilisation. An expanding population required more land for arable farming. In many areas, increasing population put pressure on the available land which triggered the need for further reclamation of land as new families, new branches sought new outlets. More land was brought into production, by draining marshlands or cutting down woodland. Such opportunities translated into more wealth and encouraged earlier marriages and more children. New settlements were made in new areas by those searching new agricultural opportunities, and migrations from the countryside to market towns. Records of individual manors as far apart as Forncett (Norfolk) and Duchy (Cornwall) in the 1200s of chevage payments, licensing people (non-free peasants) to live outside their own manors confirmed high rates of emigration. Although, rather like the 1990s poll tax situation, some *nativi* disappeared from records after paying for a period.

In the population data used, an illustration to explain the patterns of population: population fell from 1550-60s with depression and 1555-7, years of consecutive harvest failures followed in 1557-9 by:

> *"A widespread influenza epidemic causing a substantial increase in deaths in those years"*
>
> *Fisher (1965) 2nd Ser.XVIII*

Also, population increased until 1640-50, due to a series of good harvest years, reduced bouts of disease and/or plague and earlier marriages and increased fertility. The average age of first marriages of women, from 1500s to 1640s was around 23-26 years. However, a rise from about 1640s in the average age of marriage may have contributed to the slackening off of population growth after 1640-50. From 1640-50 outbreaks of infectious disease such as typhus, (also other fevers "agues", "sweating sickness", influenza and malaria) broke out in different parts of the country, affecting towns much more than rural populations. For example, Leeds (a rising cloth-making centre) lost about one-third of its population for varying causes. Also this was a period of very bad harvests, as bad as 1590s. In 1646, the reports of a very wet season, with corn:

> *"rotted and spoiled in the fields", and*

in June 1648:

> *"floods every week, hay rotted abroad .. corn laid, pulled down with weeds; we never had the like in my memory" ... [in Aug 1648] "continual rain" ... [Sept 1648] "some say that divers cattle that feed in the meadows die, their bowels being eaten out with gravel and dirt."*
>
> *Coleman (1977) pp 94-5, quote from MacFarlane (1970) pp 73-4, diary of an Essex clergyman*

Other troughs or dips in the log transformed data population can probably be explained by 1730-45 agricultural depression and poor harvest. In the 1730-1740s, unhealthy lifestyles epitomised by Hogarth's drawings of gin-guzzling Londoners were published. In 1741-2, outbreaks of typhus coupled with poor harvests contributed to many deaths. Then finally, the most significant dips in population occurred in the twentieth century, the timing is attributed to the two World Wars.

6.6 THE WAR DATA

6.6.1 Introduction

The intention in this section is to identify major sources of data on war and additionally, evaluate some of the studies which have utilised war data, in varying degrees in identifying long cycles. Kondratieff found war to be a passive manifestation of long cycles. Therefore further evaluation is included on war as a dataset for the investigation of long cycles.

The original aim was to build a dataset by which to measure wars and investigate for long cycles. This aim was modified to adopting Levy's (1983) data, as adjusted by Goldstein (1988). Levy, faced the same problem as Wright, that of not having available the annual battle death rates and so Levy overcame the problem by assigning an even distribution figure per year over the war period. Goldstein modified this by assigning smaller figures for death rates in the first and last years of any war.

6.6.2 The detail of the sources and reliability of the war data

Wright's (1942, 1965) massive Beveridge-like tome covered wars from 1480s up to World War II. Wright's study also drew on others' war studies, such as Sorokin's (1937) where his criteria for inclusion was not as well-defined as Wright, but is referred to as covering all known wars. Sorokin included estimates of troop numbers and battle casualties from ancient times to 1925. Wright also referred to Woods and Baltzly's study in preparing his own dataset.

Disappointingly, contemporary war studies except for Levy (1983) covered quite short periods, only 150 years or so of data, being no more than Kondratieff's data length for war, despite the extra 70 years since his study. For instance, contemporary studies by Small & Singer (1972, 1982) applied spectral analysis and could find no cyclical fluctuations. Although in another study on wars from 1816-1965, Singer & Cusack (1981) they admitted that their data length was not long enough to detect cycles.

> *"Thus the war cycle would be so long as to make its occurrence barely visible in the span under scrutiny here."*
>
> *Singer & Cusack (1981) p 419*

Levy's (1983) data on global war spanned 480 years, and covered the changing "Great Power System" over time. All the wars involving England/Great Britain were included as one of the mainstay players in conflicts, like France. Levy (1983) also drew on

Wright's study and others' (Sorokin, Woods & Baltzly) and particularly the 150-year period of Singer & Small's study. However, he excluded any civil wars and imperial wars unless there was outside intervention. His dataset drew on a 1000-battle deaths criteria as his inclusion criteria, by cross-referencing his choice it was found that Levy covered those wars which was also included by at least two out of three of the major war data sources, of Wright, Sorokin and Woods & Baltzly.

For earlier wars, pre-1500, other sources, particularly Dupuy & Dupuy (1977)'s provided encyclopaediac detail of medieval battles. For contemporary references, other 1980s/early 1990s studies really did not add anything further to the war data although Goldstein (1988) modified Levy's data but failed to address Wright's massive study at all. Keegan (1993)'s meandering history of warfare disappointingly did not address any empirical data, and barely commented on the Falklands and Gulf wars. The more recent hostilities are noted only, for example, the Falklands/Malvinas, the Gulf War, but in following Levy's participant criteria they are not included. It is likely that for modern warfare to be included, the war measurement requires differing criteria to participants and battle mortalities given that modern wars vary regarding technology hardware, size and troops at the front and on the high seas, duration and total combatants, in comparison to earlier ones, even to the world wars of this century.

The definition of war in assessing the inclusion in the dataset was problematical, Levy (1983) found Wright's (1965) criteria for war, excessively legalistic, but Wright more clearly defined his criteria for the data inclusion than any other researcher, (for example, Sorokin (1937)). Wright's study covered the wars from 1480s-1940 and included:

> *"all hostilities .... whether international, civil, colonial, or imperial, which were recognised as states of war in the legal sense or which involved over 50,000 troops. Some other incidents are included in which hostilities of considerable but lesser magnitude,... led to important legal results such as the creation or extinction of*

> *states, territorial transfers, or changes of government."*
>
> *Wright (1965) p 636*

> *"It has been thought better to group compound wars [Thirty Years' War, Napoleonic Wars, WWI] under single name, as has usually been done by historians, ...* [and] ... *Unsuccesful revolutionists, rebels or insurgents which lacked even* **de facto** *status, ... have not been listed,"*
>
> *Wright pp 636-7*

Even the start date for a war is not straightforward, Singer & Small (1972) referred to accepting the formal declaration of the start of the war only if :

> *"it is followed immediately by sustained military combat."*
>
> *Singer & Small (1972) p 45*

and similarly, the close of war being marked by the actual end of military conflict. Levy (1983) concurred with the Singer & Small criteria of adopting a common-sense approach rather than a legalistic one and referred to Wright's evaluation as necessary.

Other war measurements include the *number of casualties* as criteria, for instance, Richardson in "Statistics of Deadly Quarrels" covered the period 1820-1949 and applied the criteria of 317 mortalities, as per Wright (1965 p 1544). But, others varied from Gaston's 2000 deaths which included those missing in action, to Singer & Small's 1000, Levy concurred on the 1000 deaths criteria. But the problem is that a large proportion of the period of Singer & Small's study (1816-1965) was a relatively peaceful time and the 1000 deaths may preclude smaller, but significant conflicts and also ignores the increased population over time.

Wright (1965 p 638) referred to 4 types of war: "balance-of-power, civil, defensive, and imperialistic wars.". Where a balance of power war was a war between recognised states, a civil war was one within a state, an imperial war was one where the actions of a recognised state to expand was at the expense of those people not recognised as a state, and finally for a defensive war, the defence of a recognised state against attacks from others outside. The balance-of-power wars steadily accounted for about 50% of all wars. However, these type distinctions have diminished over time. The difference between balance-of-power wars and civil wars was sometimes blurred, civil wars being second in importance and necessarily included in any analysis. In the twentieth century, the distinction between imperial and defensive was not clear-cut either. Also, some civil wars were supported by outside intervention.

The advantage in this thesis of concentrating analysis on British data is England and Britain's longevity as one of the great powers, albeit with fluctuating fortunes over more recent times. England and Britain was a frequent and major player in wars, only one other country, France was slightly more combatative. Levy similarly stressed the importance of the balance-of-power wars and the "distinctiveness of their behaviour", and the need to separate out major players from the minor.

> *"significant patterns of Great Power behavior may be obscured by noise generated by smaller states operating in more restricted regional systems."*
>
> *Levy (1983) p 4*

The implication of not separating minor and major players in measuring wars for the occurrence of cycles was illustrated by Levy's argument. This was that the Correlates of War Projects (1816-1965 data) and the associated Singer & Small studies suffered from such noise and so may well have contributed to the failure to identify any meaningful results statistically.

The measurement of wars was generally applied as an intensity or severity measure rather than the straightforward record of the incidence of war, to give a richer, more meaningful measure of the impact on society of its occurrence. However, in measuring the intensity of the conflict Levy attributed fatalities per war and not per year of the war. The severity was measured by the total battle fatalities suffered by great powers, in thousands whereas the intensity was measured by, the battle fatalities of great powers per million European population (Levy, Goldstein).

Levy's measurement of war encompassed magnitude, which accounted for extent and duration, extent referring to the number of great powers taking part and duration to the number of war years. Levy's severity accounted for the total number of battle deaths, like Wright's measurement. Levy's intensity was different to Singer & Small's, it encompassed the ratio of battle deaths to the average population separately identifying concentration by the ratio of the number of deaths to the total magnitude (duration x extent = total nation years of war). Levy, faced the same problem as Wright, of not having available, the annual battle death rates, Levy overcame the problem by assigning an even distribution figure per year over the war period. Goldstein modified this by assigning smaller figures for the first and last years of the war.

The severity of war deaths in both Levy's and Singer & Small's cases did not include civilians, although Richardson's did. The preference in this data would have been to include civilians, but historians generally excluded them from their estimates. For pre-1815 data, Levy relied on Sorokin's estimates. Sorokin drew on generally known battle strengths where available, to determine the average army size. The average casualty rate was estimated annually for each war.

The intensity measure of fatalities to general pre-war population figures was used by Singer & Small. Levy (1983 p 87) preferred global population estimates produced by Wilcox & Carr-Sanders, Kuczynski and Grauman. Wright (1965 p 612) similarly drew on Kuczynski's data which was based on Wilcox, and where Grauman's figures were the same as Kuczynski's.

Sorokin's magnitude of casualty measurement was estimated relative to population size which he carried out European-wide and 4-countrywide (France, Great Britain, Austria-Hungary and Russia). Having reviewed the work of John Graunt, William Petty and Gregory King, Sorokin estimated a 40% increase:

> *"from the twelfth to the sixteenth century inclusive, with the exception of the fourteenth century when the population decreased from one-fifth to one-third"*
>
> *Sorokin (1937) vol III p 344*

6.6.3 The relevance and patterns in the data series: cyclical trends identified

Sorokin (1937) in his original study could find no periodicity, no rhythm, no uniformity and concluded that there was:

> *"trendless shifting"*
>
> *Sorokin (1937) vol III pp 359-60*

in the occurrence of wars. Others drawing on his same data do find cycles though.

Wright's (1965) study referred to:

> *"political oscillations"*
>
> *Wright (1965) p 220*

and found a 50-year fluctuation in wars. Disappointingly, Wright's 50-year oscillation assertion was not easily tested for objectivity due to his approach: that of 10-year aggregations of data, omitting the detail. Wright's self-confessed shortcoming was:

> *"Neither the battle, the campaign, nor the war is entirely satisfactory as a unit of statistical tabulation."*
>
> *Wright (1965) p 102*

Wright arrived at his 50-year oscillation via a system of weighting to produce intensity of war by the number of battles between 10 great powers. Thompson (1988) referred to the subjectivity in battle inclusion in data and relative significancy and suggested:

> *"we need to be careful in according too much importance to findings based on battle frequency data."*
>
> *Thompson (1988) p 91*

Those studies that have identified cycles in war include Denton and Phillips (1968)[9] who drew on Wright's and Richardson's data (and implicitly Sorokin's data). Denton and Phillips (1968) found 20-year peaks up until the 1680s, and after, 30-year ones. Denton and Phillips created a combined *amount of violence* indicator which they analysed over 5-year and 20 year-aggregations and have identified between 60/80- to 120-year cycles. The composite index covered the frequency, duration, number of battles etc but not loss of life. However, Richardson (1960 pp 128-31) found, based on 1-year aggregations no periodicity and that outbreaks of war displayed a poisson (random) distribution. Singer & Small (1972) replicated Richardson's random distribution over the period 1816-1965.

Dewey (1971 p 150) reported finding in 1951, over the period 1765-1930, 3 complete 57-year cycles, and over the period 1400-1930, 25 repetitions of a 22-year cycle which he reported pushing back in 1956 to 116 repetitions for data from 600 BC. Later he added a 11.241-year cycle going back to 600 BC. However it is difficult to evaluate the efficacy of the findings, Dewey presented them visually in chart form with no hard data or discussion of methodology.

Singer & Small's (1972) 150-year study and Singer & Cusack (1981) were predisposed not to find cycles and did not separate out *pattern* of cycles from

---

[9] Denton F H & Phillips W "Some Patterns in the History of Violence" (1968), cited by Thompson (1988).

causation, strongly equating the two, that they must go together. The updated Small & Singer (1982) reaffirmed their earlier 1972 study:

> *"the evidence does not support the cyclical view"*
>
> *Small & Singer (1982) p 212*

even with their finding of 20-year or 40-year peaks of magnitude which occurred once a war was underway:

> *"While we cannot say with certainty that war underway exhibits a 20- or 40-year cycle, we can say that this range of cycles is unusually powerful. A test of the hypothesis that the true spectrum is flat leads to its rejection at the .05 level of significance. This in turn leads us to conclude that there is some periodicity in international war underway."*
>
> *Small & Singer (1972) p 209*

In the update, Singer & Small (1982) removed the effects of the two World Wars and found that the now refined 20- to 30-year cycle disappeared and a 14- to 21-year cycle emerged. The Singer-led Correlates of War (COW) project took a serious analytical approach to data evaluation but could not overcome its most serious drawback of all, of simply, too short a time period. The data series of 150 years was just not long enough to produce any convincing arguments for or against the evidence of long war cycles.

Levy (1983) like Singer & Small found no uniformity in the intervals between the commencement of wars, that wars seemed to start at random, and could find:

> *"by a visual inspection of the scattergrams presented ... no hints of any cyclical pattern in either the occurrence of war or in any of its other dimensions."*
>
> *Levy (1983) p 137*

Levy's conclusion was directly at odds with the later study by Goldstein (1988) using Levy's total global dataset. However, Levy did concede that his analysis lacked any "complex" statistically testing for cycles such as that carried out, via spectral analysis by Singer & Small. However, as they failed to detect cycles Levy refrained from attempting any "sophisticated statistical techniques" to uncover any patterns which he did not believe to be significantly present anyway. Goldstein using Levy's data, slightly modified, found an average 50-year cycle:

> *"For nine successive long waves, until 1918, each war peak occurs near the end of an upswing phase period."*
>
> *Goldstein (1988) p 239*

For the global war cycles (as opposed to only British cycles not analysed separately) Goldstein's average 50-year cycle ranges from 27- to 65-year global cycles. The difference between the two studies based on the same data is due to methodology: Levy, as discussed earlier, visually examined for cycles, Goldstein tested statistically. Goldstein's approach was to pre-construct the long phase dates by drawing on Braudel (1972), Frank (1978), Kondratieff (1935) and Mandel (1980) rather than examining the data to identify the phases. He then statistically tested the data for good fits for upswings and downswings, which he generally found. Goldstein's findings based on pre-constructed phase periods supported Kondratieff's assertion that wars were characteristic of the long upswing and not for Mensch's clustering in the early part of the long downswing.

Thompson's (1988) approach in examining global warfare was to identify those wars with greater systemic significance reviewing Toynbee (1954), Farrar (1977), Modelski & Thompson (1981), Modelski (1984), Levy (1985) and Thompson & Rasler (1988). Systemic wars of significance were those wars where the major players succeeded in transforming the global system as against those wars where they failed to do so. World Wars I and II were treated as one global war period because no dominant power emerged from 1918-19 period. Thompson (1988) and with Modelski, related global war's role in enhancing the leading sectors in the lead world economy by increasing demand and expanding infrastructure and causing setbacks, sometimes temporarily, to the war's losers. Thompson:

> *"is quite supportive of the long cycle argument. Some wars bring about significant structural reconcentration while others do not."*
>
> *Thompson (1988) p 109*

Also, global wars were accompanied not only by economic strength in leading sectors but military power, particularly, naval strength. For example, Britain's output in leading sectors, pig iron and cotton demand 1780-1820 increased over 500%, Thompson (1988 p 150) over this war period of British naval supremacy. But suffered decline from 1870s. Positional changes in leading sectors being gradual, except naval, declining in spurts:

> *"Relative economic decline therefore facilitates relative politico-military decline"*
>
> *Thompson (1988) pp 165-6*

and added the rider, that it was debateable how far back Kondratieffs could be traced:

> *"but the impact of war, and especially global wars, on prices certainly becomes easily discernible between the late eighteenth and the midnineteenth centuries - the period with which Kondratieff was most concerned."*
>
> *Thompson (1988) p 195*

and Thompson therefore remained agnostic regarding the existence of Kondratieffs.

In conclusion, Sorokin (1937), Richardson (1960), Singer & Small (1972, 1982), Singer & Cusack (1981), Levy (1983) did not find cyclical war periods, but Kondratieff, Wright (1965) and Goldstein (1988) did, all asserted a 50-year cycle, with Thompson (1988) an agnostic regarding pre-eighteenth century cycles. War is deemed to be an appropriate time series for inclusion because of the impact on socio-economic life, but because of the inconsistency regarding periodicity or not, spectral modelling of the data, as discussed earlier in Chapter 5, is a suitable method to investigate for long cycles.

CHAPTER 7

THE MODELLING USED TO INVESTIGATE FOR LONG CYCLES

7.1 INTRODUCTION

This section explains the approach in evaluating and analysing the long data in the investigation of long cycles. It expands the methodology introduced earlier concerning the heuristic approach and the scientific-seeing in Chapter 5, "A Methodological Approach for Modelling Long Data". The model framework encompasses negative heuristic, the unchanging core assumptions and the positive heuristic, adjustable, flexible criteria to facilitate the working of the model.

The long data used in the whole analysis of long cycles is tin production (metal ore), population, and war (battle fatalities), the longest series is tin, 1150s-1990s as discussed in Chapter 6, "The Data". However, before the tin data is subjected to spectral analysis, in order to illustrate the spectral modelling applied, sunspot data is used as this is reasonably assumed to be a stationary series.

The negative heuristic of the First Stage Modelling reduces heteroscedasticity in the raw data by eliminating the trend. It involves submitting the long data to log transformation, transposition of variables (independent and dependent) and regression analysis. This is carried out on all the data series. Any additional alternative deemed appropriate in the first stage modelling, that of stepped regressions is allowable in accordance with the model's positive heuristic flexibility to facilitate the modelling of the data.

The negative heuristic of the Second Stage Modelling is the application of spectral analysis and white noise tests to the residual output from the First Stage Modelling in the investigation of long cycles. The model's positive heuristic is to allow flexibility in the size and shape of the spectral or kernel windows applied to the periodogram. To illustrate the spectral modelling applied, sunspot data is used. This is because sunspots data has a generally accepted 11-year cycle and Granger's (1971) application of sunspots is repeatedly and widely reported as illustrative of cyclical analyis.

Sunspot data however, is not used to illustrate the reduction of heteroscedasticity as a stationary series, the tin data is used for this. The tin data is the longest time series and because of its focal point in the study, is treated to further modelling.

Extensive use is made of appendices because of the vast amount of calculations necessary to eliminate the trend in the First Stage Modelling and to produce the power spectrums from the spectral analysis in the Second Stage Modelling. In order to reduce the volume of appendices particularly from the spectral modelling (in the "PER" Appendix), the empirical results are shown for the power spectrum over the frequency scale for π from 0 to 0.6 approximately. The results above 0.6 are available but only produced minuscule but voluminous movements which, if included would have meant a "PER" Appendix about six times longer, without adding anything further to long cycle investigation. The appendices are summarised thus:

Table 7.1 Three appendices covering: inputs, ordinates and graphs

The input variables (raw data, log data, trend, residual, etc):	"VAR"	pages 1- 56
The periodogram and spectral density ordinates calculated over varying spectral windows for the power spectrums:	"PER"	pages 1-136
The graphs of variables and power spectrums:	"GR"	pages 1-135

The "PER" Appendix identifies the spectral results (to 0.6 frequency) and shows *all* the empirical findings: the non-cyclical and cyclical. Then, within the thesis in Chapter 8, tables are produced from the "PER" Appendix identifying the cyclical findings. The main findings are then summarised under cycle bandwidths at the end of the results of each of the three data sections (the end of Sections 8.2, 8.3 and 8.4) and evaluated according to the comparative strength of cyclical fluctuation within the data series. The graphs are a visual representation of the spectral results, over the whole frequency, and also the inclusion of "zooms" for closer illustration of cycles within the power spectrum of the data series.

7.2 FIRST STAGE MODELLING : TO REDUCE HETEROSCEDASTICITY IN THE DATA BY TREND ELIMINATION

7.2.1 Modelling actually undertaken to reduce heteroscedasticity in the data

The first stage of the modelling undertaken reduces heteroscedasticity in the raw data by trend elimination, some alternatives to the one used were outlined in Chapter 5. The method is to submit the raw long data to log transformation, (to ease re-scaling of the time series spread over centuries, for the data covers 1150s to the 1990s). This is followed by transposition of the 2 variables, of time (x, the independent variable) and of the logged raw data (y, the dependent variable). After transposition, they are regressed to identify the *constant*, (the y intercept) and the *x coefficient* (slope for each independent variable). The constant and x coefficient derived are then recast in order to calculate the trend for dependent variable y. The trend is then deducted from the original logged data and the residual left is deemed to be the Basic Homoscedastic Approximation Model. Alternative trend elimination is undertaken in large stepped blocks of the data due to the drawbacks in applying regression analysis (see Chapter 5), these are offered as Heteroscedasticity-reduced stepped Models. This stage of the modelling particularly draws from Chatterjee & Price (1977), and Chatfield (1989,1992), Granger & Hatanaka (1971), Granger & Newbold (1986).

Each variable of the First Stage Modelling is shown in the variables Appendix "Var" (pages 1-53) which identifies the initial raw and log data, and all the other variables thus, the "Input Variables: Pre-Spectral Modelling".

Table 7.2 Appendix "VAR" pages 1-53 - "Input Variables: Pre-Spectral Modelling"

The tin data	pages 1-31
The population data	pages 32-44
The war (battle fatalities) data	pages 45-53
The sunspot data (for testing only)	pages 54-56

The 7 columns of variables for each data type cover:

1*	Time (in years) (x)
2	Raw data
3	Log of data (y)
4	Transposed variable 1/x
5	Transposed variable y/x
6*	Trend
7*	Residual

In the heteroscedasticity-reduced trend modelling, just the three essential* columns are actually shown rather than the full seven, where the first column is Time, the second, the new Trend and the third, the Residual for the pre-spectral or First Stage Modelling.

The graphs from the First Stage Modelling are located in the graphs Appendix "GR" (pages 1-135), particularly as follows:

Table 7.3 Appendix "GR"- graphs for the First Stage Modelling (pre-spectral)

The tin:	pages 4- 8	(Spectral: 9-44)
The population:	pages 45-48	(Spectral: 49-82)
The war:	pages 83-85	(Spectral: 86-135)
The sunspots (for testing only):	page 1	(Spectral: 2-3)

The raw data is the basic input variable for the First Stage Modelling, the residual produced is after eliminating the trend (basic or heteroscedastic) from the First Stage Modelling to provide the Input Variable - Pre-Spectral Modelling for the Second Stage Modelling where spectral analysis is applied.

7.2.2 The theoretical underpinning for the modelling undertaken

The transformation of variables introduces some linearity into non-linear data to enable modelling to commence. The linear model is postulated in the original data series thus,

$$y=\alpha+\beta x+\mu \qquad 1.$$

where mu is some random disturbance in the relationship between x, time, the independent variable, and y, the log of the raw data, the dependent variable. The beta coefficient is some increment in y corresponding to a standard unit increase in x. The goodness of fit identifying the proportion of the variability in y explained by x is indicated by the square of the correlation coefficient of R^2. However, this is with some reservation, (Chatterjee & Price (1977), Anscombe (1973)) the model assumes normality and homoscedasticity where it may not exist, the standard deviation of residuals in the long time series increases as the explanatory variable increases. So the error variance is not equal or constant. With some qualification, where R^2 is close to 1 (range 0-1), the model fits the data well, (Tin data: $R^2=67\%$ fit in original log transformed data.)

The further transformation of variables aids analysis where the distribution of the dependent variable y is non-normal. So transformation to stabilise the error variance should lead to homoscedasticity of the data, a necessary pre-condition for cyclical modelling using spectral analysis. To reduce heteroscedasticity, support for the modelling described above is thus given: based on the premise that standard deviation of residuals increases as the explanatory variable increases, so the error variance is not equal or constant. The hypothesis is thus, that standard deviation of residuals is proportional to x, (the corresponding columns for the calculations are given in the "VAR" Appendix immediately following when illustrating the Basic Model), Chatterjee & Price (1977)[1] specifies the model with error term thus:

$$Var(u_i) = k^2 x_i^2, \quad k > 0$$

2.

If the model is postulated as:

$$y_i = \alpha + \beta x_i + \mu_i$$

3.

which is then divided by x on both sides to give a new model:

$$\frac{y_i}{x_i} = \frac{\alpha}{x_i} + \beta + \frac{\mu_i}{x_i}$$

4.

If the new components are defined thus:

---

[1] Chatterjee & Price (1977) Chapter 2, and pp 45-49.

$$\begin{aligned}\acute{y} &= \frac{y}{x},\\ \acute{x} &= \frac{1}{x},\\ \acute{\alpha} &= \beta,\\ \acute{\beta} &= \alpha;\\ \acute{\mu} &= \frac{\mu}{x}.\end{aligned}$$

5.

The model is redefined in these terms and becomes:

$$\acute{y}_i = \acute{\alpha} + \acute{\beta}\acute{x}_i + \acute{\mu}_i$$

6.

In the transformed model, the variance $\acute{\mu}_i$ is held to be constant and equals k^2 and if the error term holds, given at the start, then the model is fitted on the basis of the transformed variables.

So it follows that if the fitted model for the transformed data is

$$\frac{y}{x} = \acute{\alpha} + \frac{\acute{\beta}}{x}$$

7.

then in terms of the original variables the fitted model becomes:

$$y = \acute{b} + \acute{a}x.$$

8.

So fitting the transposed 1/x, y/x means that estimates for a and b in terms of the original model can be made. The transposed model's regression coefficient becomes the constant in the original, the transformed constant becomes the original model's regression coefficient and fitted to remodel the y variable. This transformed model will be referred to as the *"Basic (Homoscedastic Approximation) Model"*.

7.2.3 To illustrate the application of the *"Basic (Homoscedastic Approximation) Model"*

The "Basic Model" takes the log transformed data series as its starting point, for example, the Tin Production series. After the 2 variables: x, (time) the independent variable, and log y, (log of the raw data) the dependent variable have been transposed formed to form new variables as described above, columns 4 and 5, in the "VAR" Appendix, pages 1-15. Th newly transposed variables are subject to regression to form new transformed coefficients. The results for the transformed tin series is that the x coefficient=-1.07 and the constant is 0.003.

In column 6, in the "VAR" Appendix, pages 1-15, the coefficients from the newly transformed variables are then fitted in order to re-model the y dependent variable where the transformed variable x coefficient becomes the constant in the re-modelling, and the constant of the transformed variable becomes the X coefficient, thus re-modelled as

$$y = -1.07 + 0.0031x \qquad 9.$$

This working model, thus re-models variable y as its trend line. The trend line is then deducted from log y, log of the raw data, to give the "Residual" with reduced heteroscedasticity in the data, column 7, in the "VAR" Appendix, pages 1-15.

The graphical depiction for the tin production are in the graphs "GR" Appendix, the inputs for the raw data and log of data, (page 4) the residual forming the "Basic Homoscedastic Approximation Model, (page 5) with its 3 individual subsets broken over the period 1156-1455, 1456-1755 and 1756-1992 , (pages 6-7). This *"Basic (Homoscedastic Approximation) Model"* theoretically should have homoscedastic errors and the least square theory assumptions should hold. The forms the basis of the input variables for the later spectral analysis in the Second Stage Modelling. Because of the length of the time series, it was thought useful to alternatively model the Basic Model in terms of stepped periods with reduced heteroscedasticity providing for other scenarios, where necessary, allowable under the model's positive heuristic approach.

The other scenarios entail transposing new variables in Columns 4 and 5 in the "VAR" Appendix, pages 1-15 for tin and fitting the transformed coefficients regressed over the same stepped periods of 150- and 300- years, to give further re-modelling of the y variable. In the stepped scenario over 300-year periods the newly transformed variables are subject to regression to form new transformed coefficients over 300-year steps. The results for the transformed tin series is given as follows:
that the x coefficients are -1.11575, -0.75675 and 0.86976 and the constants are 0.00556, 0.00135 and -0.00047 which are then fitted with x coefficients as the constants and the constants as coefficients of x.

For the 300-year stepped model, the trend is re-modelled in steps as

$$\begin{aligned} y = {} & -1.11575 + 0.00556x, \\ & -0.75675 + 0.00135x \text{ and} \\ & 0.86976 - 0.00047x \end{aligned} \qquad \textit{10.}$$

The re-modelled trend line is then deducted from the logged data to give the residual for the stepped-300-year periods, which becomes the input data for later spectral analysis. In the stepped scenario over 150-year periods the newly transformed variables from Columns 4 and 5 are subject to regression to form new transformed coefficients over 150-year steps and similarly treated. The trend is re-modelled in steps as

$$
\begin{aligned}
y = &-1.17665 + 0.00921x,\\
&-0.57296 + 0.00087x,\\
&-0.94033 + 0.00192x\\
&-2.56630 + 0.00473x,\\
&-2.19916 + 0.00420x \text{ and}\\
&\ \ 2.16660 - 0.00231x
\end{aligned}
\qquad 11.
$$

The new trend and heteroscedasticity-reduced residuals for both the stepped models for 300- and 150-years are shown in Columns 2 and 3, pages 16-31, in the "VAR" Appendix. These form the basis for the later spectral modelling of the "Heteroscedasticity-reduced: stepped Models". The graphical representation is "GR" Appendix, page 8.

7.3 SECOND STAGE MODELLING : TO INVESTIGATE LONG CYCLES VIA SPECTRAL ANALYSIS

7.3.1 Introduction

The second stage of the modelling applies spectral analysis and white noise tests to the residual output from the First Stage Modelling. The residuals are subjected to spectral analysis and the ordinates for the periodogram are subjected to varying size and shape of spectral or kernel windows being applied to produce spectral density estimates. The spectral density estimates are graphed against a frequency of π, 3.14 to examine for peaks in the power spectrum. This is the preferred choice of grapical depiction rather than a straight periodical presentation because very slim peaks are more easily *visually* detected over a frequency range expressed as λ radians. This analysis particularly draws from Harvey (1993), Granger & Newbold (1986), Fuller (1976), Wei (1993).

To illustrate the spectral modelling applied, sunspot data is used. This is because sunspots data has a generally accepted 11-year cycle and Granger's (1971) application of sunspots is repeatedly and widely reported as illustrative of cyclical analyis.

The approach taken to the investigation of cycles applies spectral analysis over the frequency domain applying spectral or kernel windows rather than autocorrelation analysis, a time domain technique of the autocovariance function with lag windows. The results from the spectral density (also referred to as the power spectrum) compared to the time domain technique of the autocovariance function, is generally considered to be very similar. The power spectrum is simply a linear combination of the autocovariances. Harvey (1993) refers to the power spectrum and the autocovariance function as highlighting:,

> *"the properties of the series in different ways.".*
>
> *Harvey (1993) pp 168-69*

7.3.2 Defining the spectral density, estimating the power spectrum

Spectral analysis uses the finite Fourier transform whereby data is decomposed into sine and cosine waves, then the time series is regressed to give the sine and cosine coefficients, their squares are summed to produce the periodogram ordinates, which are then smoothed by moving average to give the spectral density estimates of a time series. The *spectral representation model* widely given for a times series and which is adopted here, eg. Granger & Newbold (1986), Chatfield (1989,92) is summarised in Harvey (1993 p 175):

$$y_t = \alpha \, cos\lambda_t + \beta \, sin\lambda_t, \; t=1,..., \; T$$

12.

where α are β are fixed parameters in a stationary series.

The periodogram is the sum of the squares of the sine and cosine coefficients divided by 2 for number of frequencies, calculated to 2 degrees of freedom for each of the frequencies. However, the one periodogram ordinate value to 1 degree of freedom is not used for the spectral density estimates and the white noise test.

Another spectral representation, known as Cramer's representation extends the stationary model, it replaces α and β with two random variables, u and v which have zero mean and variance, and includes more frequencies, J frequencies, λ_1, ..., λ; thus,

$$y_t = \sum_{j=1}^{J} (u_j \, cos\lambda_j t + v_j \, sin\lambda_j t)$$

13.

and further extended by allowing J frequencies to go to infinity and replace the summation sign with the integral. The variables u and j are replaced by continuous functions too of λ, thus becoming $y(0) = 2 \int \pi 0 \; f(\lambda) \; d\lambda$ and to show that the spectral density may viewed as a decomposition of the variance into cyclical components over the continuum, 0, π. So, Cramer's representation is given by,

$$y_t = \int_0^{\pi} u(\lambda) \; cos\lambda t \; d\lambda \; + \int_0^{\pi} v(\lambda) \; sin\lambda t \; d\lambda$$

14.

Granger & Newbold's representation of the spectral density or power spectrum is referred to as S(ω) and is summarised thus:

$$S(\omega) = [\sigma^2/(2\pi)] \; [1 + 2 \sum_{\tau=1}^{\infty} \rho_\tau \cos(\tau\omega) \;] \qquad 0 \leq \omega \leq 2\pi$$

15.

and similarly is the standard function defined over the frequency domain range, $-\pi$, π but in fact all the information is contained in the range, 0, π. This is because the integral of the power spectrum from 0 to 2π is equal to σ^2 and S(ω) = S(2π - ω). In other words, the cyclical trigonometric function, y = cos x, measures x in terms of radians, (λ). As there are 2π radians to the circle, and as x moves from 0 *to* 2π then it follows that y will show its values over the whole range. The frequency in radians, λ, also referred to as the angular frequency when defined as a parameter allows for variable y to be expressed as a cyclical function of time. By substituting λt in place of variable x along the horizontal axis means that different time horizons are allowable as λ changes. The period of the cycle, with period along the horizontal axis, shows how long it takes, ie. number of periods in order to complete a cycle, thus period $=2\pi/\lambda$. Or, over the frequency domain, 2π/jth peak of λ radians (ie. time units) gives the period length of the cycle. In other words, the cycle j has a frequency λ (Granger's frequency expressed as ω_j) whose peak over the plotted range denotes a cycle's recurrence every $2\pi/\lambda$ time units.

To sum up, the preference in the thesis as stated earlier, is to depict the power spectrum graphically over the frequency rather than period because the slight peaks seem visually easier to illustrate this way. As the investigation is for long cycles, any peaks denoting frequencies close to 0 in the plotted spectrum will be of more interest than those closer to π, which are more associated with shorter cycles. Should no clear peaks emerge, this may be indicative of no long cycles and/or leakage problems whereby overlay of many different length cycles, if existing, may be rolling around on top of each other so no impression can be drawn regarding any particular cycle. Potentially this could be a Catch-22 situation, to eliminate a cycle from the power spectrum, one must have knowledge of the length of that cycle. However, the big advantage of applying spectral analysis is that, there is no prejudgement of cycle lengths. Thus it is not necessary to eliminate (apart from the trend elimination and stationarity pre-condition) a cycle or thereby introduce a false cycle: a whole picture of the power spectrum can be visually studied, and then pinpointed more directly for closer visualisation. The trend procedure in the First Stage as indicated earlier in Chapter 5, uses regression rather than filters so as not to colour any potential medium-cycles which might be identified, thus during the Second Stage Modelling any weighting can be carried out in the spectral procedure on the periodogram.

The graphical representation of the jth peak or lack of, in the data, plotted over the frequency domain is shown in the Graphs Appendix, the appendix beginning "GR".

7.3.3 The spectral or kernel window in the spectral density (power spectrum)

An approach to reduce the variance in a spectrum is to smooth it and produce a spectral estimator of the sample spectrum from some type of weighted average function of local frequencies, local being to the left and right of a target frequency. This weighting function is referred to as the window. As the thesis has taken a frequency domain approach to the spectrum production, the window is therefore known as the *spectral or kernel window*, alternatively the time domain approach incorporates a *lag* window.

The impact of the spectral window, which Tukey refers to as:

> *"window carpentry"*
>
> *Wei (1993) p 279*

on the resulting power spectrum is that the variance of the smoothed spectrum decreases with the larger bandwidth of the window. The larger bandwidth incorporates more ordinates from the periodogram calculated through the weighting function to produce the spectral density estimates and therefore a smoother spectral estimator. The positive heuristic allows choice in the spectral analysis regarding the size and shape of the kernel window used for the data type. This is a useful device to enable identification and for cycles to emerge which otherwise would be submerged, the danger to be borne in mind is Hanson's reminder of the drawback to scientific-seeing so that the investigation does not become pre-disposed to any particular cycle. This is to be remedied by applying common sized kernel windows across all the data studied.

There are an increasing number of lag and spectral windows described in the literature, with the main ones being Bartlett, Parzen, Tukey-Hanning, Tukey-Hamming and Blackman-Tukey (Harvey 1993, Wei 1993, Granger & Newbold 1986). The windows can be generally described in terms of rectangular and triangular spectral windows. A spectral window should be nonnegative, otherwise some frequencies are going to fall outside the measured symmetry 0 to π. The spectral window which is more triangular (such as Bartlett's) has a main lobe with the side peaks or lobes of decreasing magnitude, in effect, the Bartlett's window has smaller side lobes than a more rectangular window. This may possibly reduce the potential for leakage of other frequencies by allowing a smaller contribution in the smoothing of frequencies from the more distant ordinates in the general locality in the weighting function.

The literature does not suggest any optimal window shape or bandwidth, there being a need to balance stability (smoothing) with resolution (peaks visibility). The general recommendation is to undertake "window closing". This is summed up neatly by Wei (1993) which is to select broader bandwidths in the initial calculation of spectral density estimates, then recalculate:

> *"using gradually smaller bandwidths until the desired stability and resolution are achieved."*
>
> *Wei (1993) p 280*

With a given set of observations, an estimator for the spectrum can be a *sample* spectral density and is given thus:

$$I(\lambda) = \frac{1}{2\pi} [c(0) + 2\sum_{\tau=1}^{T-1} c(\tau) cos\lambda\tau], \quad 0 \leq \lambda \leq \pi \qquad 16.$$

Harvey (1993) p 198

The T here is finite, and $I(\lambda)$ as calculated gives the periodogram for the spectral density estimate. The weights for the periodogram in order to produce the spectral density estimates are scaled and normalised to sum to $(1/4\pi)$ and scaled relative to the rectangular or triangular window being used. Generally in the thesis, both types (rectangular and triangular) are computed and plotted. The more rectangular window smooths the peaks in the spectrum and make it more stable but may reduce resolution. There is no optimum in the literature regarding the best window size and generally it is thought experience is the best practice which is why the positive heuristic allows choice in the spectral analysis regarding the size and shape of the kernel window used depending on the data type.

The width of the spectral window in the estimator of the spectral density is defined in the window's weighting procedure. The width of the window in simple terms is the length of its base. The width can be measured at least two ways: through its range for lag windows or through its bandwidth in the spectral density which is $2\pi m/T$ in λ radians, the time units over the frequency domain. Briefly, through its range for lag windows, and the number for the completely independent estimators, that is, n spectral points / m is illustrated through a simple example for the window width: if T=101 observations, n spectral points = (T-1)/2 = 50 points in the spectrum, and m=5, Granger's m varies from 3 to 6. So n/m = 50/5 = 10 estimators. Thus, for n spectral points of 50, and the interval width of 5 @ 10 estimator points, gives (5, 10, 15, 20, 25, 30, 35, 40, 45, 50).

However the one used in the thesis is the width of the spectral window in the spectral density as measured through its bandwidth which is $2\pi m/T$ in λ radians, the time units over the frequency domain. So, using the same simple example, T=101, if m=5, n spectral points = (T-1)/2=50 and the rectangular or triangular window choice is made over those points, with the smoothed frequencies varying from 3 to 11 generally.

7.3.4 **Testing the spectral representation model and the results from the sunspots time series**

In order to test the spectral representation model used in the thesis, the model is tested out on some data prior to the long cycle investigation. The test data is sunspots density, which is chosen because it has a generally accepted 11-year cycle and Granger's (1971) application of sunspots is widely reported as illustrative of cyclical analysis. However, the application of sunspots in this thesis differs from Granger in two ways: the data is about 95 years longer than Granger's, being 1700-1993 rather than 1755-1952; and spectral or kernel windows rather than lag windows are used over the frequency domain.

The sunspots data is based on monthly averages of minimum and maximum density of sunspot activity from 1700-1988. The data from 1988-1993 is supplied by Rutherford Appleton Laboratory, Stamper (1994). The raw data for minimum and maximum activity is subject to monthly averaging and then the annual mean is calculated, (however the Rutherford data is based on more detailed readings, and where possible, daily observations over some part of the period, then averaged for a monthly and then annual mean by them). The raw data used here is plotted and shown in the graphs, "GR" Appendix, page 1.

The total data is subjected to periodogram calculation and then various spectral windows applied to produce differing spectral density estimates. The resulting ordinates from the periodogram calculation and various spectral density estimates are located in the "PER" Appendix, pages 1-8. The resulting power spectrum based on the various rectangular and triangular spectral windows are plotted graphically. The various windows are tested over both the rectangular and triangular 7, 5 and 3 (over 7, 5, 3 smoothed frequencies). The windows for 5 and 3 are depicted in the graphs "GR" Appendix, pages 2-3. The period of the cycle is $2\pi / \lambda$ over the frequency domain, by calculating 2π/jth peak of λ radians to obtain the period length of the cycle in years.

The sunspot analysis is summarised thus:

Table 7.4 Sunspots Density: Spectral results

Sunspots Density Anticipated Cycle Length 11.1 yrs

Spectral Window	Ordinates*: Period-gram	Ordinates*: Spectral Density Estimates	Frequency **	Cycle Length	Cycle Range
Rectangular=R Triangular=T			λ radians	$2\pi/\lambda$	years
R7	20165	3057	0.5556	11.3 yrs	10.9-11.3
T7	73876	3972	0.5984	10.5 yrs	10.5-10.9
R5	88948	3950	0.5770	10.9 yrs	10.5-10.9
T5	73876	4727	0.5984	10.5 yrs	10.5-10.9
R3	73876	5741	0.5984	10.5 yrs	10.5-10.9
T3	73876	5775	0.5984	10.5 yrs	10.5-10.9

Notes to above Table:

* /See Appendix "PER", pages 1-6 :PER, -R7,-T7,-R5,-T5,-R3 and -T3.

** /See Appendix "GR", pages 1-3 :GR, -R5,-T5,-R3 and -T3.

and for the input variables, see Appendix "VAR", pages 54-56.

Support for a sunspot cycle length of 11.1 years is given by Rutherford Appleton Laboratory[2]. The difference is probably due to the raw data used from 1700-1988 being less accurately measured than Rutherford's, being based on averaging of minimum and maximum activity whereas Rutherford's 11.1 years is based on more detailed readings, with some daily observations over part of the period. The Rutherford Laboratory state they regard my derived cycle "as entirely consistent with the data" (July 1994). The intention of using sunspot data here being to illustrate the working of spectral analysis as applied in the long data investigation rather than to pinpoint the *exact* length of sunspot cycles.

---

[2] Stamper, R (1994) also cites McKinnon (1987), USA.

The sunspot graphs (Graphs Appendix "GR" pages 2-3) for the power spectrum are *visually* more informative than the summarised tabular results above drawn from the appendices. They show that the larger and more rectangular the spectral window, the flatter the spectrum frequency giving a broader range to the cycle length. The wider spectral window may be more appropriate for data with some estimation by allowing for a broader range of values. The narrower and more triangular windows produce a sharper peak in the frequency, perhaps suggesting a more precise cycle than there really is given the original starting data. In this case, with a larger spectral window, the stability may actually provide *better* resolution rather than less, by allowing a broader range from 10.9 to 11.3 years rather than a narrower 10.5 peak with more smaller windows. So the choice of window really depends on the data itself, therefore all the appropriate windows will be tested on the long data.

7.3.5 Testing for white noise

White noise tests are applied to the estimate of the spectral density in to order to ascertain whether the movements in the time series are due to random movements. Under the null hypothesis, that the time series is white noise, the white noise test would produce a flat line parallel to the horizontal axis.

Fuller (1976) particularly covers two white noise tests: the Fisher-Kappa and Bartlett's Kolmogorov-Smirnov, and these are the tests used in the thesis on the long data. The periodogram ordinates are treated as multiples of chi-square independent, random, each with 2 degrees of freedom. To test the hypothesis of independence, Fuller describes Bartlett's test based on the normalised cumulative periodogram:

$$C_k = cum[I_n(\omega_k)] = [\sum_{j=1}^{m} I_n(\omega_j)]^{-1} \sum_{j=1}^{k} I_n(\omega_j)$$

17.

Fuller (1976) p 285

which is plotted as a sample distribution function, the periodogram ordinates are calculated for the deviations from trend, to 2 degrees of freedom (where Fuller's ω relates to bandwidth described by others as λ in terms of 2πk/n or 2πm/T). The hypothesis that the original time series is white noise is based on the periodogram ordinates plotted as a sample distribution for a sample $m-1$ selected from the uniform (0,1) distribution. Then the Kolmogorov-Smirnov test is applied to find the maximum absolute difference of the standardised partial sums of the periodogram and the uniform (0,1) random variable.

The Bartlett's Kolmogorov-Smirnov test is suitable for "m" sample size over 30, thus

$$(m-1) > 30$$

18.

and at the 95% critical point, Birnbaum (1952) suggests the Kolmogorov-Smirnov test statistic is approximately

$$1.36(m-1)^{-1/2},$$

19.

for the 99% critical point, the test statistic is about

$$1.63(m-1)^{-1/2}.$$

20.

To illustrate Bartlett's Kolmogorov-Smirnov white noise test using the sunspot density test data:

Table 7.5 Sunspots Density

Bartlett's Kolmogorov-Smirnov white noise test:

Time series data : Sunspot density
Period of observations of data : 1700 -1993
No. of observations for processing : 294
No. of ordinates calculated : 148
No. with 2 degrees of freedom
for m for the white noise test: 147

Bartlett's Kolmogorov-Smirnov white
noise Test Statistic : 0.6803

To compare the Test Statistic to critical points, $(m-1=146)$ @
5% critical point : $1.36(m-1)^{-1/2} = 0.1126$
1% critical point : $1.63(m-1)^{-1/2} = 0.1349$

(The periodogram ordinates calculated are given in "PER" Appendix pages 1-6.)

So, as the Bartlett's Kolmogorov-Smirnov Test Statistic of 0.6803 is well above both the values of the critical points, the white noise null hypothesis is rejected. Thus, it can be inferred that the original sunspot density series does not comprise of white noise.

There is a secondary, less rigorous test for white noise, the Fisher-Kappa test. Fuller (1976) covers this test and provides the Table[3] giving the 1, 5 and 10 percentage points

---

[3] Fuller (1976), Table 7.1.2 "Percentage points for the ratio of largest periodogram ordinate to the average", p 284.

for the distribution, to compare to the Fisher-Kappa Test Statistic.

Table 7.6 Sunspots Density

The Fisher-Kappa white noise test:

The Fisher-Kappa model is : (m-1) x (max P) / Sum P
where m-1 is as above for the BKS test,
max P is the maximum periodogram ordinate calculated,
sum P being the sum of ordinates.

For the sunspot density data, as above used in the BKS,

m-1	: 146
max P	: 88948.49
sum P	: 480957.69

The Fisher-Kappa Test Statistic

$$= \frac{146 \times 88948.49}{480957.69} = 27.0013$$

To compare the Test Statistic to Fuller's Table 7.1.2 (Table m=150)@

5% critical point : = 7.832
1% critical point : = 9.372

(From ordinates calculated given in Appendix "PER" pages 1-6.)

Therefore, as the Fisher-Kappa Test Statistic of 27.0013 is well above both the values of the critical points, the white noise null hypothesis is rejected. Thus, it can be inferred that the original sunspot density series does not comprise of white noise.

To conclude, there has been successful testing of the spectral model and white noise tests to be applied in the Second Stage Modelling, on sunspots data, where pre-knowledge of the sunspot cycle was known. The results from the test confirms the length of the sunspot cycle at 10.5-11.3 years which is entirely consistent with the pre-known 11.1 year cycle. The model is therefore taken forward and applied in the investigation of long cycles on data series for tin production, population and war (battle fatalities), reported in the next chapter, "Spectral Data Results". The significant findings which are reported and evaluated by data type in the next chapter are based on the spectral results shown in detail in the Appendix "PER":

Table 7.7 Appendix "PER"- Periodogram ordinates and spectral density estimates

The sunspot data (for testing only)	PER 1-6
The tin data	PER 7-55
The population data	PER 56-96
The war (battle fatalities) data	PER 97-136

The 4 columns of variables for each data type cover:

1 Frequency in λ radians
2 Period in years ($2\pi/\lambda$)
3 Periodogram ordinates (P_01)
4 Spectral density estimates (S_01)

Nb: Additional columns (P_02) and (S_02) are included as necessary to show the log results on the same page as the raw (P_ 01, S_01).

7.3.6 Testing the robustness of the model variations for the spectral analysis

For the spectral analysis, the results of which are detailed in Chapter 8, the data is subjected to a number of model variations for spectral modelling, at varying levels of reduced hetereoscedasticity, in the search for long cycles.

Granger (1986, 1971) asserts that in investigating for cyclical fluctuations the problem is that:

> *"It is this very mixture of regularity and non-regularity that has provided the main difficulty in econometric model building and in statistically describing (and thus analysing) economic series."*
>
> *Granger (1971) p 17*

Spectral analysis provides a mathematically convenient approach to this regularity and non-regularity problem because economic data is likely to have fluctuations which vary in duration and amplitude even though there is some average cycle or fluctuation present. The spectral approach essentially describes the fluctuations in economic data by generalising this idea, moving from a sum of sine terms to an integral of a sine function over a band of periods. So although spectral analysis was originally designed for continuous and strictly periodic functions of time, the great advantage of the approach is the facility to comprehend a band of periods. As long as, of course, the data is of sufficient length, covering 7-10 potential cycle lengths.

Thus, in order to make the band(s) of period comprehensible and come into view in the spectrum, it was thought necessary to vary the models of data trend manipulation for the spectral analysis. So, log transformation as the starting point or starting model is useful in maintaining the low frequencies (long cycles) in economic data by allowing all the data to be shown without any loss of information. However, the additional models of the Basic (Homoscedastic Approximation) Model and the

Hetereoscedasticity-reduced Models, as detailed earlier, provide further variations for this mixture of regularity and non-regularity assessment.

The robustness of these model variations for spectral analysis is tested on the tin data, with the detailed results being studied in the following Chapter 8. The tin data length of 837 years is broken down into 32 blocs of 25-years (exception being the first bloc at 36-years). The mean and the variance is calculated for each bloc, for every model variation subjected to spectral modelling: the log, the basic model and the heteroscedasticity-reduced models, stepped over 150- and 300-years, shown in Tables 7.8-7.9.

Table 7.8 Mean and variance for Tin data's Log and Basic Models

BLOCS FROM 1156 - 1992 IN 32@25-YEAR BLOCS (1st=36y)

Bloc Periods	BASIC MODEL		LOG TRANSFORMATION	
	mean	var	mean	var
Total over whole period	-0.31	0.20	-0.78	0.24
1156-1191	0.25	0.07	-0.76	0.08
1192-1216	0.46	0.01	-0.46	0.01
1217-1241	0.22	0.01	-0.62	0.01
1242-1266	0.07	0.00	-0.69	0.00
1267-1291	0.17	0.00	-0.51	0.00
1292-1316	0.13	0.01	-0.48	0.01
1317-1341	0.23	0.03	-0.30	0.03

1342-1366	-0.19	0.05	-0.64	0.05
1367-1391	-0.01	0.01	-0.39	0.01
1392-1416	0.10	0.00	-0.20	0.00
1417-1441	-0.10	0.00	-0.32	0.00
1442-1466	-0.28	0.00	-0.43	0.00
1467-1491	-0.25	0.00	-0.32	0.00
1492-1516	-0.21	0.00	-0.20	0.00
1517-1541	-0.19	0.00	-0.10	0.00
1542-1566	-0.30	0.00	-0.13	0.00
1567-1591	-0.45	0.00	-0.20	0.00
1592-1616	-0.54	0.00	-0.22	0.00
1617-1641	-0.60	0.01	-0.21	0.00
1642-1666	-1.07	0.49	-0.60	0.51
1667-1691	-0.51	0.01	0.04	0.01
1692-1716	-0.50	0.00	0.13	0.00
1717-1741	-0.51	0.00	0.20	0.00
1742-1766	-0.42	0.01	0.37	0.01
1767-1791	-0.41	0.00	0.46	0.00
1792-1816	-0.50	0.01	0.44	0.00
1817-1841	-0.39	0.00	0.63	0.00
1842-1866	-0.31	0.01	0.79	0.01
1867-1891	-0.20	0.00	0.97	0.00
1892-1916	-0.54	0.01	0.71	0.01
1917-1941	-1.06	0.06	0.27	0.06
1942-1966	-1.37	0.00	0.03	0.01
1967-1992	-1.01	0.02	0.48	0.02

Table 7.9 Mean and variance for Tin data's Stepped Hetereoscedasticity-reduced Models

BLOCS FROM 1156 - 1992 IN 32@25-YEAR BLOCS (1st=36y)

	HETEROSCEDASTICITY-REDUCED MODELS			
Bloc Periods	Stepped-150 years		Stepped-300 years	
	mean	var	mean	var
Total over whole period	-0.01	0.07	-0.07	0.11
1156-1191	0.25	0.04	0.25	0.06
1192-1216	0.27	0.01	0.39	0.01
1217-1241	-0.12	0.02	0.09	0.01
1242-1266	-0.43	0.00	-0.13	0.00
1267-1291	-0.48	0.00	-0.09	0.00
1292-1316	-0.24	0.14	-0.19	0.01
1317-1341	0.12	0.03	-0.15	0.02
1342-1366	-0.24	0.05	-0.63	0.05
1367-1391	-0.01	0.01	-0.52	0.01
1392-1416	0.16	0.00	-0.47	0.00
1417-1441	0.01	0.00	-0.73	0.01
1442-1466	-0.08	0.00	-0.38	0.15
1467-1491	-0.00	0.00	0.00	0.00
1492-1516	0.07	0.00	0.09	0.00
1517-1541	0.12	0.00	0.15	0.00
1542-1566	0.04	0.00	0.09	0.00
1567-1591	-0.08	0.00	-0.02	0.00
1592-1616	0.08	0.03	-0.07	0.00

1617-1641	0.12	0.01	-0.09	0.01
1642-1666	-0.39	0.48	-0.51	0.50
1667-1691	0.13	0.01	0.10	0.01
1692-1716	0.10	0.00	0.15	0.00
1717-1741	0.05	0.00	0.18	0.00
1742-1766	0.07	0.00	-0.02	0.04
1767-1791	0.03	0.00	-0.11	0.00
1792-1816	-0.09	0.01	-0.12	0.00
1817-1841	-0.00	0.00	0.08	0.00
1842-1866	0.05	0.01	0.25	0.01
1867-1891	0.13	0.00	0.45	0.00
1892-1916	0.11	0.05	0.20	0.01
1917-1941	-0.11	0.06	-0.24	0.06
1942-1966	-0.29	0.01	-0.46	0.01
1967-1992	0.21	0.03	-0.00	0.02

It was also thought useful to show the total mean and variance for each model variation as extracted from the above two Tables, 7.8 and 7.9, and summarised in Table 7.10 below.

Table 7.10 Extract showing Total mean and variance of all the Models subjected to spectral analysis in the Tin data

BLOCS FROM 1156 - 1992 : IN 32@25-YEAR BLOCS

TOTALS:	mean	var
Log Transformation	-0.78	0.24
Basic Model	-0.31	0.20
Hetereoscedasticity-reduced:		
300-yr Step Model	-0.07	0.11
150-yr Step Model	-0.01	0.07

Having calculated the mean and variance in 25-year blocs over the various forms of the models subjected to the later spectral analysis, examination of Tables 7.8 and 7.9 shows that each model variation, whilst never achieving true homoscedasticity, the mean and variances very gradually move closer to zero. The Log Transformation model, as expected shows the largest mean and variances over the 25-year blocs of data, with the Basic Model, comparatively revealing slightly smaller mean and variances. The two Hetereoscedasticity-reduced Models, as expected, show movements closer to zero, with the Stepped-150 years Model illustrating the closest approximation to weak stationarity of all of the models subjected to spectral analysis. However, the slightest period for weak stationarity, for all the models, is over the period from the 1900s.

The summarised total figures for the mean and variance in Table 7.10 reveals a total mean starting in the Logged data at -0.78 which reduces to -0.01 in the Heteroscedasticity-reduced Model, Stepped-150 years. Similarly, the total variance for the Logged data at 0.24 to a final modelling at 0.07 in the Heteroscedasticity-reduced Model. This confirms the validity of the model variations in reducing hetereoscedasticity as applied to the economic data in the thesis, given the choice of spectral analysis as the technqiue for cyclical investigation.

The lack of complete stationarity in the data is consistent with Granger's prediction regarding economic data, thereby allowing for slight trends to exist. The strict imposition of the condition of stationarity was not envisaged in other than physical science data. Thus the range of the variance illustrated in the above tables is in line with Granger's (1971) assertion that economic data approximating to weak stationarity is acceptable for spectral analysis. Kendall (1983, 1968) similarly finds weak stationarity acceptable for spectral modelling. The same methodology was also applied to the other data, battle fatalities and population.

Indeed, Granger did not always attempt any trend elimination if he believed there was "no visible trend", as per his method in his spectral analysis of the New York Commercial Paper Rates. He preferred to rely on his bandwidth estimator in the spectral modelling, particularly varying the spectral windows. As the bandwidth of the window increases, more spectral ordinates are averaged, and so the resulting estimator becomes smoother, more stable with smaller variance but less resolution in the spectrum. The drawback is that the bias increases because more and more spectral ordinates are used in the smoothing procedure so lowering the peak, and important features may be smoothed out. The advantage of spectral analysis as an investigative technique is that it enables "window carpentry" to be undertaken, as discussed earlier in this chapter, 7.3.3. Where there is still some trend remaining in the data, the data exhibiting particularly weak stationarity then smoothing over a narrow bandwidth can produce a higher resolution but less stability. This may not be particularly informative if the higher resolution shows peaks in the power spectrum at say, 10, 11, 13 years. A lower resolution is required, over a broader bandwidth, so the frequency clarifies to a cycle centred at 11.5 years, for example. As stated earlier, the choice has to balance a compromise between variance reduction and high resolution or high stability.

Granger on examining the results of the width of the peaks in the spectrum, found the wider the width, the larger the range of the cyclical fluctuation. Also, any confirming harmonics (multiples of the the first peak) found gives more confidence to the first peak found in the spectrum (closest to zero) indicative of the cycle length. Thus the data with weak stationarity, such as the New York Commercial Paper Rate, which Granger subjected to spectral analysis (and no modelling variations to eliminate trend) was found to have a 40-month fluctuation (width of peak varying indicative of a 37-43 month range, Granger p 64). Granger deemed the finding to be significant as it was accompanied by smaller peaks of 20-months and 10-months which suggested confirming harmonics supporting the first peak at 40-months. So altogether, the flexibility of the spectral approach aided the evaluation of data such as economic and social data which was not truly made stationary.

To sum up Granger (1986,1971), on which Kendall (1983,1968) concurred, regarding economic data, weak stationarity and spectral analysis: he recognised it would be poor practice not to attempt to remove any "visible trends" in economic data to be subjected to spectral analysis, but that:

> *"one need not worry about a slight trend existing in the data that one has missed (or that an important trend has not been entirely removed)."*
>
> *Granger (1971) p 192*

This was because achieving *complete* stationarity in economic data was so fraught with difficulty compared to data in the physical sciences, that it was not reasonable to apply the condition of complete stationarity to data such as economic data as strictly as that applied in the physical sciences.

As a result and the attested ability of spectral modelling to cope with data with some unresolved trend, ideally suited the technique for the modelling purposes of this thesis. It reduces the problem of trend elimination to one of eliminating the *gross* visible trends from the data series, and the smoothing of the residual peaks are then dealt with in the spectral (kernel) window modelling.

CHAPTER 8

SPECTRAL DATA RESULTS

8.1 INTRODUCTION

This section examines the results of the spectral analysis carried out on the long data. The methodological approach was addressed in Chapter 5 which identified the model's heuristics and the terms by which the evaluation of the cyclical findings would be made and comparatively interpreted, thus:

P Powerfully strong,
S Strong,
M Medium,
W Weak and
v for very weak.
Plus, C for any finding which crosses over into another cyclical range as defined,
(where the centred jth peak is identified as S, M, W or v).

Based on the methodological approach in Chapter 5, the modelling used to investigate the long cycles was explained in Chapter 7: to reduce heteroscedasticity was covered in the "First Stage Modelling" section, where tin data was used for illustration; the modelling of the spectral analysis was identified in the "Second Stage Modelling" section and illustrated by application to homoscedastic sunspot data series. The residual output from the first stage modelling is the input material for the spectral analysis modelling.

The results from the spectral modelling are reported by analysing the power spectrum for all the ranges, translating the frequency given in lambda (λ) radians and thereby reporting it as a cycle length, in years. The spectral results are reported in the tables in this section, for all the weak jth peaks identified. This summarises the appendices containing the "PER" calculations of the periodogram ordinates and spectral density estimates. Reporting and evaluating all the weak peaks in the power spectrum allows the significance of the peak or otherwise to develop as the detailed investigation unfolds, across the various power spectrums, in the different kernel windows. At the end of each section on the three main empirical data series, that is, at the end of sections 8.2, 8.3 and 8.4 for tin, population and war, there are overall summary tables drawing together the main findings with frequency bandings of the cycles identified. The overall summary tables also include the evaluatory terms referring to the strength of the cyclical findings.

As in traditional or normal economic time series, the findings are not as clearly cyclical or non-cyclical, as for example, those found in the sunspot data series used to illustrate the spectral modelling.

8.2 THE SPECTRAL RESULTS AND WHITE NOISE TESTS FOR TIN

8.2.1 Introduction

This section examines the results of the spectral analysis carried out on tin data, 1156-1992 with the tin residuals investigated under various scenarios. The scenarios are based on the Original Raw Data, the Original Data Log Transformed, the residual outputs from the "First Stage Modelling" thus, the Basic (Homoscedastic Approximation) residual, the Heteroscedasticity Reduced 300-year Stepped Model residual and the Heteroscedasticity Reduced 150-year Stepped Model residual. The separate scenarios are treated to spectral analysis with varying sized windows and white noise tests carried out. The spectral windows are rectangular and triangular drawn from any or all of 3, 5,7, 9, 11, 20-21 and 41 smoothed frequencies.

The variables from the First Stage Modelling which form the inputs to this stage are located in the "VAR" Appendix, pages 1-15 for the Basic Model, and pages 16-31 (16-23 and 24-31) for both the Heteroscedastic models, graphically depicted "GR" Appendix, pages 4-8.

8.2.2 The Original Raw Data and its Log Transformation

8.2.2.1 The results of the spectral analysis

The original raw data from 1156-1992 and its log transformation are visually presented, (Graphs Appendix: "GR"-Tin, pages 4-5). Only limited spectral analysis is undertaken because this is the trended raw data. The application of varied sized spectral windows, both rectangular and triangular windows, when tested revealed little in the way of long cycles in the spectrum. The results of the rectangular windows smoothed over 9 and 5 frequencies only are illustrated graphically and summarised below.

The results of the spectral analysis of the tin original RAW data and its LOG showing jth peaks in the power spectrum is summarised thus:

Table 8.2.1 Raw and Log data: Spectral windows

Tin data Activity

Anticipated Cycle Length: None.

Kondratieff Cycle Length: 48-60 yrs.

		Ordinates*:				
Spectral Window		Period-gram	Spectral Density Estimates	Frequency **	Cycle Length	Cycle Range
Rectangular=R				λ radians	$2\pi/\lambda =$	years
Triangular=T					$2(3.14)/\lambda$	
R9	Raw	7.53	0.949	0.1351	46.5 yrs	46.5-49.2 yrs
	"		0.380	0.1877	33.5 yrs	33.5-34.9 yrs
	"	11.56	0.400	0.2702	23.3 yrs	23.3-28.9 yrs
	"		0.055	0.3753	16.7 yrs	--
	"		0.053	0.4054	15.5 yrs	15.5-.8 yrs
	"		0.099	0.5330	11.8 yrs	11.8-13.3 yrs

R5	Raw	23.96	1.393	0.1201	52.3 yrs	52.3-59.8 yrs
	"	7.00	0.447	0.173	36.4 yrs	36.4-38.0 yrs
	"	8.24	0.603	0.2627	23.9 yrs	23.9-27.0 yrs
	other minor peaks					
	"		0.132	0.518	12.1 yrs	12.1-.9 yrs
	"		0.060	0.563	11.2 yrs	11.2-.3 yrs
R9	Log	0.63	0.160	0.075	83.7 yrs	--
	"	0.97	0.173	0.0976	64.4 yrs	64.4-69.8 yrs
	"	0.04	0.119	0.113	55.8 yrs	--
	"	0.109	0.082	0.150	41.9 yrs	--
	"	0.007	0.044	0.225	27.9 yrs	--
	"	0.123	0.043	0.263	23.9 yrs	23.9-26.2 yrs
	other very minor peaks					
	"	0.068	0.008	0.556	11.3 yrs	--
R5	Log	0.337	0.179	0.0526	119.6 yrs	--
	"	5.04	0.213	0.0826	76.1 yrs	76.1-83.7 yrs
	"	1.192	0.093	0.1426	44.1 yrs	44.1-46.5 yrs
	"	0.628	0.065	0.1802	34.9 yrs	--
	"	0.524	0.051	0.255	24.6 yrs	24.6-27 yrs
	"	0.411	0.022	0.308	20.4 yrs	--
	other very minor peaks					
	"		0.015	0.495	12.7 yrs	12.7-.9 yrs
	"		0.008	0.540	11.6 yrs	--

Notes to above Table:

*For the raw data and its log, for the full periodogram ordinates and spectral density estimates see:

Spectral Window	Shown in "PER" Appendix, Pages 7-10
Rectangular 9	PER-Tin-II-Raw+Log-R9
Rectangular 5	PER-Tin-II-Raw+Log-R5.

**For the graphical presentation of the power spectrum over the various kernel windows see:

Spectral Window		Shown in Graphs "GR"Appendix, Pages 9-12
Rectangular	9	GR-Tin-II-Raw-R9
Rectangular	9	GR-Tin-II-Log-R9
Rectangular	5	GR-Tin-II-Raw-R5
Rectangular	5	GR-Tin-II-Log-R5.

8.2.2.2 The conclusion on spectral results

The graphical representation of the power spectrum also includes zooming into the spectral window in order to highlight the slight peaks identified. The summarised results shown above for the rectangular windows for 9 and 5 smoothed frequencies for the raw data and log are given. For kernel window 9, the raw data's power spectrum shows Medium peaks at 46-52 years and the hint of a harmonic at 23 years, a Weak finding. There is a Weak fluctuation at 33.5-35 years. In window 5, there is a Strong wave from 52-60 years, peaking at 52.3 years. A Medium wave at 24-27 years, peaking at 24 years. Also, very weak blips at 36-38 years and 12.1 and 11.2 years.

The log data's power spectrum shows jth peaks in rectangular window 9 with a Medium wave at 64-76 years, and Weak findings at 84 years, 56 years, 42 years, at 24 and 28 years and a very weak 11.3 years. For window 5 for the log data, there is a Strong wave at 76-84 years, Medium waves at 120 years and 25-27 years (weakly found in the larger window). Then, Weak findings for 44-47 years, and very weak at 35 years, 20.4 years, plus 12.7 and 11.6 years.

Since the results are based on trended data and really no conclusion regarding any long cycles can be inferred from the spectral modelling of the initial data. Further pre-spectral modelling is required, to reduce the trend and make it more homoscedastic.

8.2.2.3 The results of the white noise tests

The results of the white noise tests of the tin original raw data and its log are summarised thus:

Table 8.2.2 Raw and Log data

Bartlett's Kolmogorov-Smirnov white noise test:

Time series data : Original raw data and its log
For each series:
Period of observations of data : 1156 -1992
No. of observations for processing : 837
No. of ordinates calculated : 419
No. with 2 degrees of freedom
for m for the white noise test: 418

Bartlett's Kolmogorov-Smirnov white
noise Test Statistic : 0.9161 (Raw Data)
0.8442 (Its Log)

To compare the Test Statistic to critical points, $(m-1=418)$ @
5% critical point : $1.36(m-1)^{-1/2} = 0.0665$
1% critical point : $1.63(m-1)^{-1/2} = 0.0797$

(The periodogram ordinates calculated are given in Appendix PER-Tin-II-Raw+Log-R9-5, pages 7-10)

Since the Bartlett's Kolmogorov-Smirnov Test Statistic of 0.9161 for the Original Raw Data and 0.8442 for its Log are well above the values of the 5% and 1% critical points, the white noise null hypothesis is rejected for both series. Thus, it can be inferred that in the tin series, the original raw data and its log do not comprise of white noise.

Table 8.2.3 Raw and Log data

This is a less rigorous test for white noise,

The Fisher-Kappa white noise test:

The Fisher-Kappa model is (m-1) x (max P) / Sum P
where m-1 is as above for the BKS test,
max P is the maximum periodogram ordinate calculated,
sum P being the sum of ordinates.
For the tin data, as above used in the BKS,

	Original Raw Data	Its Log
m-1	: 418	418
max P	: 1596.4	101.4
sum P	: 3710.6	202.9

The Fisher-Kappa Test Statistic

$$\frac{418 \times 1596.4}{3710.6} = 179.8 \qquad \frac{418 \times 101.4}{202.9} = 208.9$$

To compare the Test Statistic to Fuller's Table[1] (Table m=400)@

5% critical point : = 8.889
1% critical point : = 10.480

(from ordinates calculated given in Appendix PER-Tin-II-Raw+Log-R9-5, pages 7-10.)

Since the Fisher-Kappa Test Statistic of 179.8 for the Original Raw Data and 208.9 for its Log are well above the values of the 5% and 1% critical points, the white noise null hypothesis is rejected for both series. Thus, it can be inferred that in the tin series, the original raw data and its log do not comprise of white noise.

---

[1] Fuller (1976), Table 7.1.2 "Percentage points for the ratio of largest periodogram ordinate to the average", page 284.

8.2.3 The Basic (Homoscedastic Approximation) Model

8.2.3.1 Introduction

The Basic (Homoscedastic Approximation) Model (1156-1992) is the residual output from the First Stage Modelling decribed earlier, variables are shown in "VAR" Appendix, pages 32-40 and visually shown in the graphs appendix, "GR", Tin, pages 5-7). This forms the base material input to the modelling in this section. The Basic (Homoscedastic Approximation) Model is subjected to spectral analysis with various spectral windows, rectangular and triangular smoothed over differing frequencies. More analysis has been carried out on this model than any of the others as it is the model which represents the fundamental de-trended residual output for the tin data.

The Basic Model is first treated to some general spectral analysis for both rectangular and triangular windows. This involves the specification of the whole range of the spectral density estimates for all the windows used. The frequencies specified range from very large windows of 41 and 21 then relatively medium sized windows of 11 and 9, and then smaller windows of 5 and 3 frequencies. The anticipation being that there are no long cycles in the data, so by selecting such a wide variety over the whole spectrum it was thought that no peaks would be discernible across the spectrum over differing windows. The general advice in the spectral literature is to start with larger windows and move down to smaller ones over fewer frequencies.

The Basic (Homoscedastic Approximation) Model is also subjected to further investigation. This further investigation entails breaking the Model's data into three separate Subsets of 300-, 300- and the remaining 237-year periods. The data is not changed, it is the same as that in the whole range of the Basic (Homoscedastic Approximation) Model, but broken down in three separate components for individual analysis. The intention of breaking the Model into three separate components for separate spectral analysis is to aid the identification or otherwise, of long cycles. The notion being that should long cycles exist, whether their length changes over the centuries which thus would be missed in examining the *whole* data range as in the first investigation of The Basic (Homoscedastic Approximation) Model.

As with the Raw and Log Data, all of the Basic (Homoscedastic Approximation) Model, including its three separate component Subsets is also more closely scrutinised. The close scrutiny involves zooming into a common-scaled range or more detailed one for the spectral density estimates and frequency range rather than the whole 0 to π in order to highlight more clearly any slight fluctuations found in the power spectrum.

8.2.3.2 The Results of the The Basic (Homoscedastic Approximation) Model

The methodology for the general spectral modelling is described in the earlier section "Second Stage Modelling" where the periodogram and spectral density (power spectrum) are defined. The tables below identify the detailed findings, the summary results at the end of the tin section tabulates the main findings.

8.2.3.2.1 The results from the larger windows

The Basic (Homoscedastic Approximation) Model is subjected to periodogram calculations and the larger spectral windows of triangular 41, triangular 21, rectangular 20 are applied to produce differing power spectrums. The resulting ordinates from the periodogram calculations and various spectral density estimates are located in the "PER" Appendix, for the larger spectral windows and the power spectrums are visually shown in the Graphs Appendix, "GR", pages given below.

From the power spectrum graphs, it can be visually seen that they appear to depict the traditional economic time series, displaying no discernible cycles. However, minute investigation of the power spectrums reveal the slightest peaks as follows and is summarised thus:

Table 8.2.4 Basic (Homoscedastic Approximation) Model: Large windows

Tin data Activity — Anticipated Cycle Length: None.

Kondratieff Cycle Length: 48-60 yrs.

	Ordinates:*				
Spectral Window	Period-gram	Spectral Density Estimates	Frequency **	Cycle Length	Cycle Range
Rectangular=R			λ radians	$2\pi/\lambda =$	years
Triangular=T				$2(3.14)/\lambda$	
T41	No peaks perceived in the power spectrum.				
R20	0.448	0.0303	0.1802	34.9 yrs	--
	0.199	0.2908	0.2027	31.0 yrs	--
	0.408	0.0261	0.2252	27.9 yrs	--
	0.262	0.0226	0.2552	24.6 yrs	--
	0.151	0.0201	0.2853	22.0 yrs	--
	0.214	0.0182	0.3228	19.5 yrs	--
	0.074	0.0172	0.3453	18.2 yrs	--
	0.324	0.0150	0.3753	16.7 yrs	--
	0.248	0.0143	0.3979	15.8 yrs	--
	0.079	0.0149	0.4129	15.2 yrs	--
	0.421	0.0133	0.4429	14.2 yrs	--
	0.024	0.0118	0.4879	12.9 yrs	--
	0.117	0.0120	0.5105	12.3 yrs	--
	0.216	0.0100	0.5555	11.3 yrs	--
T21	No peaks perceived in the power spectrum.				

Notes to above Table:

Notes to above Table:

*For the full periodogram ordinates and spectral density estimates see:

Spectral Window		Shown in "PER" Appendix, Pages 11-13
Triangular	41	PER-Tin-II-Basic-T41
Rectangular	20	PER-Tin-II-Basic-R20
Triangular	21	PER-Tin-II-Basic-T21

**For the graphical presentation of the power spectrum over the various large kernel windows see:

Spectral Window		Shown in Graphs "GR"Appendix, Pages 13-14
Triangular	41	GR-Tin-II-Basic-T41.
Rectangular	20	GR-Tin-II-Basic-R20.
Triangular	21	GR-Tin-II-Basic-T21.

The jth peaks ranging from 11 to 35 years in the power spectrum of the rectangular window smoothed over 20 frequencies are of the very slimmest and could not reasonably be described as (weak) discernible cycles.

8.2.3.2.2 The results from the medium windows

The Basic (Homoscedastic Approximation) Model is subjected to periodogram calculations and medium-sized spectral windows of rectangular 11, triangular 11, rectangular 9 and triangular 9 are applied to produce differing power spectrums. The resulting ordinates from the periodogram calculation and various spectral density estimates are located in the "PER" Appendix for the medium spectral windows and the power spectrums. These are visually shown in the Graphs Appendix, "GR" including more detailed illustrations of the kernel window to highlight any slight peaks.

Table 8.2.5 Basic (Homoscedastic Approximation) Model: Medium windows

Tin data Activity — Anticipated Cycle Length: None.

Kondratieff Cycle Length: 48-60 yrs.

	Ordinates:*				
Spectral Window	Period-gram	Spectral Density Estimates	Frequency **	Cycle Length	Cycle Range
Rectangular=R			λ radians	$2\pi/\lambda =$	years
Triangular=T				$2(3.14)/\lambda$	
R11	0.874	0.0523	0.1126	55.8 yrs	--
	0.816	0.0359	0.1501	41.8 yrs	41.8-44 yrs
	0.487	0.0298	0.1877	33.5 yrs	33.5-34.9/38 yrs
	0.269	0.0255	0.2177	28.9 yrs	--
	0.365	0.0238	0.2327	27.0 yrs	--
	0.019	0.2345	0.2627	23.9 yrs	--
	0.151	0.0205	0.2853	22.0 yrs	--
	0.059	0.1963	0.3078	20.4 yrs	--
	0.373	0.0161	0.3378	18.6 yrs	--
	0.072	0.0159	0.3603	17.4 yrs	--
	0.080	0.0146	0.4054	15.5 yrs	--
	0.421	0.0133	0.4429	14.2 yrs	--
	0.033	0.0133	0.4729	13.3 yrs	--
	0.081	0.0116	0.4955	12.9 yrs	--
	0.096	0.0117	0.5180	12.1 yrs	12.1-.3 yrs
	0.132	0.0111	0.5330	11.8 yrs	--
	0.349	0.0091	0.5705	11.0 yrs	--
T11	0.448	0.0288	0.1802	34.9 yrs	--
	0.382	0.0224	0.2477	25.4 yrs	--
	0.699	0.0231	0.2702	23.3 yrs	23.3-23.9 yrs

	0.373	0.1548	0.3378	18.6 yrs	--
	0.319	0.0156	0.3528	17.8 yrs	--
	0.421	0.0137	0.4429	14.2 yrs	14.2-.9 yrs
	0.222	0.0136	0.4579	13.7 yrs	--
	0.216	0.1098	0.5555	11.3 yrs	11.3-11.8 yrs
R9	0.057	0.0381	0.1351	46.5 yrs	--
	0.135	0.0356	0.1576	39.9 yrs	--
	0.448	0.0304	0.1802	34.9 yrs	34.9-36.4 yrs
	0.368	0.0280	0.1952	32.2 yrs	--
	0.038	0.0240	0.2402	26.2 yrs	--
	0.262	0.0220	0.2778	22.6 yrs	22.6-23.3 yrs
	0.402	0.0201	0.3003	20.9 yrs	--
	0.214	0.1699	0.3228	19.5 yrs	--
	0.167	0.0167	0.3678	17.1 yrs	17.1-18.2 yrs
	0.079	0.0136	0.4129	15.2 yrs	--
	0.043	0.0129	0.4279	14.7 yrs	--
	0.026	0.0149	0.4504	14.0 yrs	--
	0.033	0.0143	0.4729	13.3 yrs	13.3-.5 yrs
	0.242	0.0123	0.4879	12.9 yrs	--
	0.084	0.0104	0.5255	12.0 yrs	--
	0.020	0.0110	0.5405	11.6 yrs	--
	0.057	0.0098	0.5780	10.9 yrs	--
T9	0.448	0.0294	0.1802	34.9 yrs	--
	0.382	0.0223	0.2477	25.4 yrs	--
	0.699	0.0241	0.2702	23.3 yrs	--
	0.214	0.0153	0.3228	19.5 yrs	--
	0.319	0.0158	0.3528	17.8 yrs	17.8-18.6 yrs
	0.167	0.0156	0.3678	17.1 yrs	--

	0.247	0.0122	0.4204	14.9 yrs	--
	0.222	0.1395	0.4579	13.7 yrs	13.7-14.4 yrs
	0.084	0.0092	0.5255	12.0 yrs	--
	0.216	0.0116	0.5555	11.3 yrs	11.3-.6 yrs

Notes to above Table:

*For the periodogram ordinates and spectral density estimates see:

Spectral Window	Shown in "PER" Appendix, Pages 14-17
Rectangular 11	PER-Tin-II-Basic-R11
Triangular 11	PER-Tin-II-Basic-T11
Rectangular 9	PER-Tin-II-Basic-R9
Triangular 9	PER-Tin-II-Basic-T9

**For the graphical presentation of the power spectrum over the various large kernel windows see:

Spectral Window	Shown in Graphs "GR"Appendix Pages 15-18
Rectangular 11	GR-Tin-II-Basic-R11
Triangular 11	GR-Tin-II-Basic-T11
Rectangular 9	GR-Tin-II-Basic-R9
Triangular 9	GR-Tin-II-Basic-T9

From the power spectrum graphs given above, it can be seen that again they appear to generally to depict the traditional economic time series. However, minute examination reveals some slight fluctuations that can be discerned in the spectrum, more so than with the larger windows however. These again are described in the clearer terms of Strong, Medium, Weak and very weak fluctuations in the power spectrum. The minuscule very weak ones tabulated above are not to be included in the summary results, being too small as to be negligible.

In the medium windows, the rectangular window 11 shows a number of Weak and very weak findings. The Weak findings are 41-44 years, and with a number of very weak ones including 33.5-35 years given in the table above and ranging from 11 to 30 years. The triangular window 11 shows minuscule very weak cyclical fluctuations ranging from 11 to 35 years, with only the range 23-24 years being described as very weak. Rectangular window 9 shows very weak findings at 46.5 years, 40 years, 35-36 years and 26 years. Minute fluctuations range from 11 to 23 years detailed in the above table which are not to be counted as very weak for the summary data results. The findings for rectangular 9 show a very weak fluctuation at 23 years, and again minute ones ranging from 11.3 to 35 years (in above table) which are too small to be included in the overall summary results.

8.2.3.2.3 The results from the smaller windows

The Basic (Homoscedastic Approximation) Model is subjected to periodogram calculations and the smaller spectral windows of rectangular 5, triangular 5, rectangular 3 and triangular 3 are applied to produce differing power spectrums. The resulting ordinates from the periodogram calculations and various spectral density estimates are located in the "PER" Appendix for the smaller spectral windows and the power spectrums are visually shown in the Graphs Appendix, "GR".

However, exhaustive investigation of the power spectrums reveal the slightest peaks as follows and is summarised thus:

Table 8.2.6 Basic (Homoscedastic Approximation) Model: Small windows

Tin data Activity — Anticipated Cycle Length: None.

Kondratieff Cycle Length: 48-60 yrs.

	Ordinates:*				
Spectral Window	Period-gram	Spectral Density Estimates	Frequency **	Cycle Length	Cycle Range
Rectangular=R			λ radians	$2\pi/\lambda =$	years
Triangular=T				$2(3.14)/\lambda$	
R5	0.080	0.0379	0.1426	44.0 yrs	--
	0.639	0.0336	0.1652	38.0 yrs	38-39.9 yrs
	0.448	0.0320	0.1802	34.9 yrs	--
	0.368	0.0283	0.1952	32.2 yrs	--
	0.365	0.0233	0.2327	27.0 yrs	--
	0.019	0.0258	0.2627	23.9 yrs	23.9-24.6 yrs
	0.151	0.0281	0.2853	22.0 yrs	--
	0.059	0.0169	0.3078	20.4 yrs	--
	0.373	0.0171	0.3378	18.6 yrs	18.6-19 yrs
	0.319	0.0160	0.3528	17.8 yrs	17.1-.8 yrs
	0.112	0.0168	0.3829	16.4 yrs	--
	0.080	0.0137	0.4054	15.5 yrs	--
	0.043	0.0141	0.4279	14.9 yrs	--
	0.026	0.0151	0.4504	14.0 yrs	--
	0.081	0.0137	0.4955	12.7 yrs	12.7-.9 yrs
	0.096	0.0103	0.5180	12.1 yrs	12.1-.3 yrs
	0.200	0.0104	0.5405	11.6 yrs	11.6-.8 yrs
	0.026	0.0136	0.5630	11.2 yrs	11.2-.3 yrs
T5	1.294	0.0448	0.1276	49.2 yrs	49.2-55.8 yrs
	0.816	0.0316	0.1501	41.9 yrs	--

	0.639	0.0318	0.1652	38.0 yrs	--
	0.448	0.0306	0.1802	34.9 yrs	--
	0.408	0.0248	0.2252	27.9 yrs	27.9-28.9 yrs
	0.699	0.0272	0.2702	23.3 yrs	23.3-24.6 yrs
	0.373	0.0176	0.3378	18.6 yrs	18.6-19.5 yrs
	0.319	0.0158	0.3528	17.8 yrs	--
	0.112	0.0160	0.3829	16.4 yrs	16.4-17.1 yrs
	0.421	0.0157	0.4429	14.2 yrs	14.2-.7 yrs
	0.416	0.0143	0.4804	13.1 yrs	13.1-.3 yrs
	0.216	0.0131	0.5555	11.3 yrs	11.3-.8 yrs
	0.349	0.0134	0.5705	11.0 yrs	--
R3	8.03	1.4646	0.0300	209.3 yrs	--
	1.03	0.0941	0.0826	76.1 yrs	--
	0.059	0.0591	0.1201	52.3 yrs	--
	0.057	0.0380	0.1351	46.5 yrs	--
	0.135	0.0422	0.1576	39.9 yrs	39.9-41.9 yrs
	0.070	0.0307	0.1727	36.4 yrs	--
	0.487	0.0346	0.1877	33.5 yrs	--
	0.408	0.0277	0.2252	27.9 yrs	27.9-28.9 yrs
	0.262	0.0295	0.2778	22.6 yrs	22.6-23.9 yrs
	0.254	0.0214	0.2928	21.5 yrs	--
	0.095	0.0181	0.3303	19.0 yrs	19-19.5 yrs
	0.074	0.0203	0.3453	18.2 yrs	--
	0.112	0.0170	0.3829	16.4 yrs	16.4-17.4 yrs
	0.027	0.0177	0.4504	14.0 yrs	14-14.7 yrs
	0.033	0.0166	0.4729	13.3 yrs	13.3-.5 yrs
	0.024	0.0138	0.4880	12.9 yrs	--
	0.117	0.0115	0.5105	12.3 yrs	12.3-.5 yrs
	0.084	0.0083	0.5255	12.0 yrs	--

	0.026	0.0157	0.5630	11.2 yrs	11.2-.6 yrs
	0.057	0.0131	0.5780	10.9 yrs	--
T3	1.030	0.0910	0.0826	76.1 yrs	--
	1.294	0.0538	0.1276	49.2 yrs	49.2-55.8 yrs
	0.816	0.0367	0.1501	41.9 yrs	--
	0.487	0.0356	0.1877	33.5 yrs	33.5-34.9 yrs
	0.408	0.0289	0.2252	27.9 yrs	27.9-28.9 yrs
	0.382	0.0212	0.2477	25.4 yrs	--
	0.699	0.0334	0.2702	23.3 yrs	23.3-.9 yrs
	0.402	0.0222	0.3003	20.9 yrs	20.9-21.5 yrs
	0.373	0.0182	0.3378	18.6 yrs	18.6-19.5 yrs
	0.324	0.0184	0.3753	16.7 yrs	16.7-17.1 yrs
	0.248	0.0155	0.3979	15.8 yrs	15.8-16.1 yrs
	0.247	0.0122	0.4204	14.9 yrs	--
	0.421	0.0192	0.4429	14.2 yrs	14.2-.4 yrs
	0.416	0.0177	0.4804	13.1 yrs	13.1-.3 yrs
	0.221	0.0127	0.5030	12.5 yrs	--
	0.084	0.0079	0.5255	12.0 yrs	--
	0.216	0.0132	0.5555	11.3 yrs	11.3-.6 yrs
	0.349	0.0155	0.5705	11.0 yrs	--

Notes to above Table:

*For the periodogram ordinates and spectral density estimates see:

Spectral Window		Shown in "PER" Appendix Pages18-21
Rectangular	5	PER-Tin-II-Basic-R5
Triangular	5	PER-Tin-II-Basic-T5
Rectangular	3	PER-Tin-II-Basic-R3
Triangular	3	PER-Tin-II-Basic-T3

**For the graphical presentation of the power spectrum over the various large kernel windows see:

Spectral Window		Shown in Graphs "GR"Appendix Pages 19-22
Rectangular	5	GR-Tin-II-Basic-R5
Triangular	5	GR-Tin-II-Basic-T5
Rectangular	3	GR-Tin-II-Basic-R3.
Triangular	3	GR-Tin-II-Basic-T3.

The detailed examination of the smaller windows reveal a number of minuscule very weak fluctuations in the power spectrum which are not to be included in overall summary results. A few very weak cycles are identified. In rectangular window 5, a Weak to very weak fluctuation of 44 years, and very weak ones of 38-40 years, 35 years (placed together at 35-40 form a Weak wave), 24 years and 22 years. The minucule blips in the power spectrum range from 11.2 to 20 years. In triangular window 5, Weak to very weak cyclical fluctuations at 49-56 years and 23.3-24.6 years. Then very weak waves at 35 years, 28-29 years, and very minor ones ranging from 11 to 20 years.

There is a slender hegemony cycle in spectral window 3 peaking at 209 years in the rectangular only, Medium strength. Also, Medium wave at 76 years, Weak at 52 and 40-42 years. Most of the other ones tabulated above are very weak, from 11 to 46 years. In triangular window 3, there are 2 Medium waves around 76 and 49-56 years. Weak oscillations around 42, 33-35 and 23 years, with very weak ones of 28-29, 16-21, 13-14 and 11 years.

8.2.3.2.4 Conclusion on window results

In conclusion, given the results from the overall Basic (Homoscedastic Approximation) Model, no strong cyclical fluctuations have emerged across the various power spectrums.

In the medium windows, the rectangular window 11 is clearer than the triangular one, showing a number of Weak and very weak findings as detailed earlier. The Weak findings are around 41-44 years. In both, there are minute ones ranging from 11.3 to 35 years which are too small to be included in the overall summary results.

The detailed examination of the smaller windows reveal a few very weak cycles. In rectangular window 5, a Weak to very weak fluctuation of 44 years, in the triangular window 5, Weak to very weak cyclical fluctuations at 49-56 years and 23.3-24.6 years. There is a slender hegemony cycle in spectral window 3 peaking at 209 years in the rectangular only, Medium strength. Also, Medium wave at 76 years, Weak at 52 and 40-42 years. In triangular window 3, there are 2 Medium waves around 76 and 49-56 years. Weak oscillations around 42, 33-35 and 23 years.

As a result of the slimness of fluctuations that are found, and given that none were expected, it is thought worthwhile to explore the Basic (Homoscedastic Approximation) Model over three separate periodical Subsets in the following section after the white noise tests.

8.2.3.2.5 The results of the white noise tests

The results of the white noise tests of the Basic (Homoscedastic Approximation) Model data is summarised thus:

Table 8.2.7 Basic (Homoscedastic Approximation) Model

Bartlett's Kolmogorov-Smirnov white noise test:

Time series data	:	Basic (Homoscedastic Approximation) Model
Period of observations of data	:	1156 -1992
No. of observations for processing	:	837
No. of ordinates calculated	:	419
No. with 2 degrees of freedom		

for *m* for the white noise test: 418

Bartlett's Kolmogorov-Smirnov white noise Test Statistic : 0.8441

To compare the Test Statistic to critical points, *(m-1=418)* @

5% critical point : $1.36(m-1)^{-1/2} = 0.0665$

1% critical point : $1.63(m-1)^{-1/2} = 0.0797$

(The periodogram ordinates calculated are given in Appendix PER-Tin-R11-7, pages 11-21.)

Since the Bartlett's Kolmogorov-Smirnov Test Statistic of 0.8441 for the Basic (Homoscedastic Approximation) Model is above the values of the 5% and 1% critical points, the white noise null hypothesis is rejected for the series. Thus, it can be inferred that in the tin series, the Basic (Homoscedastic Approximation) Model does not comprise of white noise.

Table 8.2.8 Basic (Homoscedastic Approximation) Model

The Fisher-Kappa white noise test:

The Fisher-Kappa model is (m-1) x (max P) / Sum P
where m-1 is as above for the BKS test,
max P is the maximum periodogram ordinate calculated,
sum P being the sum of ordinates.

For the tin data, as above used in the BKS,

m-1	: 418
max P	: 51.74
sum P	: 165.7

The Fisher-Kappa Test Statistic

$$\frac{418 \times 51.74}{165.70} = 130.5$$

To compare the Test Statistic to Fuller's Table[2] (Table m=400)@

5% critical point : = 8.889

1% critical point : = 10.480

(from periodogram ordinates calculated given in Appendix PER-Tin-R11-7, pages 11-21.)

Since the Fisher-Kappa Test Statistic of 130.5 for the Basic (Homoscedastic Approximation) Model is above the values of the 5% and 1% critical points, the white noise null hypothesis is rejected for the series. Thus, it can be inferred that in the tin series, the Basic (Homoscedastic Approximation) Model does not comprise of white noise.

8.2.3.3 The results of The Basic (Homoscedastic Approximation) Model broken down into 3 separate subset periods

8.2.3.3.1 Introduction

The Basic (Homoscedastic Approximation) Model is subjected to further investigation. This further investigation entails breaking the Model's data down in to three separate Subsets of 300-, 300- and the remaining 237-year period. The data is not changed, it is the same as that in the whole range of the Basic (Homoscedastic Approximation) Model, but broken down into separate components, referred to as "Subsets" for their individual analysis. The variables from the First Stage Modelling which form the

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[2] Fuller (1976), Table 7.1.2 "Percentage points for the ratio of largest periodogram ordinate to the average", page 284.

inputs to this stage are located in the "VAR" Appendix, pages 1-15 for the Basic Model, and pages 16-31 for the Heteroscedastic models, graphically depicted "GR" Appendix, pages 4-8.

The intention of breaking the Model into separate components for separate spectral analysis is to aid the identification or otherwise, of long cycles. This is due to the slimness of the fluctuations that are discerned in the overall investigation of power spectrums in the previous section, given that none were expected. Whether their length changes over the centuries which would be missed in examining the *whole* data range as in the first investigation of The Basic (Homoscedastic Approximation) Model.

Given the results of the investigation of the whole data range earlier, where spectral windows from 41 down to 3 were examined, the spectral windows are refined for the modelling in this section by eliminating the larger and some of the medium windows. Therefore the spectral windows, both rectangular and triangular are examined over 9, 5 and 3 smoothed frequencies. The three components are over time periods of 1156-1455, 1456-1755 and 1756-1992. These are referred to as Subset1, Subset2 and Subset3 respectively.

The spectral investigation of the three Subsets over the differing spectral windows is based on the whole scaled range of their individual spectral density estimates. This is refined by zooming in for closer scrutiny over shorter spectral density estimates on a common scale or smaller one for all three Subsets in order to illustrate more effectively the slightness of any fluctuations found in the data.

The Basic (Homoscedastic Approximation) Model (1156-1992) is the residual output from the First Stage Modelling decribed earlier and is visually shown in the graphs appendix, (Graphs Appendix: GR-Tin, pages 5-7). This forms the base material input to the modelling in this section. Its component Subsets are visually shown in the graphs appendix. The variables in "VAR" Appendix, pages 1-15.

8.2.3.3.2 The results of Subset 1

Subset1 covers the 300-year period from 1156-1455 of The Basic (Homoscedastic Approximation) Model. The spectral investigation of the Subset is over spectral windows, both rectangular and triangular over 9,5 and 3 smoothed frequencies to produce 6 differing power spectrums. The spectral modelling is based on the whole range of the Subset's individual spectral density estimates and then zooming in for closer scrutiny over a common-scaled or smaller scaled spectral density estimate for all three Subsets.

Table 8.2.9 The Basic (Homoscedastic Approximation) Model: Subset1

Tin data Activity — Anticipated Cycle Length: None.
Kondratieff Cycle Length: 48-60 yrs.

Spectral Window		*Ordinates*:* Period-gram	Spectral Density Estimates	Frequency **	Cycle Length	Cycle Range
Rectangular=R Triangular=T				λ radians	$2\pi/\lambda =$ $2(3.14)/\lambda$	years
R9	#	0.038	0.0071	0.3561	17.6 yrs	--
	#	0.037	0.0065	0.3979	15.8 yrs	--
	#-	0.007	0.0021	0.6493	9.7 yrs	--
T9	#	0.225	0.0072	0.4398	14.3 yrs	14.3-15.8/17.6 yrs
R5	#	0.403	0.0193	0.2304	27.3 yrs	--
	#	0.037	0.0069	0.3979	15.8 yrs	15.8-17.6 yrs
	#	0.225	0.0079	0.4398	14.3 yrs	--
	#	0.028	0.0047	0.5236	12.0 yrs	--
	#e	0.059	0.0023	0.5655	11.1 yrs	--

T5	#	0.403	0.0199	0.2304	27.3 yrs	27.3-30.0 yrs
	#e	0.225	0.0089	0.4398	14.3 yrs	14.3-17.6 yrs
	#e	0.059	0.0027	0.5655	11.1 yrs	--
R3	#-	0.177	0.0238	0.2094	30.0 yrs	30-33.3 yrs
	#-	0.059	0.0190	0.2513	25.0 yrs	--
	#	0.038	0.0052	0.3561	17.6 yrs	17.6-18.8 yrs
	#-	0.045	0.0082	0.4189	15.0 yrs	15-15.8 yrs
	#	0.009	0.0110	0.4608	13.6 yrs	--
	#	0.017	0.0060	0.5027	12.5 yrs	--
	#	0.027	0.0028	0.5864	10.7 yrs	10.7-11.5 yrs
T3	#-	0.177	0.0214	0.2094	30.0 yrs	30.0-33.3 yrs
	#ex	0.089	0.0050	0.3770	16.7 yrs	16.7-18.8 yrs
	#e	0.225	0.0100	0.4398	14.3 yrs	14.3-15 yrs
	#e	0.059	0.0031	0.5655	11.1 yrs	11.1-11.5 yrs

Notes to above Table:

The resulting ordinates from the periodogram calculations and various spectral density estimates are located in the "PER" Appendix and the 6 resulting differing power spectrums are visually shown in the Graphs Appendix, "GR" detailed below.

#ex Cycle length *exactly* the same as a cycle length found in the complete range of The Basic (Homoscedastic Approximation) Model investigation.

#e Cycle length *almost exactly* the same as a cycle length, to 0.1 of a year, found in the complete range of The Basic (Homoscedastic Approximation) Model investigation.

Cycle length within *very similar* range, (0.1-0.9 of a year) of a cycle length found in the complete range of The Basic (Homoscedastic Approximation) Model investigation.

#- Cycle length within *similar* range,(1-4 years) of a cycle length found in the complete range of The Basic (Homoscedastic Approximation) Model investigation.

*For the periodogram ordinates and spectral density estimates see:

Spectral Window	Shown in "PER" Appendix, Pages 22-27	
Rectangular	PER-Tin-II-Sub1	-R9 to
and Triangular 9-3	"	-T3

**For the graphical presentation of the power spectrum over the various large kernel windows see:

Spectral Window	Shown in Graphs "GR"Appendix, Pages 23-25	
Rectangular	GR-Tin-II-Sub1	-R9 to
and Triangular 9-3	"	-T3

Detailed investigation of the power spectrums across the various windows for Subset1 reveals no long cycle fluctuation in any of the spectral windows. In spectral window rectangular 9 there is a Medium to Weak peak occurring at around 17-18 years and a Weak one of 16 years. This is similar, to within one year, for that range found in the overall Basic (Homoscedastic Approximation) Model for the same window. In triangular 9 there is a Strong to Medium wave of 14-17.6 years.

In the spectral window of 5, there is a Strong wave at 27 years which is more discernible in the triangular over the range 27-30 years, consistent with the overall Basic Model. Both windows reveal clearer peaks at 14 years which ranges 14-18 years, at Medium to Strong wave strength. A Weak wave at 12 years, and a minuscule very weak one occurs at 11 years, at almost exactly the same point (to within 0.1 of a year) as the overall Basic Model. In spectral window 3, the clearest fluctuation peaks at 30 years and which ranges 30-33 years, at Strong level, this is to within a three years range of a similarly found one in the overall Basic Model. There is a Medium wave of 13-14 years, Weak ones at 25, 15-16, very weak ones at 17-19 and 12.5 years, and a very weak 10.7-11.5 years.

In conclusion, the spectral windows of 5 and 3 smoothed frequncies reveal more information regarding the slim fluctuations which were hardly perceptible in the overall Basic (Homoscedastic Approximation) Model investigated earlier. The frequencies identified are largely consistent with those of the overall Model and the 300-year fluctation perceived confirms the impression gained from the original raw time series for tin. Subset1's clearest frequency centres on 30 years (30-33 range) and 14 years (14-18 range), Medium strength is centred at 27 years.

8:2.3.3.3 The results of Subset 2

Subset2 covers the 300-year period from 1456-1755 of The Basic (Homoscedastic Approximation) Model. The spectral investigation of the Subset is over spectral windows, both rectangular and triangular over 9, 5 and 3 smoothed frequencies to produce six differing power spectrums, although little information is gleaned over the spectral window of 9. The spectral modelling is based on the whole range of the Subset's individual spectral density estimates and then a closer scrutiny over a smaller range to highlight slight peaks in the power spectrum.

Table 8.2.10 The Basic (Homoscedastic Approximation) Model: Subset2

Tin data Activity — Anticipated Cycle Length: None.
Kondratieff Cycle Length: 48-60 yrs.

		Ordinates*:				
Spectral Window		Period-gram	Spectral Density Estimates	Frequency **	Cycle Length	Cycle Range
Rectangular=R Triangular=T				λ radians	$2\pi / \lambda =$ $2(3.14)/\lambda$	years
R9	#	0.359	0.0356	0.3142	20.0 yrs	--

T9	No peaks found in the power spectrum					
R5	#	0.464	0.0377	0.2932	21.4 yrs	21.4-23 yrs
	#e	0.110	0.0166	0.5236	12.0 yrs	--
	#	0.165	0.0127	0.5864	10.7 yrs	--
T5	#	0.570	0.0392	0.2723	23.1 yrs	23.1-27.3 yrs
R3	#-	0.663	0.0622	0.1466	42.9 yrs	--
	#	0.570	0.0405	0.2723	23.1 yrs	23.1-25 yrs
	#	0.381	0.0333	0.3561	17.7 yrs	--
	#e	0.227	0.0142	0.5655	11.1 yrs	--
T3	#-	1.858	0.1152	0.0834	75.0 yrs	--
	#	0.570	0.0417	0.2723	23.1 yrs	23.1-27.3 yrs
	#	0.482	0.0339	0.3351	18.8 yrs	--
	#ex	0.319	0.0197	0.5027	12.5 yrs	12.5-13 yrs
	#e	0.227	0.0152	0.5655	11.1 yrs	--

Notes to above Table:

The resulting ordinates from the periodogram calculations and various spectral density estimates are located in the "PER" Appendix and the resulting differing power spectrums are visually shown in the Graphs Appendix, "GR" detailed below.

#ex Cycle length *exactly* the same as a cycle length found in the complete range of The Basic (Homoscedastic Approximation) Model investigation.

#e Cycle length *almost exactly* the same as a cycle length, to 0.1 of a year, found in the complete range of The Basic (Homoscedastic Approximation) Model investigation.

Cycle length within *very similar* range, (0.1-0.9 of a year) of a cycle length found in the complete range of The Basic (Homoscedastic Approximation) Model investigation.

#- Cycle length within *similar* range,(1-4 years) of a cycle length found in the complete range of The Basic (Homoscedastic Approximation) Model investigation.

*For the periodogram ordinates and spectral density estimates see:

Spectral Window	Shown in "PER" Appendix, Pages 28-33	
Rectangular	PER-Tin-II-Sub2	-R9 to
and Triangular 9-3	"	-T3

**For the graphical presentation of the power spectrum over the various large kernel windows see:

Spectral Window	Shown in Graphs "GR"Appendix, Pages 26-31	
Rectangular	GR-Tin-II-Sub2	-R9 to
and Triangular 9-3	"	-T3

Spectral window 9 shows one single Weak oscillation, 20 years. No fluctuations appear in the triangular window. Moving down the windows, to 5 and 3, more fluctuations come into focus. In window 5, a Weak wave of 21-23 years, which strengthens to a Medium wave of 23-27 years to be the only one in the triangular window. It's similar to within a year of one found in the overall Basic Model and to within three years of one detected in Subset1.

A modest long cycle fluctuation is perceived in spectral window 3: a Weak one at 43 years for the rectangular and a Weak 75 years for the triangular window. The clearest frequency of Medium strength occurs over 23-27 years, peaking at 23 years in both windows, and is consistent with the overall Basic Model, to within a year. This also compares with a Medium wave of 27-30 years, peaking at 27 years in the power spectrum of Subset1 in a slightly larger window of 5 not 3. A very weak fluctuation is still persisting into Subset2, peaking at 11 years coinciding at exactly the same point as the overall Basic Model as with Subset1. Additionally, in triangular window 3 a Weak fluctuation can be distinguished peaking at a 12.5 year frequency which coincides with one exactly in Subset1 and the overall Model.

To sum up, Subset2's strongest wave is a Medium 23 years (23-27 range).

8.2.3.3.4 The results of Subset 3

Subset3 covers the 237-year period from 1756-1992 of The Basic (Homoscedastic Approximation) Model. The spectral investigation of the Subset is over spectral windows, both rectangular and triangular 9, 5 and 3 smoothed frequencies to produce six differing power spectrums. The spectral modelling is based on the whole range of the Subset's individual spectral density estimates and then zooms in to a smaller scale to aid the highlighting of any peaks in the power spectrum.

Table 8.2.11 The Basic (Homoscedastic Approximation) Model: Subset3

Tin data Activity — Anticipated Cycle Length: None.
Kondratieff Cycle Length: 48-60 yrs.

		Ordinates:*				
Spectral Window		Period-gram	Spectral Density Estimates	Frequency **	Cycle Length	Cycle Range
Rectangular=R Triangular=T				λ radians	2π/λ = 2(3.14)/λ	years
R9	#	0.076	0.0080	0.3712	16.9 yrs	--
	#	0.070	0.0072	0.4772	13.2 yrs	13.2-.9 yrs
	#	0.292	0.0087	0.5567	11.3 yrs	11.3-.9 yrs
T9	-	0.450	0.0159	0.2121	29.6 yrs	--
	#ex	0.292	0.0095	0.5567	11.3 yrs	11.3-13.9 yrs
R5	#-	0.019	0.0150	0.1591	39.5 yrs	--

	#	0.042	0.0197	0.2386	26.3 yrs	26.3-29.6 yrs
	#	0.025	0.0106	0.3181	19.8 yrs	--
	#e	0.028	0.0051	0.4242	14.8 yrs	14.8-15.8 yrs
	#	0.025	0.0109	0.5037	12.5 yrs	12.5-13.2 yrs
	#	0.025	0.0102	0.5833	10.8 yrs	--
T5	#	0.450	0.0184	0.2121	29.6 yrs	29.6-47.4 yrs
	#ex	0.292	0.0112	0.5567	11.3 yrs	11.3-15.8 yrs
R3	#	0.042	0.0191	0.2386	26.3 yrs	26.3-39.5 yrs
	#e	0.144	0.0064	0.4507	13.9 yrs	13.9-15.8 yrs
	#e	0.292	0.0125	0.5567	11.3 yrs	11.3-12.5 yrs
T3	#-	0.450	0.0227	0.2121	29.6 yrs	29.6-33.9 yrs
	#	0.322	0.0179	0.2916	21.6 yrs	21.6-23.7 yrs
	#	0.076	0.0034	0.3712	16.9 yrs	--
	#	0.144	0.0077	0.4507	13.9 yrs	13.9-14.8 yrs
	#ex	0.292	0.0152	0.5567	11.3 yrs	11.3-.9 yrs

Notes to above Table:

The resulting ordinates from the periodogram calculations and various spectral density estimates are located in the "PER" Appendix and the resulting differing power spectrums are visually shown in the Graphs Appendix, "GR" detailed below.

#ex Cycle length *exactly* the same as a cycle length found in the complete range of The Basic (Homoscedastic Approximation) Model investigation.

#e Cycle length *almost exactly* the same as a cycle length, to 0.1 of a year, found in the complete range of The Basic (Homoscedastic Approximation) Model investigation.

Cycle length within *very similar* range, (0.1-0.9 of a year) of a cycle length found in the complete range of The Basic (Homoscedastic Approximation) Model investigation.

#- Cycle length within *similar* range,(1-4 years) of a cycle length found in the complete range of The Basic (Homoscedastic Approximation) Model investigation.
*For the periodogram ordinates and spectral density estimates see:

Spectral Window	Shown in "PER" Appendix, Pages 34-39	
Rectangular	PER-Tin-II-Sub3	-R9 to
and Triangular 9-3	"	-T3

**For the graphical presentation of the power spectrum over the various large kernel windows see:

Spectral Window	Shown in Graphs "GR"Appendix, Pages 32-36	
Rectangular	GR-Tin-II-Sub3	-R9 to
and Triangular 9-3	"	-T3

Close scrutiny of Subset3's power spectrum shows a broader range to the long cycle fluctuations. Whereas none were detected in Subset1, although its clearest longest one was 30-33 years and a 43-year frequency in Subset2, there is a very weak peak of 40 years in rectangular window 5 in Subset3. This broadens and strengthens to a Weak wave of 30-47 years in the triangular window. In the smaller window of 3, the long cycles broadens in the rectangular window to a Weak wave of 26-40 years, and focusses in the triangular to a Weak one of 30-34 years.

Rectangular window 9 shows no long cycles, only very weak fluctuations around 17, 13 and 11 years. The triangular, a very weak 30 year and a Weak 11 year fluctuation. The scale is necessarily shortened to highlight the very weak waves without any further zoomed graphs produced.

There is a Weak peak of 26/30 years in both 5 and 3 spectral windows, which is comparative to the Medium wave 27/30 year frequency range in Subset1 and more clearer, but Medium wave still, 23/27 years in Subset2. There occurs again across the windows a Weak frequency of 11 years which is stronger in Subset3 than the very weak or minuscule waves of 11 years seen in the other subsets.

The bulk of the frequencies in Subset3 fall within the range 26/40 years to provide relatively the most sigificant peaks in the spectrum, being still described comparatively as mainly Weak. This is consistent with the broadening and flattening of the spectrum identified for the subset in the earlier investigation. For the most part, the peak for this subset is centred around 26/30 years. With the other next relative and consistent peak at 11.3 years.

8.2.3.3.5 Conclusion

Long cycle fluctuations are very modest peaks in the data from 30-47 years, particularly a Strong 30-33 years in Subset1, a Weak 43 years in Subset2 and again Weak in Subset3, peaking at 40 years, broadening to 47 years in Subset3.

However, a slightly stronger frequency range than the Kondratieff type overall is viewed at around 23-29 years at Medium strength, shifting from 27/29 in Subset1, to 23/27 in Subset2 and 26/29 years in Subset3 (Weak to Medium).

To sum up, the long fluctuations in terms of Kondratieffs (48-60 years) are not consistently found across the 837 years. Subset1's Strongest frequency centres on 30 years (30-33 range) and 14 years (14-18 range), and also Medium strength is centred at 27 years. Subset2's clearest one is a Medium 23 years (23-25 range). Subset3's strongest is a Weak 30 years (26-30/40 range), and a Weak 11-12 years. A surprising frequency, albeit a very modest one which has persisted across *all* the Subsets and spectral windows, from minuscule very weak to very weak to Weak (being its highest strength). A coincidence is that the test data for sunspots used to illustrate spectral modelling is 11.1 years.

8.2.4 The Heteroscedasticity reduced Models

8.2.4.1 Introduction

This section examines the spectral results of the spectral analysis carried out on the scenarios for the heteroscedastic reduced models for the tin data, 1156-1992.

The methodology for reducing heteroscedasticity was covered in the "First Stage Modelling" section, where tin data was used for illustration. The residual output from the first stage modelling is the input material for the spectral analysis modelling. The methodology for the general spectral modelling was identified in the earlier section "Second Stage Modelling" where the periodogram and spectral density (power spectrum) are defined, and the spectral density tested against stationary sunspot data. The particulars of the two hetereoscedastic scenarios are based on the residual outputs from the "First Stage Modelling" and are referred to as the Heteroscedasticity Reduced 300-year Stepped Model and the Heteroscedasticity Reduced 150-year Stepped Model. The two separate scenarios are treated to spectral analysis with varying sized spectal windows. Given the earlier investigations, the windows are refined to rectangular and triangular for 11, 9, 5 and 3 smoothed frequencies. The variables from the First Stage Modelling which form the inputs to this stage are located in the "VAR" Appendix, pages 16-31 (16-23 and 24-31) for both the Heteroscedastic models, graphically depicted "GR" Appendix, page 8.

8.2.4.2 The spectral results of the Heteroscedasticity Reduced: 300-year Stepped Model

The Heteroscedasticity Reduced 300-year Stepped Model (1156-1992) is subjected to spectral analysis over the whole period with various spectral windows, rectangular and triangular smoothed over 11, 9, 5 and 3 smoothed frequencies to produce differing power spectrums. The variables from the First Stage Modelling which form the inputs to this stage are located in the "VAR" Appendix, pages 16-23, graphed "GR" Appendix, page 8. The resulting ordinates from the periodogram calculations and various spectral density estimates are located in the "PER" Appendix, pages 40-47 and the power spectrums are visually shown in the Graphs Appendix, "GR", pages 37-40.

Detailed investigation of the power spectrums reveal the slightest peaks as follows with only the longest and the clearest of them being cited, summarised thus:

Table 8.2.12 Heteroscedasticity Reduced: 300-year Stepped Model

Tin data Activity — Anticipated Cycle Length: None.
Kondratieff Cycle Length: 48-60 yrs.

	*Ordinates**:				
Spectral Window	Periodgram	Spectral Density Estimates	Frequency **	Cycle Length	Cycle Range
Rectangular=R			λ radians	$2\pi/\lambda =$	years
Triangular=T				$2(3.14)/\lambda$	
R11	0.5128	0.0702	0.1201	52.3 yrs	--
	0.5658	0.0336	0.1802	34.9 yrs	--
	0.4156	0.0277	0.2177	28.9 yrs	26-30 yrs
T11	0.4156	0.0261	0.2177	28.9 yrs	25-29 yrs
R9	3.0000	0.0908	0.0901	69.8 yrs	--
	0.5658	0.0358	0.1802	34.5 yrs	--
	varied*				22-31 yrs
T9	3.0000	0.0975	0.0901	69.8 yrs	--
	0.6191	0.0441	0.1501	41.9 yrs	--
	0.4156	0.0254	0.2177	28.9 yrs	23-27 yrs

R5	14.148	0.8748	0.0225	279 yrs	--
	0.2946	0.1191	0.0751	83.7 yrs	--
	0.0835	0.0950	0.0976	64.4 yrs	--
	0.1859	0.0524	0.1426	44.1 yrs	--
	0.4938	0.0445	0.1652	38.0 yrs	--
	0.5142	0.0290	0.1952	32.2 yrs	--
	varied*				22-29yrs
T5	3.0000	0.1163	0.0901	69.8 yrs	70-76 yrs
	1.0551	0.0499	0.1576	39.9 yrs	40-42 yrs
	varied*				23-29 yrs
R3	2.2374	0.8483	0.0300	209.3 yrs	--
	0.9446	0.1004	0.0676	93.0 yrs	--
	0.0835	0.1225	0.0976	64.4 yrs	64-76 yrs
	0.5128	0.0621	0.1201	52.3 yrs	--
	1.055	0.0575	0.1576	39.9 yrs	40-42 yrs
	0.2425	0.0351	0.1877	33.5 yrs	--
	varied*				23-28 yrs
T3	15.596	0.8057	0.0375	167.4 yrs	--
	3.0000	0.1499	0.0901	69.8 yrs	70-76 yrs
	1.1800	0.0622	0.1276	49.3 yrs	49-52 yrs
	1.0551	0.0641	0.1576	39.9 yrs	40-42 yrs
	0.2425	0.0311	0.1877	33.5 yrs	33-35 yrs
	varied*				23-29 yrs

Notes to above Table:

*For the full periodogram ordinates and spectral density estimates see:

Spectral Window	Shown in "PER" Appendix, pages 40-47	
Rectangular	PER-Tin-II-Step300	-R11 to
and Triangular 11-3	"	-T3

**For the graphical presentation of the power spectrum over the various large kernel windows see:

Spectral Window	Shown in Graphs "GR"Appendix, Pages 37-40	
Rectangular	GR-Tin-II-Step300	-R11 to
and Triangular 11-3	"	-T3

The peaks in the power spectrum over the various windows can be broadly located in the same categories as those found in the Basic Model. The longest persistent cycle is centred around 70 years, ranging 64-76 years with strength varying from very weak to becoming more Strongly focussed in the smaller spectral windows. The other long cycle is centred around 40 years, ranging 38-42 years, waving around Weak to Medium. Both are outside the Kondratieff range of 48-60 years.

A lesser, weaker fluctuation is at 33 years (32-35 range) and a slightly stronger frequency at mainly Weak level, 23-29 years. These are in keeping with the frequencies found in the Basic (Homsoscedastic Approxm) Model, particularly the long frequency of 70 years which lies outside the Kondratieff range.

8.2.4.3 The spectral results of the Heteroscedasticity Reduced: 150-year Stepped Model

The Heteroscedasticity Reduced: 150-year Stepped Model (1156-1992) is the residual output from the First Stage Modelling decribed earlier and is visually shown in the graphs appendix, "GR" page 8, variables in "VAR" Appendix pages 24-31. This forms the base material input to the modelling in this section.

The Heteroscedasticity Reduced: 150-year Stepped Model (1156-1992) is subjected to spectral analysis over the whole period with various spectral windows, rectangular and triangular smoothed over 11, 9, 5 and 3 smoothed frequencies to produce differing power spectrums. The resulting ordinates from the periodogram calculations and various spectral density estimates are located in the "PER" Appendix and the power spectrums are visually shown in the Graphs Appendix, "GR".

Close investigation of the power spectrums reveal the slightest peaks as follows with only the longest and the clearest of them being cited, summarised thus:

Table 8.2.13 Heteroscedasticity Reduced: 150-year Stepped Model

Tin data Activity — Anticipated Cycle Length: None.
Kondratieff Cycle Length: 48-60 yrs.

	Ordinates:*					
Spectral Window	Period-gram	Spectral Density Estimates	Frequency **	Cycle Length	Cycle Range	
Rectangular=R Triangular=T			λ radians	$2\pi / \lambda =$ $2(3.14)/\lambda$	years	
R11	2.8815	2.0554	0.0300	209.3 yrs	--	
	1.1159	0.2053	0.0526	119.6 yrs	--	
	0.2601	0.0707	0.1201	52.3 yrs	--	
	0.2936	0.0474	0.1426	44.1 yrs	--	
	0.7833	0.0371	0.1576	39.9 yrs	--	
	0.5702	0.0307	0.1802	34.9 yrs	--	
	varied*				24-32	yrs
T11	6.5585	0.2462	0.0375	167.4 yrs	--	
	0.7833	0.0338	0.1576	39.9 yrs	--	
					27-29	yrs

	varied*				23/25-34 yrs
					17-19 yrs
					12.7-14 yrs
R9	6.5585	0.2257	0.0375	167.4 yrs	--
	0.2065	0.1041	0.0976	64.4 yrs	--
					46.5 yrs
					39-41 yrs
					27-33 yrs
	varied*				23/25-34 yrs
					13-14 yrs
T9	6.5585	0.2682	0.0375	167.4 yrs	--
	0.7833	0.0324	0.1576	39.9 yrs	--
	varied*				25-29/35 yrs
					17-20 yrs
					12.5-14 yrs
R5	2.8815	0.2991	0.0300	209.3 yrs	--
	0.1494	0.1348	0.0751	83.7 yrs	--
	0.0294	0.0416	0.1426	44.1 yrs	--
	varied*				36-40 yrs
	varied*				23-32 yrs
T5	6.5585	0.3327	0.0375	167.4 yrs	--
		0.034-.039	0.16-.2		32-40 yrs
					38-40 yrs
					32-35 yrs
	varied*	0.15-.045			27-29 yrs
					23 yrs
					17-20 yrs
					12.5-14 yrs

R3	6.5585	0.3532	0.0375	167.4 yrs	--	
	0.1494	0.1389	0.0751	83.7 yrs	--	
	varied*				64	yrs
	varied*				47-56	yrs
	varied*				38-42	yrs
	varied*				31-34	yrs
	varied*				23\26-29	yrs
T3	6.558	0.3954	0.0375	167.4 yrs	--	
					93	yrs
	varied*				70-76	yrs
					60	yrs
					49	yrs
	varied*				40-42	yrs
	varied*				32-35	yrs
	varied*				23\25-28	yrs

Notes to above Table:

*For the full periodogram ordinates and spectral density estimates see:

Spectral Window	Shown in "PER" Appendix, Pages 48-55
Rectangular	PER-Tin-II-Step150 -R11 to
and Triangular 11-3	" -T3

**For the graphical presentation of the power spectrum over the various large kernel windows see:

Spectral Window	Shown in Graphs "GR"Appendix, Pages 41-44
Rectangular	GR-Tin-II-Step150 -R11 to
and Triangular 11-3	" -T3

The resulting power spectrums are more fragmented than in the other models. Broadly, the fluctuations fall in to frequency bands 12.5-14 years, 17-20 years, 23 years, 27-29 years, 32-35 years, 38-40 years, 44 years, 47-56 years, 64 years and 84 years. These range from Weak to Medium strength, with the 27-29 year frequency being about Medium to Strong, relatively.

8.2.5 Conclusion and Results Summary Table

The peaks in the power spectrum over the various windows can be broadly located in the same categories as those found in the Basic Model. The longest persistent cycle is centred around 70 years and 64 years in the two stepped models, ranging 64-84 years. The other long cycle is centred around 40 years, ranging 38-42 years, waving around Weak to Medium. Both are outside the Kondratieff range of 48-60 years. A lesser, weaker fluctuation is at 33 years (32-35 range) and a slightly stronger frequency at mainly Weak level, 23-29 years. These are in keeping with the frequencies found in the Basic (Homoscedastic Approximation) Model.

The main results are summarised on the next page:
Table 8.2.14 Results Summary Table: Tin

TABLE 8.2.14

RESULTS SUMMARY TABLE 1 : TIN

CYCLE	W	I	N	D	O	W	S	I	Z	E
LENGTH	R11	T11	R9	T9	R7	T7	R5	T5	R3	T3
Raw/Log: *Basic:* *Sub:1/2/3*	*R/L* *B* *123*	*R/L* *B* *123*	*R/L* *B* *123*	*R/L* *B* *123*	*R/L* *B* *123*	*R/L* *B* *123*	*R/L* *B* *123*	*R/L* *B* *123*	*R/L* *B* *123*	*R/L* *B* *123*
209	-/- 0 ---	-/- 0 ---	0/0 0 000	-/- 0 000	-/- - ---	-/- - ---	0/0 0 000	-/- 0 000	-/- M 000	-/- 0 000
121-166	-/- 0 ---	-/- 0 ---	0/0 0 000	-/- 0 000	-/- - ---	-/- - ---	0/0 0 000	-/- 0 000	-/- 0 000	-/- 0 000
118-120	-/- 0 ---	-/- 0 ---	0/0 0 000	-/- 0 000	-/- - ---	-/- - ---	0/M 0 000	-/- 0 000	-/- 0 000	-/- 0 000
86-100	-/- 0 ---	-/- 0 ---	0/0 0 000	-/- 0 000	-/- - ---	-/- - ---	0/0 0 000	-/- 0 000	-/- 0 000	-/- 0 000
83-85	-/- 0 ---	-/- 0 ---	0/W 0 000	-/- 0 000	-/- - ---	-/- - ---	0/C 0 000	-/- 0 000	-/- 0 000	-/- 0 000
76-82	-/- 0 ---	-/- 0 ---	0/0 0 000	-/- 0 000	-/- - ---	-/- - ---	0/S 0 000	-/- 0 000	-/- M 000	-/- M 000
71-75	-/- 0 ---	-/- 0 ---	0/0 0 000	-/- 0 000	-/- - ---	-/- - ---	0/0 0 000	-/- 0 000	-/- 0 000	-/- 0 0W0
64-70	-/- 0 ---	-/- 0 ---	0/M 0 000	-/- 0 000	-/- - ---	-/- - ---	0/0 0 000	-/- 0 000	-/- 0 000	-/- 0 000
61-63	-/- 0 ---	-/- 0 ---	0/0 0 000	-/- 0 000	-/- - ---	-/- - ---	0/0 0 000	-/- 0 000	-/- 0 000	-/- 0 000
55-60	-/- 0 ---	-/- 0 ---	0/W 0 000	-/- 0 000	-/- - ---	-/- - ---	C/0 0 000	-/- C 000	-/- 0 000	-/- C 000
51-54	-/- 0 ---	-/- 0 ---	0/0 0 000	-/- 0 000	-/- - ---	-/- - ---	S/0 0 000	-/- W 000	-/- W 000	-/- M 000
48-50	-/- 0 ---	-/- 0 ---	C/0 0 000	-/- 0 000	-/- - ---	-/- - ---	0/0 0 000	-/- W 000	-/- 0 000	-/- M 000
46-47	-/- 0 ---	-/- 0 ---	M/0 v 000	-/- 0 000	-/- - ---	-/- - ---	0/C 0 000	-/- 0 000	-/- v 00C	-/- 0 000
41-45	-/- W ---	-/- 0 ---	0/W 0 000	-/- 0 000	-/- - ---	-/- - ---	0/W W 000	-/- 0 00C	-/- C 0W0	-/- W 000
38-40	-/- 0 ---	-/- 0 ---	0/0 v 000	-/- 0 000	-/- - ---	-/- - ---	0/0 v 00v	-/- 0 00C	-/- W 00C	-/- 0 000
36-38	-/- 0 ---	-/- 0 ---	0/0 c 000	-/- 0 000	-/- - ---	-/- - ---	v/0 0 000	-/- 0 00C	-/- v 00C	-/- 0 000
33-35	-/- v ---	-/- 0 ---	W/0 v 000	-/- 0 000	-/- - ---	-/- - ---	0/v v 000	-/- v 00C	-/- v 00C	-/- W 00C
30-33.3	-/- 0 ---	-/- 0 ---	0/0 0 000	-/- 0 000	-/- - ---	-/- - ---	0/0 0 000	-/- 0 00W	-/- 0 S0C	-/- 0 SSW
26-30	-/- 0 ---	-/- 0 ---	C/W 0 000	-/- 0 00v	-/- - ---	-/- - ---	C/C 0 M0W	-/- v MC0	-/- v 00W	-/- v 0C0
23.1-25	-/- 0 ---	-/- v ---	W/W 0 000	-/- 0 000	-/- - ---	-/- - ---	M/M v 000	-/- W 0M0	-/- v WMM	-/- W 0MC
21.3-23.4	-/- 0 ---	-/- 0 ---	0/0 v 000	-/- v 000	-/- - ---	-/- - ---	0/0 v 0W0	-/- 0 000	-/- v 000	-/- 0 00W
20.1-21.5	-/- 0 ---	-/- 0 ---	0/0 0 000	-/- 0 000	-/- - ---	-/- - ---	0/v 0 000	-/- 0 000	-/- 0 000	-/- v 000
17-20	-/- 0 ---	-/- 0 ---	0/0 0 MWv	-/- 0 C00	-/- - ---	-/- - ---	0/0 0 000	-/- 0 000	-/- v vv0	-/- v vvv
14-16	-/- 0 ---	-/- 0 ---	v/0 0 W00	-/- 0 S00	-/- - ---	-/- - ---	0/0 0 M0v	-/- 0 S0C	-/- v C0v	-/- v M0v
12-13	-/- 0 ---	-/- 0 ---	c/0 0 00v	-/- 0 00C	-/- - ---	-/- - ---	v/v 0 WvW	-/- 0 00C	-/- v MvC	-/- v 0W0
10.8-11.9	-/- 0 ---	-/- 0 ---	v/v 0 00v	-/- 0 00W	-/- - ---	-/- - ---	v/v 0 00v	-/- 0 00W	-/- v 00W	-/- vv vvW

Notes to Summary table:

- Cycle length ranged in years.
- R denotes rectangular window.
- T denotes triangular window.
- Numbers 11-3 denotes number of smoothed frequencies in spectral window.

For a clearer summary, windows 41,20 and 21 are not shown here being only carried out for tin. They can be seen in summary under tin's "The results from the larger windows".

- Some slight overlaps between ranges occur to allow for cycle periodicities as they arise.
- Letter Symbols:

P	Powerfully strong fluctuation.
S	Strong fluctuation.
M	Medium fluctuation.
W	Weak fluctuation as slight blip in the power spectrum.
v	very weak fluctuation.
C c	Crossing over from the range below.
0	Zero, denoting no peaks in the power spectrum.
-	Window not necessarily calculated or shown.

8.3 THE SPECTRAL RESULTS AND WHITE NOISE TESTS FOR POPULATION

8.3.1 Introduction

This section examines the results of the spectral analysis carried out on population data, 1541-1992, 452 years. The investigation examines scenarios based on inputs from the Original Raw Data, the Original Data Log Transformed, then the residual outputs from the "First Stage Modelling" thus, the Basic (Homoscedastic Approximation) residual, and the Heteroscedasticity Reduced Stepped Model residual. The Basic Model is further investigated when broken down into 2 sub-ranges or subsets. A step of about 200 years seemed apparent in the raw population data. However, the ranges were selected as a 215/237 year split. The second (final) subset coincides with the period of the final subset of the tin data. The separate scenarios are treated to spectral analysis with varying sized windows and white noise tests carried out. The spectral windows are rectangular and triangular drawn from any or all of 3, 5, 7, 9 and 11 smoothed frequencies. The larger windows were examined, but no peaks in the spectrum were identified and so are not shown. The variables including the raw data from the First Stage Modelling which forms the inputs to this stage are lcoated in the "VAR" Appendix, pages 32-40 for the Basic Model, and pages 41-44 for the Heteroscedastic model, graphically depicted in "GR" Appendix, pages 45-48.

8.3.2 The Original Raw Data and its Log Transformation

8.3.2.1 The results of the spectral analysis

The original raw data and its log from 1541-1992 (Graphs Appendix: GR-Pop, p 45) visually showed an upward trend and roughly 200-year dips. The approach is the same as for tin, which is to take the initial data and subject it to limited spectral analysis as this is untrended raw data. A range of rectangular and triangular windows reveal more peaks in the spectrum than for the raw tin data. However, the larger windows reveal no peaks and therefore are not shown. The medium spectral windows of 11 and 9 show no fluctuations for window 11 in both the raw and log population data. However, some limited peaks are identified in the rectangular 9 window only. For the smaller windows, window 7 show very limited peaks in the triangular for the raw data only. However for windows 5 and 3 frequencies, more slight fluctuations can be seen in the power spectrum and the results of these are detailed in the appendices, graphically and by ordinates and are summarised below.

The spectral analysis of the population original RAW data and its LOG showing jth peaks in the power spectrum is summarised thus:

Table 8.3.1 Raw and Log data: Spectral windows

<u>Population data Activity</u> Anticipated Cycle Length: None.
Kondratieff Cycle Length: 48-60yrs.

		Ordinates:*				
<u>Spectral Window</u>		<u>Period-gram</u>	<u>Spectral Density Estimates</u>	<u>Frequency</u> **	<u>Cycle Length</u>	<u>Cycle Range</u>
Rectangular=R				λ radians	2π/λ =	years
Triangular=T					2(3.14)/λ	
R11	Raw		No peaks in power spectrum.			
T11	Raw		No peaks in power spectrum.			
R9	Raw		2536613	0.5977	10.5 yrs	10.5-.7
T9	Raw		No peaks in power spectrum.			
R7	Raw		No peaks in power spectrum.			
T7	Raw		No peaks in power spectrum.			
R5	Raw		No peaks in power spectrum.			
T5	Raw		4207263	0.4726	13.3 yrs	13.3-.7
			2898062	0.5560	11.3 yrs	11.3-.6

R3	Raw	10194119	0.3058	20.5 yrs	20.5-21.5
		6256092	0.3892	16.1 yrs	16.1-.7
		4315117	0.4726	13.3 yrs	13.3-.7
		3006425	0.5560	11.3 yrs	11.3-.6
T3	Raw	10300494	0.3058	20.5 yrs	20.5-21.5
		6378563	0.3892	16.1 yrs	--
		4352851	0.4865	12.9 yrs	12.9-13.7
		3043294	0.5560	11.3 yrs	11.3-.6
R11	Log	No peaks in power spectrum.			
T11	Log	No peaks in power spectrum.			
R9	Log	No peaks in power spectrum.			
T9	Log	No peaks in power spectrum.			
R7	Log	No peaks in power spectrum.			
T7	Log	No peaks in power spectrum.			
R5	Log	No peaks in power spectrum.			
T5	Log	No peaks in power spectrum.			
R3	Log	No peaks in power spectrum.			
T3	Log	No peaks in power spectrum.			

Notes to above Table:

*For the raw data and its log, for the full periodogram ordinates and spectral density estimates see:

Spectral Window	Shown in "PER" Appendix, Pages 56-63	
Rectangular 11-9	PER-Pop-II-Raw+Log	-R11 to
	"	-R9
Rectangular	PER-Pop-II-Raw+Log	-R7 to
and Triangular 7-3	"	-T3

**For the graphical presentation of the power spectrum over the various kernel windows see:

Spectral Window	Shown in Graphs "GR"Appendix, Pages 49-56	
Rectangular 11-9	GR-Pop-II-Raw+Log	-R11

	"	-R9
Rectangular	GR-Pop-II-Raw+Log	-R7 to
and Triangular 7-3	"	-T3

8.3.2.2 The conclusion on the spectral results

Few peaks are seen in the power spectrum, the summarised results shown above for the rectangular windows for 5 and 3 smoothed frequencies for both the raw data and its log, are very slight. For visual confirmation of very slight jth peaks in the spectrum, check graphs appendices given above. Neither the raw or log's power spectrums show any slight peaks at 46-52 years as for the tin data. So no long fluctuations are perceived in the original data. However, medium-term fluctuations are vaguely seen with the hint of jth peaks at 10-20 years. But the results again are very slim in the initial data. By allowing relativity within the power spectrum for the population modelling, then the minuscule fluctuations can be re-expressed as a Weak wave at 20-21 year, and very weaks ones at 16, 13 and 11 years.

8.3.2.3 The results of the white noise tests

The results of the white noise tests of the population original RAW data and its LOG are summarised thus:

Table 8.3.2 Raw and Log data

Bartlett's Kolmogorov-Smirnov white noise test:

Time series data : Original raw data and its log
For each series:
Period of observations of data : 1541 -1992
No. of observations for processing : 452
No. of ordinates calculated : 227
No. with 2 degrees of freedom

for *m* for the white noise test: 226

Bartlett's Kolmogorov-Smirnov white noise Test Statistic : 0.9128 (Raw Data)
0.9133 (Its Log)

To compare the Test Statistic to critical points, *(m-1=225)* @
5% critical point : $1.36(m-1)^{-1/2} = 0.0907$
1% critical point : $1.63(m-1)^{-1/2} = 0.1087$

(The periodogram ordinates calculated are given in "PER" Appendix, Pop-Raw+Log-R11-3, pages 56-63 .)

Thus, as the Bartlett's Kolmogorov-Smirnov Test Statistic of 0.9128 for the Original Raw Data and 0.9133 for its Log are well above the values of the 5% and 1% critical points, the white noise null hypothesis is rejected for both series. Therefore, it can be inferred that in the population series, the original raw data and its log do not comprise of white noise.

Table 8.3.3 Raw and Log data

The Fisher-Kappa white noise test:

The Fisher-Kappa model is (m-1) x (max P) / Sum P
where m-1 is as above for the BKS test,
max P is the maximum periodogram ordinate calculated,
sum P being the sum of ordinates.

For the population data, as above used in the BKS,

	Original Raw Data	Its Log
m-1	: 225	225
max P	: 6.45357E10	47.87
sum P	: 1.06405E11	73.34

The Fisher-Kappa Test Statistic

$$\frac{225 \times 64.5 \text{ bn}}{106.4 \text{ bn}} = 136.5 \qquad \frac{225 \times 47.87}{73.34} = 146.8$$

To compare the Test Statistic to Fuller's Table[1] (Table m=250)@

5% critical point : = 8.389

1% critical point : = 9.960

(from ordinates calculated given in "PER" Appendix, Pop-Raw+Log-R11-3, pages 56-63.)

So, as the Fisher-Kappa Test Statistic of 136.5 for Original Raw Data and 146.8 for its Log are well above the values of the 5% and 1% critical points, the white noise null hypothesis is rejected for both series. Thus, it can be inferred that in the population series, the original raw data and its log do not comprise of white noise.

8.3.3 The Basic (Homoscedastic Approximation) Model

8.3.3.1 Introduction

The Basic (Homoscedastic Approximation) Model (1451-1992) is the residual output from the First Stage Modelling which provides the base input material for the spectral modelling in this section for the *"Basic (Homoscedastic Approximation) Model"*. The variables for the population data are shown in the "VAR" Appendix, pages 1-15. The original data and the "Residual" for the Basic Model are visually shown in the graphs appendix, "GR" Appendix, Pop, pages 45-47.

The Basic (Homoscedastic Approximation) Model is subjected to spectral analysis with

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[1] Fuller (1976), Table 7.1.2 "Percentage points for the ratio of largest periodogram ordinate to the average", page 284.

various spectral windows, rectangular and triangular smoothed over differing frequencies. Again, as for the tin, more analysis has been carried out on this model than any of the others as it is the model which represents the fundamental de-trended residual output for the population data.

The Basic Model is first treated to some general spectral analysis for both rectangular and triangular windows. This involved the specification of the whole range of the spectral density estimates for all the windows used. The frequencies shown range from relatively medium sized windows of 11, 9, and 7 to shorter windows of 5 and 3 frequencies. The anticipation being that there are no long cycles in the data, so by selecting such a wide variety over the whole spectrum it was thought that no peaks would be discernible across the spectrum over differing windows. The general advice in the literature is to start with larger windows and move them down to smaller ones over fewer frequencies.

The Basic (Homoscedastic Approximation) Model is then subjected to further investigation. This further investigation entailed breaking the Model's data down in to 2 separate Subsets of about 200 years, in fact 215 and 237 years, thereby Subset2 coinciding with tin's Subset3. The data is not changed, it is the same as that in the whole range of the Basic (Homoscedastic Approximation) Model, but broken down in 2 separate component periods for individual analysis, graphically depicted "GR" Appendix page 47. The length of period is selected for 2 main reasons: firstly, because the initial raw data appeared to show 200-year dips, and secondly, the period is long enough to cover several Kondratieff cycles (48-60 years) should they exist. The intention of breaking the Model into 2 separate components for separate spectral analysis is to aid the identification or otherwise, of long cycles. The notion being that should long cycles exist, would their length change over the centuries which would be missed in examining the *whole* data range as in the first investigation of The Basic (Homoscedastic Approximation) Model. The 2 Subsets are examined over the whole of their spectral density estimates range.

Having investigated the The Basic (Homoscedastic Approximation) Model in its 2 separate component periods, the Subsets are then more closely scrutinised. The close scrutiny involves zooming into a tighter scale range over the power spectrum, amplifying by homing in on tighter scales directly, given the overall perspective of the power spectrum.

8.3.3.2 The results of The Basic (Homoscedastic Approximation) Model

8.3.3.2.1 The results of the spectral analysis

The Basic Model was first treated to some general spectral analysis for both rectangular and triangular windows. This involved the specification of the whole range of the spectral density estimates for all the windows used and then zooming in for a closer scrutiny by tightening up the scale ranges over the power spectrum. The frequencies specified ranged from relatively medium sized windows of 11, 9 and 7, to shorter windows of 5 and 3 frequencies.

The resulting ordinates from the periodogram calculation and various spectral density estimates are located in the "PER" Appendix for the medium spectral windows and the power spectrums are visually shown in the Graphs Appendix, "GR".

Table 8.3.4 Basic (Homoscedastic Approximation) Model

Population data Activity Anticipated Cycle Length: None.

Kondratieff Cycle Length: 48-60 yrs.

	Ordinates:*				
Spectral Window	Periodgram	Spectral Density Estimates	Frequency **	Cycle Length	Cycle Range
Rectangular=R			λ radians	$2\pi/\lambda =$	years
Triangular=T				$2(3.14)/\lambda$	

R11	0.0046	0.000225	0.2326	26.6 yrs	--
	varied	0.000220-194	0.264-0.29	23.8-21.5	--
	0.0005	0.000422	0.5977	10.5 yrs	10.5-10.8 yrs
T11	0.0046	0.000227	0.2363	26.6 yrs	--
	varied	0.000037-48	0.584-.653	10.8-9.6	--
R9	0.0017	0.000240	0.2780	22.6 yrs	22.6-25.1 yrs
	0.0016	0.000200	0.3475	18.1 yrs	18.1-18.8 yrs
	0.0001	0.000044	0.6116	10.3 yrs	10.3-10.8 yrs
T9	0.0036	0.000229	0.2224	28.3 yrs	--
	varied	0.000036-46	0.584-.653	10.8-9.6	--
R7	0.0013	0.000247	0.2085	30.1 yrs	--
	0.0019	0.000237	0.2641	23.8 yrs	23.8-25.1 yrs
	0.0016	0.000208	0.3475	18.1 yrs	18.1-.8 yrs
	varied	0.000044-35	0.626-.584	10-.8 yrs	--
T7	varied	0.000244-216	0.236-.209	26.6-30.1	--
	varied	0.000217-201	0.320-.292	19.7-21.5	--
	0.0007	0.000038	0.5699	11.0 yrs	11-11.3 yrs
R5	0.0018	0.000221	0.1946	32.3 yrs	--
	varied	0.00024-233	0.250-.222	25.1-28.3	--
	0.0039	0.000220	0.3058	20.5 yrs	--
	0.0010	0.000077	0.4726	13.3 yrs	13.3-.7 yrs
	0.0007	0.000042	0.5700	11-11.3	--
T5	varied	0.00027-19	0.236-.209	26.6-30.1	--
	varied	0.00023-19	0.320-.292	19.7-21.5	--
	0.00240	0.000172	0.3753	16.7 yrs	--
	0.0010	0.000076	0.4726	13.3 yrs	--
	varied	0.000042-36	0.570-.542	11-11.6	--
R3	varied	0.00030-18	0.236-.209	26.6-30.1	--
	varied	0.00027-20	0.320-.292	19.7-21.5	--
	varied	0.00019-17	0.389-.375	16.1-16.7	--

	varied	0.00008-07	0.459-.445	13.7-14.1	--
	0.0010	0.00007	0.4865	12.9 yrs	--
	0.0004	0.00004	0.5560	11.3 yrs	11.1-.3 yrs
T3	varied	0.00032-16	0.236-.209	26.6-30.1	--
	0.0027	0.000256	0.3197	19.7 yrs	19.7-21.5 yrs
	0.0025	0.000197	0.3892	16.1 yrs	16.1-.7 yrs
	0.0013	0.000081	0.4448	14.1 yrs	--
	0.0010	0.000075	0.4865	12.9 yrs	--
	varied	0.000043-39	0.570-.542	11-11.6	--

Notes to above Table:

*For the periodogram ordinates and spectral density estimates see:

Spectral Window	Shown in "PER" Appendix, Pages 64-73	
Rectangular	PER-Pop-II-Basic	-R11 to
and Triangular 11-3	"	-T3

**For the graphical presentation of the power spectrum over the various kernel windows see:

Spectral Window	Shown in Graphs "GR"Appendix, Pages 57-63	
Rectangular	GR-Pop-II-Basic	-R11 to
and Triangular 11-3	"	-T3

From the power spectrum graphs given above, it can be seen that again they appear to generally depict traditional economic time series. However, very close investigation reveals some very mild blips in the spectrum. All of these very minor ones fit in with the minor ones found in the same Basic Model for the tin data.

In summary, there seems to be cyclical fluctuations ranging from 10 to 29 years. In broad categories across the varying medium-sized rectangular and triangular windows, they can be broken down into ranges of 23-27 years, 18-19 years and 10-11 years. The most persistent and consistent range being 10-11 years.

The minute scrutiny of the smaller windows show dissimiliarities between the Basic Model for population and that for tin. There are not the slender hegemony cycles as found in the tin data, nor the long fluctuations around 44-55 years.

Slim fluctuations are identified in the power spectrums across the varying kernel windows for the population data in the following broad categories: 26-30 years, 19-22 years, 10-11.3 years. Comparing these to the Basic Model for the tin data for the smaller windows, there are slight waves around the 22-23 years and 10.5-11.7 years, thus showing some similiarity.

8.3.3.2.2 The conclusion on spectral results

In conclusion, given the results from the overall Basic (Homoscedastic Approximation) Model, no strong cyclical fluctuations have emerged across the various power spectrums. There appear to be no fluctuations longer than about 30-32 years, so no Kondratieff-type waves.

The very slender fluctuations that could be seen on close scrutiny of the power spectrums became slightly more focussed on moving down the spectral windows, as with the tin data. The most discernible of the slim peaks could be categorised broadly in the ranges for the medium-sized compared to the smaller windows respectively, and relatively expressed: Medium fluctuation centred at 26 years, ranging 23-27 years to 26-30 years, a Medium to Weak fluctuation of 18-19 years to 19-22 years and very weak ones around 16, 13 and 11 years. No fluctuations were expected, and these are very slight peaks in the varying spectrums. As with the tin findings, it is believed worthwhile to explore the Basic (Homoscedastic Approximation) Model over two separate periodical Subsets in the following section after the white noise tests.

8.3.3.2.3 The results of the white noise tests

The results of the white noise tests of the Basic (Homoscedastic Approximation) Model data is summarised thus:

Table 8.3.5 Basic (Homoscedastic Approximation) Model

Bartlett's Kolmogorov-Smirnov white noise:

Time series data : Basic (Homoscedastic Approximation) Model

Period of observations of data : 1541 -1992

No. of observations for processing : 452

No. of ordinates calculated : 227

No. with 2 degrees of freedom for m for the white noise test: 226

Bartlett's Kolmogorov-Smirnov white noise Test Statistic : 0.9601

To compare the Test Statistic to critical points, *(m-1 =225)* @

5% critical point : $1.36(m-1)^{-1/2} = 0.0907$

1% critical point : $1.63(m-1)^{-1/2} = 0.1087$

(The periodogram ordinates calculated are given in "PER" Appendix Pop-Basic-R11-7 pages 57-63.)

Thus, as the Bartlett's Kolmogorov-Smirnov Test Statistic of 0.9601 for the Basic (Homoscedastic Approximation) Model is above the values of the 5% and 1% critical points, the white noise null hypothesis is rejected for the series. So, it can be inferred that in the population series, the Basic (Homoscedastic Approximation) Model does not comprise of white noise.

Table 8.3.6 Basic (Homoscedastic Approximation) Model

The Fisher-Kappa white noise test:

The Fisher-Kappa model is (m-1) x (max P) / Sum P
where m-1 is as above for the BKS test,
max P is the maximum periodogram ordinate calculated,
sum P being the sum of ordinates.

For the population data, as above used in the BKS,

m-1	:	225
max P	:	7.05
sum P	:	8.56

The Fisher-Kappa Test Statistic

$$\frac{225 \times 7.05}{8.56} = 185.4$$

To compare the Test Statistic to Fuller's Table[2] (Table m=250)@

5% critical point	:	=	8.389
1% critical point	:	=	9.960

(from periodogram ordinates calculated given in "PER" Appendix, Pop-Basic-R11-7, pages 57-63.)

Therefore, as the Fisher-Kappa Test Statistic of 185.4 for the Basic (Homoscedastic Approximation) Model is above the values of the 5% and 1% critical points, the white noise null hypothesis is rejected for the series. Thus, it can be inferred that in the population series, the Basic (Homoscedastic Approximation) Model does not comprise of white noise.

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[2] Fuller (1976), Table 7.1.2 "Percentage points for the ratio of largest periodogram ordinate to the average", page 284.

8.3.3.3 The results of The Basic (Homoscedastic Approximation) Model broken down into 2 separate Subset periods

8.3.3.3.1 Introduction

The Basic (Homoscedastic Approximation) Model is subjected to further investigation. This further investigation entails breaking the Model's data down in to 2 separate Subsets of about 200 years. The 2 subsets are ranged over time periods of 1541-1755, 1756-1992, 215 and 237 years respectively. These are referred to as Subset1 and Subset2, with the range for Subset2 coinciding with the same period as tin data's Subset3. The data is not changed, it is the same as that in the whole range of the Basic (Homoscedastic Approximation) Model, but broken down in 2 separate component periods for individual analysis.

The length of period is selected for 2 main reasons: firstly, because the initial raw data appeared to show 200-year dips, and secondly, the period is long enough to cover several Kondratieff cycles (48-60 years) should they exist. The 2 Subsets are examined over the whole of their spectral density estimates range and then more closely scrutinised. Rather than a common-scale approach as for tin, it was found that the results of the population investigation are so slim that more amplification was necessary to aid the illustration of the findings. Therefore the further depictions for the kernel windows zooms into narrower frequency and spectral density ranges. These are reasonably close to the peaks in order to show the slight waves in the power spectrum identified.

Given the slightness of the investigation of the Basic Model for windows 11 and 9, the Subset analysis concentrates on spectral windows from 7 down to 3 smoothed frequencies. The input data for the spectral modelling in this section is the Basic (Homoscedastic Approximation) Model (1541-1992), the residual output from the First Stage Modelling decribed earlier, the variables are shown in the "VAR" Appendix, pages 32-40 and is visually shown in the graphs appendix, "GR" Appendix, page 47.

8.3.3.3.2 The results of Subset 1

Subset1 covers the 215-year period from 1541-1755 of The Basic (Homoscedastic Approximation) Model. The spectral investigation of the Subset is over spectral windows, both rectangular and triangular over 7,5 and 3 smoothed frequencies to produce 6 differing power spectrums. The analysis is based on the spectral modelling of the whole range. However, to aid the visual presentation of findings, the graphical representation of the power spectrum zooms into a narrower range and frequency. The data input for the spectral modelling of Subset1 can be visually seen, "GR" Appendix, page 47.

Table 8.3.7 Basic (Homoscedastic Approximation) Model Subset1

Population data Activity Anticipated Cycle Length: None.
Kondratieff Cycle Length: 48-60 yrs.

	Ordinates:*				
Spectral Window	Period-gram	Spectral Density Estimates	Frequency **	Cycle Length	Cycle Range
Rectangular=R			λ radians	$2\pi/\lambda =$	years
Triangular=T				$2(3.14)/\lambda$	
R7	0.00232	0.000127941	0.4676	13.4 yrs	--
	0.00235	0.000124017	0.5553	11.3 yrs	--
T7	0.00232	0.000126118	0.4676	13.4 yrs	--
	0.00235	0.000127049	0.5553	11.3 yrs	11.3-.9 yrs
R5	0.00111	0.000134591	0.5260	11.9 yrs	11.9-12.6 yrs
T5	0.00232	0.000129406	0.5553	11.3 yrs	11.3-13.4 yrs
R3	0.00072	0.000123087	0.4834	14.3 yrs	--
	0.00111	0.000131208	0.5260	11.9 yrs	11.9-12.6 yrs

R3	0.00232	0.000136521	0.4676	13.4 yrs	--
	0.00235	0.000138972	0.5553	11.3 yrs	--

Notes to above Table:

The resulting ordinates from the periodogram calculations and various spectral density estimates are located in the "PER" Appendix and the 6 resulting differing power spectrums are visually shown in the Graphs Appendix, "GR" detailed below.

*For the periodogram ordinates and spectral density estimates see:

Spectral Window	Shown in "PER" Appendix, Pages 74-79	
Rectangular	PER-Pop-II-Sub1	-R7 to
and Triangular 7-3	"	-T3

**For the graphical presentation of the power spectrum over the various kernel windows see:

Spectral Window	Shown in Graphs "GR"Appendix, Pages 64-69	
Rectangular	GR-Pop-II-Sub1	-R7 to
and Triangular 7-3	"	-T3

Due to the very slim fluctuation findings, some amplification has been necessary to graph these. Detailed analysis of the power spectrums across the various kernel windows for Subset1 reveals no long cycle fluctuation whatsoever in any of the spectral windows.

The findings of Subset1 are consistent with the whole Basic Model for the shorter ranges identified below but reveal nothing in the spectrum which could be described as Kuznets-type cycles of 20-30 years, as found in the Basic Model. The findings for Subset1 reveal some slight fluctuations recurring across the kernel windows in the ranges 13-14 years and 11.3-11.9/12.6 years. The amplification of the power spectrum shown in the graphs highlights the fluctuations showing that where the 2 peaks occur in the same windows, they generally show similar levels of strength. However, it is the wave around 11.3-11.9 years which recurs across all the power spectrums of each window. The fluctuation, although consistent is however, very weak.

8.3.3.3.3 The results of Subset 2

Subset2 covers the 237-year period from 1756-1992 of The Basic (Homoscedastic Approximation) Model, visual depiction "GR" Appendix page 47. The time period coincides with the tin data's Subset3 range. The spectral investigation of the population Subset is over spectral windows, both rectangular and triangular over 7, 5 and 3 smoothed frequencies to produce 6 differing power spectrums. The spectral modelling is based on the whole range of the Subset's individual spectral density estimates. As for Subset1, the graphical representation not only includes the whole power spectrum but a further depiction per window in order to amplify the findings to aid illustration. The analysis of Subset2 however generally reveals no fluctuations.

Table 8.3.8 Basic (Homoscedastic Approximation) Model Subset2

Population data Activity Anticipated Cycle Length: None.

Kondratieff Cycle Length: 48-60 yrs.

	Ordinates:*				
Spectral Window	Period-gram	Spectral Density Estimates	Frequency **	Cycle Length	Cycle Range
Rectangular=R			λ radians	$2\pi/\lambda =$	years
Triangular=T				$2(3.14)/\lambda$	
R7	No peaks in the power spectrum.				
T7	No peaks in the power spectrum.				
R5	No peaks in the power spectrum.				
T5	No peaks in the power spectrum.				
R3	No peaks in the power spectrum.				
T3	0.01037	0.000641248	0.3977	15.8 yrs	--

0.00771	0.000515117	0.4772	13.2 yrs	--
0.00516	0.000334004	0.5567	11.3 yrs	--

Notes to above Table:

The resulting ordinates from the periodogram calculations and various spectral density estimates are located in the "PER" Appendix and the 6 resulting differing power spectrums are visually shown in the Graphs Appendix, "GR" detailed below.

*For the periodogram ordinates and spectral density estimates see:

Spectral Window	Shown in "PER" Appendix, Pages 80-85	
Rectangular	PER-Pop-II-Sub2	-R7 to
and Triangular 7-3	"	-T3

**For the graphical presentation of the power spectrum over the various kernel windows see:

Spectral Window	Shown in Graphs "GR"Appendix, Pages 70-72	
Rectangular	GR-Pop-II-Sub2	-R7 to
and Triangular 7-3	"	-T3

Following the analysis of the spectral modelling of Subset2, the findings are that generally no fluctuations are seen across the varying kernel windows except for triangular window 3. No long cycles are identified, nor the 20-30 year types found in the Basic Model. In the triangular window 3, the findings are for 3 slight fluctuations, identified as 15.8 years, slightly stronger than the 13.2 years and 11.3 years peaks. The latter two are consistent with the findings of Subset1, but are extremely weak.

8.3.3.3.4 Conclusion on Subset spectral results

Due to the very slim findings, some amplification has been necessary to graph the fluctuations. Detailed analysis of the power spectrums across the various kernel windows for both Subsets reveal no long cycle fluctuation whatsoever in any of the spectral windows.

The fluctuations slimly identified by the spectral modelling of the Basic (Homoscedastic Approximation) Model around 20-30 years are not similarly identified in the 2 subsets analysis. However, the shorter periods of 13-16 years and 11.3-11.9/12.6 are very weakly found, which are consistent with the findings of the overall Basic Model. The extremely modest fluctuation which continues to persist across *both* the Subsets, albeit in only 1 window in Subset2 is that of 11.3-11.9 years. This compares with a similar and persistent 11.1 years in the tin data. Because of the inconclusiveness of the Subset analysis, it is thought worthwhile to explore a heteroscedastic-reduced model in the next section.

8.3.3.4 The Heteroscedasticy Reduced Model

8.3.3.4.1 Introduction

This section examines the spectral results of the spectral analysis carried out on the scenarios for the heteroscedastic-reduced model for the population data, 1451-1992. The heteroscedastic scenario is based on the residual output from the "First Stage Modelling" and is referred to as the "Heteroscedasticity Reduced-200 year step" Model.

Considering the length of the time series, it was thought useful to extend the Basic Model given the slimness of the Subset results to a stepped period with reduced heteroscedasticity to provide another scenario. It entails transforming the new variables and fitting the transformed coefficients regressed over a stepped period of about 200 years, to give further re-modelling of the y variable. In fact, it was regressed over 215/237 years. The results for the residual of stepped transformed population series is based on the trend being re-modelled in steps as

$$y = +3.4429 + 0.002204x, \text{ and}$$
$$+2.7442 + 0.004692x \qquad 1.$$

The variables are shown in the "VAR" Appendix, Pop, Stepped, pages 41-44. The graphical depiction, "GR" Appendix, page 48.

Given the earlier investigations, the windows examined are rectangular and triangular from 11, 9, 7, 5 and 3 smoothed frequencies.

8.3.3.4.2 The spectral results of the Heteroscedasticity Reduced Stepped Model

The Heteroscedasticity Reduced: 200-year Stepped Model (1451-1992) is the residual output from the First Stage Modelling decribed earlier and is visually shown in the graphs appendix, "GR" Appendix, Pop-I-Step, page 48. This forms the base material input to the modelling in this section. The residual variables are subjected to spectral analysis with various spectral windows, rectangular and triangular smoothed over 11, 9, 7, 5 and 3 smoothed frequencies to produce differing power spectrums. The resulting ordinates from the periodogram calculations and various spectral density estimates are located in the "PER" Appendix and the power spectrums are visually shown in the Graphs Appendix, "GR".

From the power spectrum graphs, visually it can be clearly seen that they depict the traditional economic time series, displaying no striking discernible cycles. However, minute investigation of the power spectrums reveal the slightest peaks as follows, summarised thus:

Table 8.3.9 Heteroscedasticity Reduced Stepped Model

Population data Activity   Anticipated Cycle Length: None.

Kondratieff Cycle Length: 48-60 yrs.

	Ordinates:*				
Spectral Window	Periodgram	Spectral Density Estimates	Frequency **	Cycle Length	Cycle Range
Rectangular=R			λ radians	$2\pi/\lambda =$	years
Triangular=T				$2(3.14)/\lambda$	
R11		0.00023947	0.3058	20.5 yrs	--
		0.00019859	0.3336	18.8 yrs	--
		0.00016094	0.3614	17.4 yrs	--
		0.00013650	0.3892	16.1 yrs	--
		0.00009910	0.4865	12.9 yrs	12.9-13.3
		0.00009295	0.5143	12.2 yrs	--
		0.00009156	0.5421	11.6 yrs	--
		0.00008816	0.5699	11.0 yrs	--
T11		0.00009376	0.4726	12.3 yrs	--
		0.00009398	0.5004	12.6 yrs	--
		0.00009308	0.5282	11.9 yrs	--
R9		0.00067087	0.2085	30.1 yrs	--
		0.00050720	0.2363	26.6 yrs	--
		0.00024710	0.2919	21.5 yrs	--
		0.00023192	0.3197	19.7 yrs	--
		0.00017413	0.3475	18.1 yrs	--
		0.00014297	0.3753	16.7 yrs	--
		0.00012783	0.4031	15.6 yrs	--
		0.00009993	0.4726	13.3 yrs	13.3-.7

	0.00009854	0.5004	12.6 yrs	--
	0.00009892	0.5560	11.3 yrs	--
T9	0.00009480	0.4587	13.7 yrs	--
	0.00009593	0.5004	12.6 yrs	--
	0.00009509	0.5282	11.9 yrs	--
	0.00009176	0.5560	11.3 yrs	--
R7	0.00058854	0.2224	28.3 yrs	--
	0.00041224	0.2502	25.1 yrs	--
	0.00026851	0.2780	22.6 yrs	--
	0.00023958	0.3058	20.5 yrs	--
	0.00021004	0.3336	18.8 yrs	--
	0.00015479	0.3614	17.4 yrs	--
	0.00011796	0.4170	15.1 yrs	--
	0.00009814	0.4587	13.7 yrs	--
	0.00009945	0.4865	12.9 yrs	--
	0.00009869	0.5421	11.6 yrs	--
	0.00010099	0.5699	11.0 yrs	--
T7	0.00009879	0.4587	13.7 yrs	13.7-14.3
	0.00009446	0.5004	12.6 yrs	--
	0.00009809	0.5282	11.9 yrs	--
R5	0.00096349	0.1807	34.8 yrs	--
	0.00069824	0.2085	30.1 yrs	--
	0.00048813	0.2363	26.6 yrs	--
	0.00031902	0.2641	23.8 yrs	--
	0.00026654	0.2919	21.5 yrs	--
	0.00021196	0.3197	19.7 yrs	--

	0.00019728	0.3475	18.1 yrs	--
	0.00010385	0.4448	14.1 yrs	14.1-.6yrs
	0.00009676	0.4726	13.3 yrs	--
	0.00009630	0.5004	12.6 yrs	--
	0.00011106	0.5282	11.9 yrs	--
	0.00010150	0.5560	11.3 yrs	--
T5	0.03625061	0.0278	226 yrs	--
	0.00092331	0.1807	34.8 yrs	--
	0.00031567	0.2641	23.8 yrs	--
	0.00025126	0.2919	21.5 yrs	--
	0.00018836	0.3197	19.7 yrs	--
	0.00018395	0.3475	18.1 yrs	--
	0.00009929	0.4587	13.7 yrs	13.7-14.6
	0.00009251	0.5004	12.6 yrs	--
	0.00011013	0.5282	11.9 yrs	--
	0.00009489	0.5560	11.3 yrs	--
R3	0.00238150	0.0973	64.6 yrs	--
	0.00111984	0.1668	37.7 yrs	--
	0.00096648	0.1946	32.3 yrs	--
	0.00060402	0.2224	28.3 yrs	--
	0.00038336	0.2502	25.1 yrs	--
	0.00034941	0.2780	22.6 yrs	--
	0.00023846	0.3058	20.5 yrs	--
	0.00019205	0.3336	18.8 yrs	--
	0.00021181	0.3614	17.4 yrs	--
	0.00009148	0.4170	15.1 yrs	--
	0.00010535	0.4587	13.7 yrs	13.7-14.1
	0.00012153	0.5143	12.2 yrs	--

	0.00012398	0.5421	11.6 yrs	--
T3	0.04572355	0.0278	226 yrs	--
	0.00245454	0.0973	64.6 yrs	--
	0.00101370	0.1593	41.1 yrs	--
	0.00031148	0.2641	23.8 yrs	--
	0.00010844	0.3892	16.1 yrs	16.1-17.4
	0.00009669	0.4170	15.1 yrs	--
	0.00011778	0.4587	13.7 yrs	13.7-14.1
	0.00010898	0.5282	11.9 yrs	11.9-12.6

Notes to above Table:

*For the full periodogram ordinates and spectral density estimates see:

Spectral Window	Shown in "PER" Appendix, Pages 86-96	
Rectangular	PER-Pop-II-Step	-R11 to
and Triangular 11-3	"	-T3

**For the graphical presentation of the power spectrum over the various large kernel windows see:

Spectral Window	Shown in Graphs "GR"Appendix, Pages 73-82	
Rectangular	GR-Pop-II-Step	-R11 to
and Triangular 11-3	"	-T3

Some long fluctuations are inconsistently identified in the smaller windows only, not previously seen in the overall Basic Model. One of 65 years, and the other is Strongly seen centred at 35 years, but ranging 30/37 years. However, the clearest fluctuation seen is consistent with the Basic Model, centred around 25-26 years, but ranging to 22-23 years, seen Medium to Weak across all the spectral windows. The Stepped Model has focussed a broader range identified in the Basic Model around 17-21.5 centred to 20.5-21.5 years here, seen from Medium to very weakly. This is a lesser fluctuation than the 25-26 range, but is persistent across the windows. Then as with the Basic Model, very weak fluctuations for 12-13 and 11 years.

8.3.3.4.3 The conclusion on the Stepped Model

Again the findings are slim, but more informative than the Subset analysis, and the fluctuations are expressed in relative terms to the spectrum. There is no support for Kondratieff type fluctuations in the range 48-60 years. There is slight evidence for a Medium wave of 35 years, ranging 30/37 years.

However, the clearest fluctuation is centred around 25-26 years, but ranging to 22-23 years, seen Medium to Weak across all the spectral windows. There is a lesser fluctuation centred to 20.5-21.5 years seen from Medium to very weakly. Also, very weak fluctuations for 12-13 and 11 years.

8.3.3.5 Conclusion and Results Summary Table

The hypothesis of no Kondratieffs is supported by the population data. Regarding the other cyclical fluctuations, the population series has shown the weakest findings of the 3 time series examined. It generally supports a Medium fluctuation relatively, centred at 25-26 years, but shifting 22-23 years particularly, 23-27 and 26-30 years. However, there are also Medium to Weak fluctuations around 18/19-19/22 years, centred at 20.-21.5 years. The main results are summarised on the next page, because of the slimness of the findings, the heteroscedastic results are also tabulated:
Table 8.3.10 Results Summary Table: Population

TABLE 8.3.10

RESULTS SUMMARY TABLE 2 : POPULATION

CYCLE	WINDOW SIZE									
LENGTH	R11	T11	R9	T9	R7	T7	R5	T5	R3	T3
Raw/Log: *Basic:* *Sub-/1/2:* *Stepped:*	*R/L* *B* *-12* S	*R/L* *B* *-12* *S*	*R/L* *B* *-12* S	*R/L* *B* *-12* *S*	*R/L* *B* *-12* *S*	*R/L* *B* *-12* *S*	*R/L* *B* *-12* *S*	*R/L* *B* *-12* S	*R/L* *B* *-12* *S*	*R/L* *B* *-12* S
209	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00
121-166	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00
118-120	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00
86-100	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00
83-85	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00
76-82	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00
71-75	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00
64-70	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00 S	0/0 0 -00 S
61-63	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00
55-60	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00
51-54	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00
48-50	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00
46-47	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00
41-45	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00 v
38-40	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00
36-38	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00 M	0/0 0 -00
33-35	0/0 0 -00 0	0/0 0 -00 0	0/0 0 -00 0	0/0 0 -00 0	0/0 0 -00 0	0/0 0 -00 0	0/0 0 -00 M	0/0 0 -00 M	0/0 0 -00 0	0/0 0 -00 0
30-33.3	0/0 0 -00 0	0/0 0 -00 0	0/0 0 -00 0	0/0 0 -00 0	0/0 0 -00 0	0/0 0 -00 0	0/0 v -00 0	0/0 0 -00 0	0/0 0 -00 M	0/0 0 -00 0
26-30	0/0 W -00 0	0/0 W -00 0	0/0 0 -00 M	0/0 W -00 0	0/0 0 -00 M	0/0 W -00 0	0/0 M -00 M	0/0 M -00 0	0/0 M -00 W	0/0 M -00 0
23.1-25	0/0 0 -00 0	0/0 0 -00 0	0/0 C -00 0	0/0 0 -00 0	0/0 W -00 M	0/0 0 -00 0	0/0 0 -00 M	0/0 0 -00 M	0/0 0 -00 M	0/0 0 -00 W
21.3-23.4	0/0 v -00 0	0/0 0 -00 0	0/0 W -00 0	0/0 0 -00 0	0/0 0 -00 M	0/0 0 -00 0	0/0 0 -00 0	0/0 0 -00 0	0/0 0 -00 W	0/0 0 -00 0
20.1-21.5	0/0 0 -00 M	0/0 0 -00 0	0/0 0 -00 M	0/0 0 -00 0	0/0 0 -00 M	0/0 C -00 0	0/0 W -00 M	0/0 C -00 v	W/0 C -00 W	W/0 C -00 0
17-20	0/0 0 -00 v	0/0 0 -00 0	0/0 v -00 v	0/0 0 -00 0	0/0 v -00 v	0/0 W -00 0	0/0 0 -00 M	0/0 W -00 W	0/0 W -00 v	0/0 W -00 0
14-16	0/0 0 --- W	0/0 0 --- 0	0/0 0 --- 0	0/0 0 --- 0	0/0 0 -00 v	0/0 0 -00 0	0/0 0 -00 W	0/0 0 -00 v	v/0 0 -c0 v	v/0 0 -0v v
12-13	0/0 0 -00 W	0/0 0 -00 v	0/0 0 -00 W	0/0 0 -00 v	0/0 0 -v0 W	0/0 0 -v0 v	0/0 v -v0 v	v/0 v -v0 v	v/0 v -v0 v	v/0 v -vv v
10.8-11.9	0/0 v -00 v	0/0 0 -00 v	0/0 0 -00 v	0/0 0 -00 v	0/0 0 -v0 W	0/0 v -v0 v	0/0 v -v0 W	v/0 v -v0 v	v/0 v -v0 v	v/0 v -vv v

Notes to table:

- Cycle length ranged in years, R denotes rectangular window, T denotes triangular.
- Numbers 11-3 denotes number of smoothed frequencies in window.
- Some slight overlaps between ranges occur to allow for cycle periodicities.
- "Sub-/1/2" denotes a dash (-/) to allow for the extra subset in the tin data for the earlier time period. Thus Subset 2 covers the same time period as tin's Subset 3. So visually, the location of the Letter symbols are placed over similar time periods.
- For the Population data only, the Stepped results are also shown.
- Letter Symbols:

P	Powerfully strong fluctuation.
S	Strong fluctuation.
M	Medium fluctuation.
W	Weak fluctuation as slight blip in the power spectrum.
v	Very weak fluctuation.
C c	Crossing over from the range below.
0	Zero, denoting no peak in the power spectrum.
-	Window not necessarily calculated or shown.

8.4 THE SPECTRAL RESULTS AND WHITE NOISE TESTS FOR WAR

8.4.1 Introduction

This section examines the results of the spectral analysis carried out on the war data, 1495-1992, 498 years being battle fatalities from the wars involving the "great powers". In this section, the spectral analysis of the war data examines the differing spectral windows in the investigation of long cycles. The scenarios are based on inputs from the Original Raw Data, the Original Data Log Transformed, then the residual outputs from the "First Stage Modelling" thus, the Basic (Homoscedastic Approximation) residual. The Basic Model is further investigated by being broken down into 2 sub-ranges or subsets. The ranges were selected as a 281/237 year split. The range being chosen so that the second subset coincides with the final subset as the earlier series for tin and population data. The spectral windows are rectangular and triangular drawn from all of 11, 9, 7, 5 and 3 smoothed frequencies consistent with the earlier time series. However, because *both* the raw data and log data display strong peaks, a more intense spectral investigation was carried out on these than in the other time series and no heteroscedastic-reduced model for war is produced.

The variables including the raw data which form the basis for the modelling are shown in the "VAR" Appendix, (pp 45-53), graphically depicted in "GR" Appendix, (pp 83-85).

8.4.2 The Original Raw Data and its Log Transformation

8.4.2.1 The results of the spectral analysis

The war data is based on battle fatalities involving the "great powers". The original raw data from 1495-1992 and its log, in "GR" Appendix (p 83), input variables in

"VAR" Appendix (pp 45-53) visually show some clear fluctuations in the raw and log data over all centuries, with the smallest peaks in the early part of the data up to the 1600s.

The approach is the same as for tin, which is to take the initial data and subject it to spectral analysis. However, because both the raw data and log data display peaks, a more intense spectral investigation was carried out than in the earlier series.

The spectral analysis of the war original RAW data and its LOG showing jth peaks in the power spectrum is summarised thus:

Table 8.4.1 Raw and Log data: Spectral windows

War data Activity Anticipated Cycle Length: None.
Kondratieff Cycle Length: 48-60 yrs.

Spectral Window	Period- gram	*Ordinates*:* Spectral Density Estimates	Frequency Length **	Cycle Range	Cycle
Rectangular=R			λ radians	$2\pi/\lambda =$	years
Triangular=T				$2(3.14)/\lambda$	
R11	Raw	88746	0.2397	26.2 yrs	26.2-45.3 yrs
		56637	0.4794	13.1 yrs	13.1-16.6 yrs
T11	Raw	97847	0.2397	26.2 yrs	26.2-45.3 yrs
		62668	0.4794	13.1 yrs	13.1-16.6 yrs
R9	Raw	95966	0.2271	27.7 yrs	27.7-45.3 yrs
		61347	0.4794	13.1 yrs	13.1-16.6 yrs

T9	Raw	101851	0.2397	26.2 yrs	26.2-41.5 yrs
		65321	0.4794	13.1 yrs	13.1-16.6 yrs
R7	Raw	101128	0.2397	26.2 yrs	26.2-49.8 yrs
		65416	0.4794	13.1 yrs	13.1-16.6 yrs
T7	Raw	105653	0.2397	26.2 yrs	26.2-49.8 yrs
		67557	0.4794	13.1 yrs	13.1-16.6 yrs
R5	Raw	105561	0.2771	27.7 yrs	27.7-45.3 yrs
		68024	0.4921	12.8 yrs	12.8-16.6 yrs
T5	Raw	109173	0.2397	26.2 yrs	26.2-45.3 yrs
		69223	0.4794	13.1 yrs	13.1-16.6 yrs
R3	Raw	117393	0.0379	166 yrs	--
		112653	0.2271	27.7 yrs	27.7-45.3 yrs
		69954	0.4921	12.8 yrs	12.8-16.1 yrs
T3	Raw	115184	0.0379	166 yrs	--
		116072	0.2397	26.2 yrs	26.2-49.8 yrs
		71685	0.4794	13.1 yrs	13.1-16.6 yrs
R11	Log	1.7780	0.0505	124.5yrs	124.5-166 yrs
		0.8990	0.1136	55.3 yrs	55.3-62.3 yrs
		0.4214	0.2271	27.7 yrs	--
		0.3423	0.3028	20.8 yrs	--
		0.2511	0.3785	16.6 yrs	16.6-17.2 yrs
		0.2568	0.4164	15.1 yrs	15.1-.6 yrs
		0.2791	0.4794	13.1 yrs	13.1-.8 yrs

		0.2392	0.5299	11.9 yrs	--
		0.2135	0.5678	11.1 yrs	--
T11	Log	0.9927	0.1009	62.3 yrs	--
		0.4257	0.2271	27.7 yrs	27.7-29.3 yrs
		0.2622	0.3659	17.2 yrs	--
		0.2962	0.5173	12.1 yrs	12.1-13.8 yrs
R9	Log	1.8098	0.0379	166 yrs	--
		0.9822	0.0883	71.1 yrs	--
		0.8313	0.1262	49.8 yrs	--
		0.4883	0.2271	27.7 yrs	27.7-29.3 yrs
		0.4087	0.2650	23.7 yrs	--
		0.3349	0.3280	19.2 yrs	19.2-.9 yrs
		0.2540	0.3659	17.2 yrs	17.2-.8 yrs
		0.2671	0.4037	15.6 yrs	15.6-16.1 yrs
		0.2937	0.4668	13.5 yrs	13.5-12.8 yrs
		0.2456	0.5425	11.6 yrs	--
T9	Log	1.0672	0.1009	62.3 yrs	62.3-71.1 yrs
		0.4305	0.2397	26.2 yrs	26.2-31.1 yrs
		0.2706	0.3154	19.9 yrs	--
		0.2765	0.3659	17.2 yrs	17.2-.8 yrs
		0.3217	0.5173	12.1 yrs	12.1-14.3 yrs
R7	Log	1.1875	0.0883	71.1 yrs	71.1-83 yrs
		0.9034	0.1388	45.3 yrs	--
		0.4657	0.2019	31.1 yrs	--
		0.4640	0.2398	26.2 yrs	--
		0.4003	0.2776	22.6 yrs	--

		0.3122	0.3154	19.9 yrs	19.9-20.8 yrs
		0.2809	0.3533	17.8 yrs	17.8-18.4 yrs
		0.2593	0.3911	16.1 yrs	16.1-.6 yrs
		0.2228	0.4542	13.8 yrs	13.8-14.2 yrs
		0.3161	0.4794	13.1 yrs	--
		0.2673	0.5551	11.3 yrs	--
T7	Log	1.1460	0.1136	55.3 yrs	55.3-83 yrs
		0.4371	0.2145	29.3 yrs	29.3-31.1 yrs
		0.4574	0.2397	26.2 yrs	--
		0.4089	0.2776	22.6 yrs	--
		0.2898	0.3533	17.8 yrs	17.8-18.4 yrs
		0.2442	0.4542	13.8 yrs	13.8-14.6 yrs
		0.3593	0.5173	12.1 yrs	12.1-13.1 yrs
R5	Log	1.1812	0.1009	62.3 yrs	62.3-99.6 yrs
		0.4432	0.1893	33.2 yrs	--
		0.4765	0.2523	24.9 yrs	--
		0.3593	0.2902	21.7 yrs	--
		0.2927	0.3407	18.4 yrs	18.4-19.2 yrs
		0.2897	0.3659	17.2 yrs	--
		0.2538	0.4416	14.3 yrs	14.3-.6 yrs
		0.3247	0.4921	12.8 yrs	--
		0.3449	0.5299	11.9 yrs	11.9-12.1 yrs
		0.1700	0.5678	11.1 yrs	--
T5	Log	0.8736	0.0631	99.6 yrs	--
		1.3386	0.1136	55.3 yrs	55.3-71.1 yrs
		0.4292	0.1766	35.6 yrs	--
		0.4525	0.2397	26.2 yrs	26.2-29.3 yrs

		0.4157	0.2776	22.6 yrs	22.6-23.7 yrs
		0.3418	0.3659	17.2 yrs	17.2-18.4 yrs
		0.2609	0.4542	13.8 yrs	13.8-15.1 yrs
		0.4149	0.5173	12.1 yrs	12.1-.8 yrs
R3	Log	1.0907	0.0631	99.6 yrs	99.6-124.5yrs
		1.5827	0.1136	55.3 yrs	55.3-71.1 yrs
		0.4502	0.1766	35.6 yrs	35.6-38.3 yrs
		0.5847	0.2271	27.7 yrs	27.7-29.3 yrs
		0.4461	0.2650	23.7 yrs	--
		0.2215	0.3280	19.2 yrs	--
		0.3981	0.3659	17.2 yrs	17.2-.8 yrs
		0.2795	0.4542	13.8 yrs	13.8-15.1 yrs
		0.4303	0.5299	11.9 yrs	11.9-12.5 yrs
		0.1222	0.5804	10.8 yrs	--
T3	Log	1.034	0.0631	99.6 yrs	99.6-124.5yrs
		1.6600	.1136	55.3 yrs	55.3-66.3 yrs
		0.5852	0.1766	35.6 yrs	35.6-38.3 yrs
		0.5123	0.2397	26.2 yrs	26.2-29.3 yrs
		0.5791	0.2776	22.6 yrs	22.6-23.7 yrs
		0.2668	0.3154	19.9 yrs	--
		0.4069	0.3659	17.2 yrs	17.2-.8 yrs
		0.2863	0.4542	13.8 yrs	13.8-14.6 yrs
		0.5262	0.5173	12.1 yrs	12.1-.5 yrs
		0.0974	0.5804	10.8 yrs	--

Notes to above Table:

*For the raw data and its log, for the full periodogram ordinates and spectral density estimates see:

<u>Spectral Window</u> <u>Shown in "PER" Appendix, Pages 97-106</u>

Rectangular window 11, 9, 7, 5 and 3.
Triangular windows 11, 9, 7, 5 and 3.

**For the graphical presentation of the power spectrum over the various kernel windows see:

Spectral Window	Shown in Graphs "GR"Appendix, Pages 86-105
Rectangular and Triangular windows 11, 9, 7, 5 and 3	-for the Raw Data on pages 86-95.
Rectangular and Triangular windows 11, 9, 7, 5 and 3	-for the Log Data on pages 96-105.

8.4.2.2 The conclusion on spectral results

In the spectral modelling of the Original Raw war data, two peaks in the power spectrum are very clearly seen across all the kernel windows. The most Powerfully strong peak is centred on 26-28 years, being 26 years in the triangular and 27.7 years in the rectangular, however its frequency ranges 26-50 years over the spectrum. The other peak, Strongly to Powerfully seen is centred on 13 years in all windows, its frequency ranges from 13-16.6 years. A peak which falls outside the range of interest in this thesis occurs Medium to Strongly across the raw data, of 9 years. This is consistent with the cycle identified by the Juglar (1889), drawing on birth- and death-rates.

The Log of the original war data also shows clear peaks across all the spectral windows investigated and focuses the frequencies more sharply than in the raw data but there are still quite broad ranges to the frequencies. The most Powerful and Strong peak is centred around 55-63 years, although it does range to 71 years, to 83 years and 99 years. A Medium strength wave is identified in the range 26-29/33 years, centred on 26 years. A Strong to Medium wave is found in the range 11.9-13.1 years across all the kernel windows. Further pre-spectral modelling of the log data to make it more homoscedastic may aid in sharpening and honing the frequency ranges.

8.4.2.3 The results of the white noise tests

The results of the white noise tests of the war original RAW data and its LOG are summarised thus:

Table 8.4.2 Raw and Log data

Bartlett's Kolmogorov-Smirnov white noise test:

Time series data : Original raw data and its log
For each series:
Period of observations of data : 1495 -1992
No. of observations for processing : 498
No. of ordinates calculated : 250
No. with 2 degrees of freedom
for m for the white noise test: 249

Bartlett's Kolmogorov-Smirnov white
noise Test Statistic : 0.6838 (Raw Data)
0.6436 (Its Log)

To compare the Test Statistic to critical points, *(m-1=248) @*
5% critical point : $1.36(m-1)^{-1/2} = 0.0864$
1% critical point : $1.63(m-1)^{-1/2} = 0.1035$

(The periodogram ordinates calculated are given in "PER" Appendix, War-Raw+Log-R11-3, pages 97-106.)

The Bartlett's Kolmogorov-Smirnov Test Statistic of 0.6838 for the Original Raw Data and 0.6436 for its Log are well above the values of the 5% and 1% critical points, thus the white noise null hypothesis is rejected for both series. It can be inferred that in the war series, the original raw data and its log do not comprise of white noise.

Table 8.4.3 Raw and Log data

The Fisher-Kappa white noise test:

The Fisher-Kappa model is (m-1) x (max P) / Sum P
where m-1 is as above for the BKS test,
max P is the maximum periodogram ordinate calculated,
sum P being the sum of ordinates.

For the war data, as above used in the BKS,

	Original Raw Data	Its Log
m-1	: 248	248
max P	: 1661720	51.78
sum P	: 37797695	362.18

The Fisher-Kappa Test Statistic

$$\frac{248 \times 1661720}{37797695} = 10.9 \qquad \frac{248 \times 51.78}{362.18} = 35.5$$

To compare the Test Statistic to Fuller's Table[1] (Table m=250)@

5% critical point : = 8.389
1% critical point : = 9.960

(from ordinates calculated given in "PER" Appendix, War-Raw+Log-R11-3, pages 97-106.)

Therefore, as the Fisher-Kappa Test Statistic of 10.9 for the Original Raw Data and

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[1] Fuller (1976), Table 7.1.2 "Percentage points for the ratio of largest periodogram ordinate to the average", page 284.

35.5 for its Log are well above the values of the 5% and 1% critical points, the white noise null hypothesis is rejected for both series. Thus, it can be inferred that in the war series, the original raw data and its log do not comprise of white noise.

8.4.3 The Basic (Homoscedastic Approximation) Model

8.4.3.1 Introduction

The Basic (Homoscedastic Approximation) Model for war (1495-1992) is the residual output from the First Stage Modelling, the methodology is described earlier, "Modelling to reduce heteroscedasticity in the data". The residual output from the First Stage Modelling provides the input material for the spectral analysis. The pre-spectral variables from raw data, to their log, the two transformed variables, the trend and residual are located in the "VAR" Appendix, (pp 106-115), graphical depiction of the Basic Model in "GR" Appendix, (p 84). The residual is based on the trend:

$$y = +0.3325 + 0.003545x \qquad 2.$$

The Basic (Homoscedastic Approximation) Model is subjected to spectral analysis with various spectral windows, rectangular and triangular smoothed over differing frequencies of 11, 9, and 7 to shorter windows of 5 and 3 frequencies. Again, as for the tin, more analysis has been carried out on this model than any of the others as it is the model which represents the fundamental de-trended residual output for the war data. The hypothesis being that there are no long cycles in the data. The analysis involved the specification of the whole range of the spectral density estimates for all the windows used and zooming into a tighter power spectrum to visually highlight any peaks identified.

The Basic (Homoscedastic Approximation) Model is then subjected to further investigation. This further investigation entailed breaking the Model's data down in to

2 separate Subsets of 281 and 237 years, thereby Subset2 coinciding with tin's Subset3. It is not thought necessary to produce a heteroscedastic-reduced model for this series, given the cyclical fluctuations clearly seen in the basic model and subsets.

8.4.3.2 The Results from The Basic (Homoscedastic Approximation) Model

8.4.3.2.1 The results from the spectral analysis

The Basic (Homoscedastic Approximation) Model was subjected to periodogram calculations and spectral windows of rectangular and triangular from 11 to 3 smoothed frequencies to produce differing power spectrums. The resulting ordinates from the periodogram calculation and various spectral density estimates are located in the "PER" Appendix for the medium spectral windows and the power spectrums are visually shown in the Graphs Appendix, "GR".

Table 8.4.4 Basic (Homoscedastic Approximation) Model

War data Activity Anticipated Cycle Length: None.
Kondratieff Cycle Length: 48-60 yrs.

	Ordinates:*				
Spectral Window	Period-gram	Spectral Density Estimates	Frequency **	Cycle Length	Cycle Range
Rectangular=R Triangular=T			λ radians	$2\pi/\lambda = 2(3.14)/\lambda$	years
R11		5.9489	0.0505	124.5yrs	124.5-166 yrs
		1.1179	0.1136	55.3 yrs	--
		0.7875	0.1514	41.5 yrs	--
		0.4161	0.2145	29.3 yrs	--
		0.4143	0.2397	26.2 yrs	--

	0.3576	0.3028	20.8 yrs	--
	0.3010	0.3280	19.2 yrs	--
	0.2660	0.3785	16.6 yrs	16.6-17.2 yrs
	0.2725	0.4164	15.1 yrs	15.1-.6 yrs
	0.2836	0.4921	12.8 yrs	12.8-13.8 yrs
	0.2066	0.5678	11.1 yrs	--
T11	0.4695	0.2397	26.2 yrs	26.2-29.3 yrs
	0.2700	0.3659	17.2 yrs	--
	0.2450	0.4164	15.1 yrs	15.1-.6 yrs
	0.2847	0.5047	12.5 yrs	12.5-14.2 yrs
R9	6.8882	0.0379	166 yrs	--
	0.4901	0.2271	27.7 yrs	27.7-29.3 yrs
	0.4632	0.2650	23.7 yrs	--
	0.3277	0.3280	19.2 yrs	19.2-.9 yrs
	0.2698	0.3659	17.2 yrs	17.2-.8 yrs
	0.2755	0.4037	15.6 yrs	15.6-16.1 yrs
	0.2973	0.4921	12.8 yrs	12.8-13.8 yrs
	0.2351	0.5425	11.6 yrs	--
T9	1.3588	0.0883	71.1 yrs	--
	0.4938	0.2397	26.2 yrs	26.2-31.1 yrs
	0.2947	0.3154	19.9 yrs	--
	0.2816	0.3533	17.8 yrs	--
	0.3013	0.5173	12.1 yrs	12.1-14.6 yrs
R7	1.5964	0.0883	71.1 yrs	71.1-83 yrs
	0.4794	0.2145	29.3 yrs	29.3-33.2 yrs
	0.5090	0.2397	26.2 yrs	--

	0.3110	0.3154	19.9 yrs	19.9-20.8 yrs
	0.3013	0.3533	17.8 yrs	17.8-18.4 yrs
	0.2545	0.3911	16.1 yrs	16.1-.6 yrs
	0.2460	0.4416	14.2 yrs	--
	0.3239	0.4794	13.1 yrs	--
	0.2597	0.5551	11.3 yrs	--
T7	1.3976	0.1009	62.3 yrs	62.3-71.1 yrs
	0.5137	0.2145	29.3 yrs	29.3-33.2 yrs
	0.5351	0.2397	26.2 yrs	--
	0.3886	0.2776	22.6 yrs	--
	0.2941	0.3533	17.8 yrs	17.8-18.4 yrs
	0.2805	0.4542	13.8 yrs	13.8-15.1 yrs
	0.3282	0.5173	12.1 yrs	12.1-13.1 yrs
R5	1.5361	0.0757	83 yrs	83-99.6 yrs
	1.4060	0.1009	62.3 yrs	--
	0.5202	0.2145	29.3 yrs	29.3-33.2 yrs
	0.5043	0.2397	26.2 yrs	--
	0.3705	0.2902	21.7 yrs	--
	0.3200	0.3407	18.4 yrs	18.4-19.2 yrs
	0.2913	0.3659	17.2 yrs	--
	0.2804	0.4542	13.8 yrs	13.8-14.2 yrs
	0.3139	0.4921	12.8 yrs	--
	0.3237	0.5299	11.9 yrs	11.9-12.1 yrs
	0.1830	0.5678	11.1 yrs	--
T5	1.3981	0.0631	99.6 yrs	--
	1.501	0.1136	55.3 yrs	55.3-62.3 yrs
	0.5598	0.2271	27.7 yrs	27.7-35.6 yrs

	0.3328	0.3659	17.2 yrs	17.2-18.4 yrs
	0.3097	0.4542	13.8 yrs	13.8-15.1 yrs
	0.3684	0.5173	12.1 yrs	12.1-.8 yrs
	0.1217	0.5930	10.6 yrs	--
R3	1.6301	0.0631	99.6 yrs	--
	1.8261	0.1136	55.3 yrs	55.3-71.1 yrs
	0.7437	0.2271	27.7 yrs	27.7-33.2 yrs
	0.2776	0.3280	19.2 yrs	--
	0.3732	0.3659	17.2 yrs	17.2-.8 yrs
	0.3328	0.4542	13.8 yrs	13.8-15.1 yrs
	0.3873	0.5300	11.9 yrs	11.9-12.5 yrs
	0.1328	0.5804	10.8 yrs	--
T3	1.6808	0.0505	124.5yrs	--
	1.7345	0.1136	55.3 yrs	55.3-71.1 yrs
	0.3992	0.1766	35.6 yrs	35.6-38.3 yrs
	0.6326	0.2271	27.7 yrs	27.7-31.1 yrs
	0.4867	0.2776	22.6 yrs	--
	0.3522	0.3154	19.9 yrs	--
	0.3848	0.3659	17.2 yrs	17.2-.8 yrs
	0.3463	0.4542	13.8 yrs	13.8-15.1 yrs
	0.4640	0.5173	12.1 yrs	12.1-.5 yrs
	0.1687	0.5930	10.6 yrs	--

Notes to above Table:

*For the periodogram ordinates and spectral density estimates see:

Spectral Window	Shown in "PER" Appendix, Pages 107-116
Rectangular and Triangular windows	11, 9, 7, 5 and 3.

**For the graphical presentation of the power spectrum over the various kernel windows see:

Spectral Window	Shown in Graphs "GR"Appendix, Pages 106-115
Rectangular and Triangular windows 11, 9, 7, 5 and 3.	

8.4.3.2.2 The conclusion on spectral results

No Kondratieff type fluctuations were expected following the spectral modelling of the de-trended data. However, peaks have been identified in the power spectrum. A hegemony cycle is intermittently seen in the kernel windows, from Weak to Strong centred on 124.5 years. This alternates with a Medium wave centred around 99.6 years.

There is a more consistent long cycle centred around 55 years to 71/83 years. The peak of 55 years becomes Strong to almost Powerfully strong on moving down the kernel windows from spectral window 11 to 3. However, it continues to have a broad band to its frequency, generally 55/62-71 years.

One of two of the most persistent cycles through the power spectrum is centred on 26 years, ranging 26-31 years. It strengthens from a Weak wave in the larger spectral window investigated to Medium and through to Strong in the smallest one, tending to be sharper in focus in the triangular kernel windows.

The other most persistent cycle is centred around 11.9-13.1 years. Not quite as strong as the 26-year one, but it also picks up strength from Weak to Medium to Strong (almost) on moving down the windows.

To sum up, for the three most persistent cycles, a harmonic relationship may tie them together being 13 years, 26 years and 55 years, but with some generous banding. As with the other time series findings, it is believed worthwhile to explore the Basic (Homoscedastic Approximation) Model over 2 separate periodical Subsets in the following section after the white noise tests.

8.4.3.2.3 The results of the white noise tests

The results of the white noise tests of the Basic (Homoscedastic Approximation) Model data is summarised thus:

Table 8.4.5 Basic (Homoscedastic Approximation) Model

Bartlett's Kolmogorov-Smirnov white noise test:

Time series data :	Basic (Homoscedastic Approximation) Model
Period of observations of data :	1495 -1992
No. of observations for processing :	498
No. of ordinates calculated :	250
No. with 2 degrees of freedom for m for the white noise test:	249
Bartlett's Kolmogorov-Smirnov white noise Test Statistic :	0.7014
To compare the Test Statistic to critical points, $(m-1=248)$ @	
5% critical point : $1.36(m-1)^{-1/2} = 0.0864$	
1% critical point : $1.63(m-1)^{-1/2} = 0.1035$	

(The periodogram ordinates calculated are given in the "PER" Appendix, War, Basic-R11-7, pages 107-116.)

Thus, as the Bartlett's Kolmogorov-Smirnov Test Statistic of 0.7014 for the Basic (Homoscedastic Approximation) Model is above the values of the 5% and 1% critical points, the white noise null hypothesis is rejected for the series. So, it can be inferred that in the war series, the Basic (Homoscedastic Approximation) Model does not comprise white noise.

Table 8.4.6 Basic (Homoscedastic Approximation) Model

The Fisher-Kappa white noise test:

The Fisher-Kappa model is (m-1) x (max P) / Sum P
where m-1 is as above for the BKS test,
max P is the maximum periodogram ordinate calculated,
sum P being the sum of ordinates.

For the war data, as above used in the BKS,

m-1	: 248
max P	: 232.2
sum P	: 589.5

The Fisher-Kappa Test Statistic

$$\frac{248 \times 232.2}{589.5} = 97.7$$

To compare the Test Statistic to Fuller's Table[2] (Table m=250)@

5% critical point	: =	8.389
1% critical point	: =	9.960

(from periodogram ordinates calculated given in the "PER" Appendix, War,Basic-R11-7, pages 107-116.)

So, as the Fisher-Kappa Test Statistic of 97.7 for the Basic (Homoscedastic Approximation) Model is above the values of the 5% and 1% critical points, the white noise null hypothesis is rejected for the series. Thus, it can be inferred that in the war

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[2] Fuller (1976), Table 7.1.2 "Percentage points for the ratio of largest periodogram ordinate to the average", page 284.

series, the Basic (Homoscedastic Approximation) Model does not comprise of white noise.

8.4.3.3 The results of The Basic (Homoscedastic Approximation) Model broken down into 2 separate periods

8.4.3.3.1 Introduction

The Basic (Homoscedastic Approximation) Model is subjected to further investigation. This further investigation entailed breaking the Model's data down in to 2 separate Subsets of 281 and 237 years, thereby Subset2 coinciding with tin's Subset3. The data is not changed, it is the same as that in the whole range of the Basic (Homoscedastic Approximation) Model, but broken down in 2 separate component periods for individual analysis. The length of the Subset periods are long enough to cover several Kondratieff cycles (48-60 years) should they exist. The intention of breaking the Model into 2 separate components for separate spectral analysis is to aid the identification or otherwise, of long cycles.

The 2 Subsets are examined over the whole of their spectral density estimates range. The Basic (Homoscedastic Approximation) Model in its 2 separate component periods, the Subsets are then more closely scrutinised. The close scrutiny involves zooming into a tighter scale range over the power spectrum. It was again found useful to undertake the Subset analysis in one section rather than in two, as for tin, and homing in on tighter scales directly, given the overall perspective of the power spectrum. The analysis of the spectrum of the 2 Subsets over the varying spectral windows is based on the whole scaled range. Rather than a common-scale approach as for tin, it was more useful to zoom into a varying spectral density range. This is because occasionally, peaks were found in the lower part of the power spectrum suggestive of long frequencies, so zooming into the window better illustrates the spectral findings.

The input data for the spectral modelling in this section is the Basic (Homoscedastic Approximation) Model (1495-1992), the residual output from the First Stage Modelling decribed earlier , variables in "VAR" Appendix (pp 45-53) and is visually shown in the graphs appendix, "GR" Appendix, (p 85) for both subsets.

8.4.3.3.2 The results of Subset 1

Subset1 covers the 281-year period from 1495-1755 of The Basic (Homoscedastic Approximation) Model. The spectral investigation of the Subset is over spectral windows, both rectangular and triangular over 11,9,7,5 and 3 smoothed frequencies. This is more than the population analysis because the war data is evaluated in more detail over the subranges without the need to break the modelling down to reduce heteroscedasticity further. The analysis is based on the spectral modelling of the whole range of the Subset's individual spectral density estimates. However, to aid the visual presentation of findings, the graphical representation of the power spectrum zooms into narrower range and frequency. The data input for the spectral modelling of Subset1, variables in "VAR" Appendix (pp 45-53) which can be visually seen, "GR" Appendix, (p 85).

Table 8.4.7 Basic (Homoscedastic Approximation) Model Subset1

War data Activity Anticipated Cycle Length: None.

Kondratieff Cycle Length: 48-60 yrs.

	*Ordinates**:*				
Spectral Window	Period-gram	Spectral Density Estimates	Frequency **	Cycle Length	Cycle Range
Rectangular=R			λ radians	$2\pi/\lambda =$	years
Triangular=T				$2(3.14)/\lambda$	
R11		0.2816	0.2683	23.4 yrs	--

	0.2624	0.3354	18.7 yrs	--
	0.0833	0.5814	10.8 yrs	10.8-11.2 yrs
T11	0.3031	0.3130	20.1 yrs	20.1-23.4 yrs
	0.0778	0.5814	10.8 yrs	10.8-.4 yrs
R9	0.2996	0.2907	21.6 yrs	21.6-23.4 yrs
	0.0859	0.5366	11.7 yrs	11.7-12.2 yrs
T9	0.3234	0.3130	20.1 yrs	20.1-25.5 yrs
	0.0754	0.5814	10.8 yrs	10.8-.0 yrs
R7	0.3588	0.3130	20.1 yrs	20.1-25.5 yrs
	0.0863	0.4919	12.8 yrs	--
T7	0.3373	0.3130	20.1 yrs	20.1-28.1 yrs
	0.0740	0.5814	10.8 yrs	--
R5	0.8516	0.0671	93.7 yrs	--
	0.3085	0.2683	23.4 yrs	23.4-28.1 yrs
	0.3583	0.3354	18.7 yrs	18.7-20.1 yrs
	0.1018	0.4696	13.4 yrs	--
T5	0.3266	0.2683	23.4 yrs	23.4-28.1 yrs
	0.3205	0.3130	20.1 yrs	--
	0.3410	0.3578	17.6 yrs	--
	0.1005	0.4696	13.4 yrs	--
	0.0752	0.5814	10.8 yrs	--
R3	0.7678	0.0894	70.3 yrs	--

	0.3899	0.2907	21.6 yrs	21.6-28.1 yrs
	0.3748	0.3578	17.6 yrs	17.6-18.7 yrs
	0.1038	0.4472	14.1 yrs	--
	0.1036	0.4919	12.8 yrs	--
T3	0.8052	0.1118	56.2 yrs	56.2-70.3 yrs
	0.3493	0.2683	23.4 yrs	23.4-28.1 yrs
	0.4287	0.3801	16.5 yrs	16.5-17.6 yrs
	0.0995	0.4472	14.1 yrs	--
	0.0754	0.5814	10.8 yrs	10.8-.4 yrs

Notes to above Table:

The resulting ordinates from the periodogram calculations and various spectral density estimates are located in the "PER" Appendix and the 6 resulting differing power spectrums are visually shown in the Graphs Appendix, "GR" detailed below.

*For the periodogram ordinates and spectral density estimates see:

Spectral Window	Shown in "PER" Appendix, Pages 117-126
Rectangular and Triangular windows 11, 9, 7, 5 and 3.	

**For the graphical presentation of the power spectrum over the various kernel windows see:

Spectral Window	Shown in Graphs "GR"Appendix, Pages 116-125
Rectangular and Triangular windows 11,9, 7, 5 and 3.	

8.4.3.3.3 The results of Subset 2

Subset2 covers the 237-year period from 1756-1992 of The Basic (Homoscedastic Approximation) Model. The time period coincides with the tin data's Subset3 range. The spectral investigation of the war Subset is again over spectral windows, both rectangular and triangular over 11,9,7, 5 and 3 smoothed frequencies to produce 10 differing power spectrums. The spectral modelling is based on the whole range of the

Subset's individual spectral density estimates. As for Subset1, the graphical representation not only includes the whole power spectrum but a further depiction per window in order to amplify the findings to aid illustration by zooming into narrower frequency and spectral density ranges.

The data input for the spectral modelling of Subset2, variables in "VAR" Appendix (pp 45-53) and shown visually in the "GR" Appendix (p 85).

Table 8.4.8 Basic (Homoscedastic Approximation) Model Subset2

War data Activity Anticipated Cycle Length: None.
Kondratieff Cycle Length: 48-60 yrs.

Spectral Window Rectangular=R Triangular=T	Periodgram	*Ordinates*:* Spectral Density Estimates	Frequency ** λ radians	Cycle Length $2\pi/\lambda = 2(3.14)/\lambda$	Cycle Range years
R11		0.5425	0.3447	18.2 yrs	--
		0.4208	0.4507	13.9 yrs	13.9-14.8 yrs
		0.3539	0.5833	10.8 yrs	10.8-11.3 yrs
T11		0.4261	0.4772	13.2 yrs	13.2-14.8 yrs
R9		0.3066	0.1326	47.4 yrs	--
		0.5502	0.3181	19.8 yrs	--
		0.4191	0.4507	13.9 yrs	13.9-14.8 yrs
T9		0.4502	0.4772	13.2 yrs	13.2-15.8 yrs

R7	0.4017	0.3977	15.8 yrs	--
	0.4571	0.5037	12.5 yrs	12.5-13.9 yrs
T7	1.5871	0.0530	118.5yrs	--
	0.4832	0.5037	12.5 yrs	12.5-15.8 yrs
R5	1.6929	0.0795	79.0 yrs	--
	1.2301	0.1856	33.9 yrs	--
	0.7415	0.2651	23.7 yrs	--
	0.3593	0.3712	16.9 yrs	--
	0.5055	0.5037	12.5 yrs	12.5-14.8 yrs
T5	0.8867	0.2386	26.3 yrs	--
	0.5035	0.5037	12.5 yrs	12.5-14.8 yrs
R3	1.5933	0.1061	59.3 yrs	--
	0.9535	0.2386	26.3 yrs	--
	0.5234	0.5037	12.5 yrs	12.5-14.8 yrs
T3	1.8064	0.1326	47.4 yrs	47.4-59.3 yrs
	1.1190	0.2386	26.3 yrs	26.3-29.6 yrs
	0.4542	0.3181	19.8 yrs	--
	0.5149	0.4772	13.2 yrs	13.2-15.8 yrs
	0.5095	0.5302	11.9 yrs	--

Notes to above Table:

The resulting ordinates from the periodogram calculations and various spectral density estimates are located in the "PER" Appendix and the 10 resulting differing power spectrums are visually shown in the Graphs Appendix, "GR" detailed below.

*For the periodogram ordinates and spectral density estimates see:

Spectral Window Shown in "PER" Appendix, Pages 127-136
Rectangular and Triangular windows 11, 9, 7, 5 and 3.

**For the graphical presentation of the power spectrum over the various kernel windows see:
Spectral Window Shown in Graphs "GR"Appendix, Pages 126-135
Rectangular and Triangular windows 11, 9, 7, 5 and 3.

8.4.3.3.4 The conclusion on the Subset spectral results

In Subset1, the longest cycle in seen is the smallest spectral window, 56-70 years. It is Strongly seen in both, centred at 70 years in the rectangular, 56 years in the triangular, where it also ranges 56-70 years. In the overall Basic Model it was seen Strongly to Powerfully strongly. The clearest cycle in Subset1 is centred around 20 to 23.4 years, Strongly perceived through all the kernel windows, and ranging up to 28 years. The centre shifts to 23.4 years in the 2 smaller windows, 5 and 3. The other clear fluctuation in the power spectrum is one centred around 16.5-18.7 years. Again, only visual in the windows 5 and 3, but Strongly seen.

In Subset2, a long fluctuation centred at 79 years only appears in spectral window 5, which had been Powerfully strongly seen in the Log data. Medium to Strongly seen is a long cycle centred at 47 years ranging to 59 years in windows 9 and 3. However, the 2 clearest cycles in Subset2 are centred around 26.3 years and 13 years, again potential harmonic linkage. The 13 year cycle ranges 12.5-16 years, and is the stronger and more persistent cycle across all the spectral windows being Strong to Medium in relative strength. It is also Weakly seen in Subset1 in the smaller windows. The 26 year fluctuation in the spectrum ranges 23 to 29.6 years, varies in the smaller windows from Weak to Strong, and almost Powerfully strong in triangular window 3.

8.4.3.4 Conclusion and Results Summary Table

The hypothesis of no Kondratieffs is not supported by the war data. There is a frequency which is Powerfully to Strongly seen, centred at 55 years, ranging 55-63 years to 71/83 years, but not persistently. Another is centred less strongly, but more consistently, at Medium to Strong, at 26 years ranging 26-29/33 years. There is a lesser, Weak to Medium/Strong fluctuation centred on 13 years, ranging 13-17 years and 11.9-13.1 years. A peak which also persists outside the range of interest is 9 years, consistent with one identified by Juglar. Thus for the war data, the three most persistent fluctuations, in order, are centred at 26 years, 13 years and 55 years with some banding. Over Subsets, the waves are supported but the peaks' centres can shift: from 26 years to 23.4 years, range 20-23 years, and wider band, 47-55 years.

The main results are summarised on the next page:
Table 8.4.9 Results Summary Table: War

TABLE 8.4.9

RESULTS SUMMARY TABLE 3 : WAR

CYCLE	WINDOW SIZE									
LENGTH	R11	T11	R9	T9	R7	T7	R5	T5	R3	T3
Raw/Log: *Basic:* *Sub-/1/2:*	*R/L* *B* *-12*	*R/L* *B* *-12*	*R/L* *B* *-12*	*R/L* *B* *-12*	*R/L* *B* *-12*	*R/L* *B* *-12*	*R/L* *B* *-12*	*R/L* *B* *-12*	*R/L* *B* *-12*	*R/L* *B* *-12*
209	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00
121-166	0/W W -00	0/0 0 -00	0/W W -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	W/0 0 -00	W/0 S -00
118-120	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -0v	0/0 0 -00	0/0 0 -00	0/C 0 -00	0/C 0 -00
86-100	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/C C -W0	0/v v -00	0/S M -00	0/S 0 -00
83-85	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/C M -00	0/0 0 -00	0/0 0 -00	0/0 0 -00
76-82	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/C C -00	0/C 0 -00	0/C 0 -0S	0/0 0 -00	0/0 0 -00	0/0 0 -00
71-75	0/0 0 -00	0/0 0 -00	0/W 0 -00	0/0 W -00	0/S M -00	0/C C -00	0/C 0 -00	0/0 0 -00	0/0 C -00	0/0 C -00
64-70	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/C 0 -00	0/0 0 -00	0/C C -00	0/C 0 -00	0/C 0 -00	0/P C -S0	0/C C -C0
61-63	0/C 0 -00	0/M 0 -00	0/0 0 -00	0/S 0 -00	0/0 0 -00	0/C W -00	0/P W -00	0/C C -00	0/C C -00	0/C C -C0
55-60	0/M W -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/S 0 -00	0/0 0 -00	0/P S -00	0/P S -0M	0/P P -SC
51-54	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -0C
48-50	0/0 0 -00	0/0 0 -00	0/v 0 -00	0/0 0 -00	C/0 0 -00	C/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	C/0 0 -0S
46-47	0/0 0 -00	0/0 0 -00	0/0 0 -0W	0/0 0 -00	C/0 0 -00	C/0 0 -00	0/0 0 -00	0/0 0 -00	0/0 0 -00	C/0 0 -00
41-45	C/0 v -00	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/M 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00
38-40	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00
36-38	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/M 0 -00	C/M W -00
33-35	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/0 C -00	C/0 0 -0M	C/W C -00	C/0 0 -00	C/0 0 -00
30-33.3	C/0 0 -00	C/0 0 -00	C/0 0 -00	C/C C -00	C/M C -00	C/C C -00	C/M C -00	C/0 C -00	C/0 C -00	C/0 C -00
26-30	P/M W -00	P/M M -00	P/S W -00	P/M M -00	P/M M -00	P/W M -C0	P/0 M -C0	P/W S -CW	P/M S -CS	P/M S -CP
23.1-25	0/0 0 -00	0/0 0 -00	0/W v -00	0/0 0 -C0	0/0 0 -C0	0/0 0 -C0	0/M 0 -SW	0/0 0 -S0	0/0 0 -C0	0/0 0 -S0
21.3-23.4	0/0 0 -M0	0/0 0 -C0	0/0 0 -S0	0/0 0 -C0	0/W 0 -C0	0/v 0 -C0	0/W W -00	0/v 0 -00	0/W 0 -S0	0/M W -00
20.1-21.5	0/W v -00	0/0 0 -S0	0/0 0 -00	0/0 0 -S0	0/0 0 -S0	0/0 0 -S0	0/0 0 -00	0/0 0 -v0	0/0 0 -00	0/0 0 -00
17-20	0/C v -vW	0/v v -00	0/M v -0v	0/W v -00	0/W v -00	0/W v -00	0/W W -Sv	0/M W -S0	0/M M -S0	0/M M -S0
14-16	C/W v -0v	C/0 v -0C	C/M v -0W	C/0 0 -0C	C/W 0 -0W	C/W v -0C	C/W W -WC	C/W W -vC	C/M M -WC	C/M M -WC
12-13	S/M W -00	S/S M -0M	S/S W -00	S/S W -0M	S/M W -vM	S/S W -0S	S/M W -0S	S/S M -0S	S/S S -vM	S/S S -0S
10.8-11.9	0/W v -vW	0/0 0 -v0	0/W v -v0	0/0 0 -00	0/v v -00	0/0 0 -00	0/M v -00	0/0 0 -v0	0/v v -v0	0/W v -vv

Notes to table:

- Cycle length ranged in years, R denotes rectangular window, T denotes triangular.
- Numbers 11-3 denotes number of smoothed frequencies in window.
- Some slight overlaps between ranges occur to allow for cycle periodicities.
- "Sub-/1/2" denotes a dash (-/) to allow for the extra subset in the tin data for the earlier time period. Thus Subset 2 covers the same time period as tin's Subset 3. So visually in the summary result tables, the location of the Letter symbols are placed over similar time periods, regardless of whether they refer to Subset 2 or 3.
- Letter Symbols:

P	Powerfully strong fluctuation.
S	Strong fluctuation.
M	Medium fluctuation.
W	Weak fluctuation as slight blip in the power spectrum.
v	Very weak fluctuation.
C c	Crossing over from the range below.
0	Zero, denoting no peak in the power spectrum.
-	Window not necessarily calculated or shown.

CHAPTER 9

THE OVERALL CONCLUSION

9.1 The summary of approach and the problems faced in the thesis

This thesis has centred on the study of long cycles, with particular respect to those termed Kondratieffs, 47/48-60 years in length. Extensive studies have been carried out on well-known and generally acknowledged business cycles, the shorter- and medium-term cycles, with relatively little investigation on the long cycles. The most widely acknowledged cycles can be summarised as *Kitchins* (3-3.3 years) relating to working capital investment such as inventory, *Juglars* (7-11 years) relating to fixed asset investment such as plant and machinery, *Kuznets* (15-25 years) relating to the construction industry and/or generational population changes. And the Kondratieff long cycles which may relate to major technological changes (Tables 2.5, 2.6). The literature on these other cycles, particularly the business ones, is vast, and an overview is presented in Chapter 1. A very early recognition of a cycle, with an underlying correlation to the harvest cycle is illustrated by Petty, who referred to a perceived average seven year cycle in corn harvests:

> *"and the medium of seven years, or rather of so many years as makes up the Cycle, within which Dearths and Plenties make their revolution,"*
>
> *Petty (1662) pp 24-25*

And for long cycles, a comment by Hyde Clark who influenced Jevons's early work:

> *".... my impression that the period of speculation was a period of ten years, but I was led also to look for a period of thirteen or fourteen years .... I was led to look for a larger period, which would contain the smaller periods, ... This gave a period of about fifty-four years,"*
>
> *Hyde Clark (1838)*

However, the basis regarding some modern-day city analysts' assumptions about the existence of long cycles, to observe and respond to markets was not entirely clear.

Some city practitioners, for example, commodity advisors, commenting on *long-term* economic movements which they believed affected markets, actually referred to them as *Kondratieff cycles* by name. They even suggested that short- and medium-term cycles (which they termed as seasonal) may be exacerbated by the synchronicity of a long-term cycle. A typical comment made by a commodity advisor, Bernstein (1989)[1] sums the situation thus:

"when seasonal cycles get in sync with long-term cycles, the force can be powerful."

Bernstein, President of Mbh
Commodity Advisors (Futures, June 1989) p 20 i

"One of the best-known cycles is the 50- to 60-year economic cycle, also known as the 54-Kondratieff wave,"

Futures (June 1989) p 20 i

This thesis therefore focussed on, and evaluated the lesser studied long cycles. Particularly those referred to as Kondratieffs, the 47/48-60 year cycle named after the Russian, Nikolai Dmitrievich Kondrat'ev, known in the West as Kondratieff. The first four chapters (Ch 1.4 - 4) contained a comprehensive examination and evaluation of the extant literature on long cycles, particularly the Kondratieffs. Overall, the literature was inconsistent, inconclusive, unclear and there was no consensus regarding the existence and causal mechanism which would drive such cycles. Indeed, studies through to the 1980s/1990 continued to produce contradictory findings: Reijnders (1990) for, Solomou (1987) against, Kleinknecht (1987) and Kindleberger (1989) non-committal. So the debate persists. The *primary research mission* of this thesis was to attempt to resolve in part, by demonstrating whether any long cycle in existence, exists in tin data and some associated series (war and population).

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[1] Bernstein, Jake, "Futures" June 1989

The implications of the literature review meant that problems to be faced in the thesis could be summarised thus: clarity of hypothesis setting, data efficacy and longevity, the trend elimination, the interpretation of the modelled residuals and scientific-seeing, and finally, the inconclusiveness of any findings across the data series.

In the thesis, the model's framework required specific data characteristics to satisfy the heuristic approach adopted. Thus the negative heuristic adopted in the model is that the empirical data be *new* to the study of long cycles, rather than just incorporate Kondratieff's data re-worked, which is the approach generally taken in quite a number of other long cycle studies. So the data in the thesis is drawn from objectively gathered socio-economic sources, that is, non-long cycle theorists. The model's heuristic approach also required the data to particularly be a non-price type, non-aggregate and gathered over a much longer period, up to 837 years, about 3-5 times longer than some of the original Kondratieff data. Kondratieff's own long cycle work was impoverished by the lack of long data.

An important advantage of concentrating on non-price data is the elimination of the price effects problem suffered by Kondratieff and other long cycle theorists when tackling such effects in the trend elimination stage. Price and value data series are prone to cyclicality anyway. Another feature specified for the data in the thesis, is that it be drawn from consistent runs, with any consecutive runs from different sources strung together to produce a single time series. The intention is to reduce variation in errors, and any errors in estimates to be consistent for one place or location and more readily identifiable. Series of average figures were felt to be not primary candidates for selection in the thesis, being based on data gathered from many places they may well contain further errors, not readily ascertainable. This was the experience of researchers under Beveridge (1939, 1929) and Thorold Rogers (1886, 1882, 1876). A further model specification in the thesis is that the non-price data be specific rather aggregate type such as an index. The literature on aggregate data found much subjectivity was incorporated into the composition of the index, which did not fit in with my model's particular specification of objectivity in the data gathered. Further, aggregates by the averaging process do not readily lend themselves to cyclical investigation, the smoothing process may not have been clearly objectively handled. In addition, the most serious defect which ruled it out of the selection choice, is that the data search found no aggregate or index series of *sufficient length* to satisfy the model requirement of a time series to cover at least 7-10 potential long cycles. This duration critieria being a particularly important feature in the data choice due to the modelling technique applied in the long cycle investigation, namely, the spectral analysis.

A number of non-price data series were identified meeting the longevity criteria but on further investigation, were found not to be satisfactory. For example, bread, beer wheat and candle production. The problems that were found included deliberate omissions, careless reporting and the changing composition of the production output, for example, during periods of poor harvests then grains normally used in animal feed were incorporated into bread production. Other problems revolved around the data efficacy and the careless reporting of production measures and so output, for example, the changing weights of *local* bushels in the reporting of wheat, varying from 8 - 10 gallons per "standard" bushel. Thorold Rogers failed to consistently detect such local differences. However, the most common problem identified in the data search was that of medieval fraud due to tax evasion, especially in production output subject to higher levels of tax, thus candle production figures was found to be especially suspect.

The tin production is the series that most closely satisified the model's heuristic, as evaluated in depth in Chapter 6.4. It is a series not used by Kondratieff, it is non-price data, its production was fairly localised with Cornwall (and Devon for a short period) being the most important medieval producer and so the data reporting provided long consecutive runs, and the local measure differences between Cornwall and Devon were readily ascertainable for consistency of the data. Tin's composition and reporting in terms of metal ore content or approximation of it, for white tin, for coinage has very long consecutive runs recorded for it. Indeed, the current mineral statistics now published by the Central Statistical Office (1994) record white tin production consistent with the reported Cornish production dating back to the 1150s. Although, tin was subject to tax and susceptible to fraud in reporting, the economic historians agree (Chapter 6.4.2, 6.4.3) that the stannary administration was quite efficient.

Apart from tin's particular longevity which was essential for the spectral analysis approach undertaken in the thesis, another major advantage to incorporating tin as the main data series is tin's ever-changing utilisation. Tin's flexibility and widespread use ensured its *continued production* and use from medieval times until the present day, (Chapter 6.4.4). Tin combined with other minerals produced new materials varying from pewter, to bronze to tin-plating, with their very varied spectrum of uses. Tin's enduring usage covers the household, the Church, the building industry for both construction use and decorative purposes, glass production, and warfare. Tin's flexible production method ensured operating costs were variable to the economic period, so during a recessive phase, the operating costs could be kept to a minimum via the unique labour system of subcontracting to tributers and tutworkers (Chapter 6.4.4.).

Although, tin's flexibility as a primary raw material in usage has contributed to it being an approximation for the general economic environment, it is only an approximation. The patterns in the raw data series for tin were visually examined for the main troughs and peaks from the 1150s to the 1990s and were found to be somewhat reflective of the prevailing general economic phase, as indicated by the historical reporting of the period in socio-economic literature, however, with less coincidence of trough/peak phasing from the 1850s . Although, some of the turning points were only 1-2 years different in the tin raw material peak/trough to the consensus date attributed for the phase by economic historians. There is some correspondence in the patterns between the tin raw data series and historical phasing which confirms the tin data as an approximation for the changing general economy, (Chapter 6.4.5 and Table 6.2), over such a very long period (837 years).

Other matters regarding the approach in the thesis is that the problems were handled by taking a different attitude to other long cycle studies in the following ways. This hypothesis statement is falsifiable, satisfying Popper's falsificationist theory: the hypothesis for the thesis is that long cycles of 48-60 years, known as Kondratieffs, do not exist. The methodology is different to other long cycle studies in the modelling of the long data by taking a heuristic approach. The core assumptions provide the model's negative heuristic, assumptions central to the model, and remain fundamentally unchanged over the modelling across the data series. The model's positive heuristic is formed by auxiliary assumptions which are sufficiently flexible to facilitate the working of the model, but not so flexible as to distort it. This is crucial in the trend elimination, (Chapter 5).

Granger (1986, 1971) identified the problem in cyclical investigation as the mixture of regularity and non-regularity in fluctuations:

> *"that has provided the main difficulty in econometric model building and in statistically describing (and thus analysing) economic series."*
>
> *Granger (1971) p 17*

Thus the trend elimination in the first stage modelling needed to retain as much information as possible, yet produce series with reduced hetereoscedasticity ready for the second stage spectral analysis, (Chapter 7). Thus, the starting point for the detrending modelling was to log transform the raw data, a technique useful in maintaining the essential *low* frequencies in the investigation of long cycles in the data. Then, the logged data was subjected to regression analysis which was the preferred method over other averaging processes such as filters and weights for smoothing, because too much flexibility could lend the approach to no longer being falsifiable and the potential arises to engineer or remove cycles. An accusation Kondratieff himself faced, as have other theorists. The trend elimination stage was facilitated by the choice of non-price data, so no price effects had to be removed.

The raw data provided a number of detrended model variations of reduced hetereoscedasticity for the second stage spectral analysis because the detrending process produced a log transformed series, a Basic (Homoscedastic Approximation) model and in the case of the tin time series, two Hetereoscedasticity-reduced models, one over 300-year and the other over 150-year steps. The length of the time series allowed additional detrended residuals for the later spectral analysis in the cyclical investigation. The variations of the regressed residuals was a useful first stage detrending technique to aid the assessment given the problem of regularity and non-regularity in cyclical fluctuations. The robustness of the Basic (Homoscedastic Approximation) and Hetereoscedasticity-reduced model variations was tested on the tin data (Chapter 7.3.6), but the same methodology for the first stage detrending modelling was similarly applied to the associated time series also used, for population and war (battle fatalities). The mean and variance in each model variation of the detrended process are shown over 25-year blocs, moving closer to zero over the whole period of the data, (Tables 7.8, 7.9 and 7.10) with the 1850s onwards being the weakest period of all for weak stationarity being achieved, across all the models. The Heteroscedasticity-reduced Model Stepped-150 years is the strongest model to achieve weak stationarity, comparative to the first detrending via the Log Transformation model. The first stage detrending modelling did not necessarily need to achieve *complete* stationarity strict condition in the data for two very important reasons. Firstly, Granger (1986, 1971) and Kendall (1983, 1968), similarly asserted that although "visible trends" should be removed:

> *"one need not worry about a slight trend existing in the data that one has missed (or that an important trend has not been entirely removed)."*
>
> *Granger p 192*

This was because achieving complete stationarity in economic data was so fraught with difficulty because of the combination in economic data of regulariy and non-regularity, compared to the regularity of data in the physical sciences, that it was not such an essential pre-requisite when further modelling the data.

Secondly, the choice of technique in the second stage modelling in the thesis, that of spectral analysis. The attested ability of spectral analysis to cope with data with some unresolved trend ideally suited the technique for the modelling of cyclical fluctuations. The problem of trend elimination therefore becomes one of reducing the obvious visible trend in the data, because the smoothing of the residual peaks can be handled in the spectral analysis via the kernel window modelling.

Spectral analysis provides a mathematically convenient approach to the problem of regularity and non-regularity in economic data when investigating cycles. It is very likely that economic data contains fluctuations which vary with duration and amplitude even if there is some average cycle or fluctuation present in the data. The spectral approach essentially describes the fluctuations in economic data by generalising this idea, moving from a sum of sine terms to an integral of a sine function over a band of periods. Although, spectral analysis was originally designed for continuous and strictly periodic functions of time, as per the physical sciences, the great advantage of the spectral approach is its facility to identify within the spectrum, a band of periods. As long as, of course, the data is of sufficient length, covering 7-10 potential cycle lengths.

The detrended models in the different stages of homoscedasticity provided variations for spectral analysis, and allowed bands of periods to come into view in the spectrum. Thus cyclical periods became clearer as the spectral analysis modelled and worked through the variations from log transformation through to the Heteroscedaticity-reduced ones. Further, because spectral analysis allows for weak stationarity in the data, the peaks in the spectrum are resolved through the bandwidth estimator in the spectral windows. Generally, each data series of tin, population and war in their various hetereoscedasticity reduced stages were spectral modelled in kernel windows ranging from 3 to 11, for both the rectangular and the triangular form, (Chapter 8). The essential feature of spectral analysis means that as the bandwidth of the kernel or spectral window increases, more spectral ordinates are averaged, and so the resulting estimator becomes smoother, more stable with smaller variance but with less resolution in the spectrum. The drawback is that the bias increases because more and more spectral ordinates are used in the smoothing procedure thereby lowering the peak in the power spectrum, resulting in some cyclical fluctuations being smoothed out. However, a narrower bandwidth can produce a higher resolution but less stability. So the choice of spectral window has to balance a compromise between variance reduction and high resolution or high stability. It really depends on visually examining the graph of the power spectrum produced from that particular window, to judge whether there is too little or too much information on band periods being conveyed. The wider the peak seen in the spectrum, then the wider the range of the cyclical period, so where too much information in the form of many minor peaks is seen, a choice of kernel window to give a wider peak, pulling the minor ones together can be more informative, by conveying a cyclical *range* rather than attempting to identify a single peak, that is, a single cycle there. Or, viewing the spectrum for any confirming harmonics (multiples of the first peak) gives more confidence to the length or range of the first peak, the cyclical fluctuation identified. Thus, although the findings produced a cycle of 26 years, the cyclical range is in a frequency band of 23/33 years.

Spectral analysis has not been systematically applied to date, on economic data in cyclical investigation for a number of reasons. Reasons for example, because of spectral analysis's identification as a technique generally applied in the physical and not the social sciences. Also, it is quite a technical approach to analysis and so has yet to gain widespread favour with social scientists. Further, the data handling power has been a problem in the past in that, normally, spectral programs, because of the memory and space required during the analysis, were only available on mainframe computers. But with the advances in computer power for pcs (portable computers), analyses can now be carried out, away from the mainframes - one estimate for the number of computations required for a data length of 400 (my longest data run was

837) was almost one-quarter of a million calculations (Wei 1993), and which is now significantly reduced by the fast fourier transform contained in most spectral program these days. Thus, spectral analysis is now within the reach of ordinary researchers. However, it is a technique which still requires *very* long runs of data, which is generally a data length of about 10 times the potential cycle under investigation, which is still a hindrance to long cycle research.

A final advantage which shows the flexibility of spectral analysis as such a valuable tool in the modelling of long cycles over the frequency domain, is in the interpretation of the empirical findings. Spectral analysis, apart from allowing for periodicity in the empirical findings does not require the specification of any predisposed or particular cycle length having to be made in advance. Such an approach has the added advantage of allowing an induced observation to be made regarding any ***unexpected*** cyclical findings, for later and further research.

The research methodology review carried out in this thesis identified the problem of scientific-seeing and the modelling of the representation of reality in evaluating the spectral data, (Chapter 4). This acknowledges Hanson's (1969) sense-datum and Papineau's (1979) under- and over-definition of terms. The problem was handled by limiting the evaluation of cyclical findings in the following terms only: Powerfully strong, Strong, Medium, Weak, very weak and zero for no findings, (Chapter 5). This ensures that the interpretation and identification of fluctuations in the power spectrums is made in a consistent fashion within a single data series, and to allow comparability of terms across the series, (Chapter 8). The positive heuristic of the model allows for the relative strengths of the descriptive findings to vary however across the series. The negative heuristic of banding the empirical results across the data series allows frequency ranges to come into view in order to identify a cycle range.

9.2 The conclusion overall

The initial hypothesis for the spectral modelling of the long empirical data, given the inconclusiveness of the literature review, was that:

Kondratieffs at 48-60 year cycles, do not exist.

The spectral findings in the tin data, a time series of 837 years, generally does not support the hypothesis. Although cycles of 48-60 years are not consistently found, they cannot be totally dismissed, because there are some *Weak* findings in the range, around 47-56 years. Longer than the Kondratieff range of 48-60 years, there is a modest *Medium* finding of a long fluctuation centred on 76 years, shifting to 64 years in the heteroscedasticity-reduced models. However, there is slightly more support in the findings for shorter long cycles of 30-33 years, a *Medium* finding.

The hypothesis of no Kondratieffs is not supported by the war data either. The findings for Kondratieff cycles are more strongly found than in the tin data, a frequency *Powerfully to Strongly* is centred at 55 years, ranging 55-63 years overall but also 47-55 years and up to 71 years is identified. Additionally, the war finding of 55 years, based on Levy's data (1983) as adjusted by Goldstein (1988) concurs with Goldstein's cyclical effect, albeit with a 5-year difference. The war finding similarly upholds Wright's (1965) 50-year finding. However, the spectral findings of the population data supports the hypothesis of no Kondratieff cycles.

However, a *more consistent frequency range* than the Kondratieff type is found centred at 26 years across the time series data, in varying strengths. This frequency is longer than the cycle postulated by Kuznets of 22-23 years. In the tin data, the finding ranges around 23-29 years at *Medium* strength, shifting from 27/29 in Subset1, to 23/27 in Subset2 and 26/29 years in Subset3 (Weak to Medium). This is similarly supported in tin's heteroscedasticity-reduced models at a 27-29 years finding. The war data also has stronger findings than Kondratieffs to support a more persistent cycle of 26 years, ranging 23/26-29/33, a *Medium to Strong* finding. The population which showed the weakest cyclical findings of all, supports a *Medium* fluctuation relatively, centred at

25-26 years, but shifting to 22-23 years particularly, 23-27 and 26-30 years. But there are also ***Medium to Weak*** ones around 18/19-19/22 years, centred at 20.5-21.5 years.

Another frequency found consistently across the empirical data are some medium-term cycles, around the 12/14-18 year range. These range from ***Weak***, to ***Medium*** to ***Strong*** in the tin data, but they are consistently found, although they seem to slow down to 12-13 years after the 1750s. The heteroscedasticity-reduced models centre the frequency in the band 12.5-14 years. The war data similarly finds a 13 year frequency, ranging 12-17 years which again is more slightly persistent than Kondratieffs. The population data also confirms very weak fluctuations around 12-13 and 11 years.

To sum up, the hypothesis that Kondratieff cycles ***do not exist***, is not supported. The primary mission of the research was to resolve the existence of long Kondratieff-type cycles, however although such cycles cannot be dismissed, they are not really strongly evidenced across all the data. The data adopted are only approximations of the significant peaks and troughs indicated in the socio-economic data via historical phasing. So Kondratieffs evidenced in the thesis data cannot be applied as a *reliable* predictor of *general* economic change as commodity analysts imply. However, there is still some useful application as an *approximate* predictor. Thus, when commodity analysts refer to a seasonal cycle being adversely or favourably affected by a long Kondratieff-type cycle, then this is not an unreasonable assertion for those commodities particularly associated with warfare and metals. However, a demographic economist would be better to note the first harmonic of a Kondratieff, a long-intermediate cycle, 26 years.

Although the research centred on long cycles, long-intermediate cycles were generally identified in the literature associated with the construction industry and/or generational population changes (sometimes referred to as Kuznets). The spectral analysis undertaken in the thesis has valuably allowed the findings in the long cycle research to make an *induced observation*, this is, to identify more support for a fluctuation centred at 26 years, a long-intermediate cycle. However, to apply a 26 year cycle as a reliable predictor is not thought to be especially useful because there is some deviation in the range 23-33 years. Whether the 26 year cycle is a fluctuation in its own right, or the first harmonic of the weakly found Kondratieffs, the implication is still the same to analysts. Thus, demographic economists and commodity analysts associated with the construction industry, and metal commodities, can look for a change in the economic condition affecting their seasonal variations, on average every 26 years, although potentially occurring within 23 years, can be looked for within 33 years, of the last economic change.

The shortcomings to the findings are discussed in the following section.

9.3 The shortcomings to the conclusion

This thesis has drawn on other than Kondratieff's data, and the data adopted represents only approximations to the significant peaks and troughs indicated in the socio-economic data via historical phasing, and which has less coincidence in historical phase movements from the 1850s. A rational framework has modelled the long data, and fluctuations in the power spectrums have been identified in a consistent fashion across the time series. However, the trend elimination in the time series could have been carried out in a number of different ways, through filters of varying types and weights, or through a polynomial model allowing a choice of degrees in the least squares fitting of the trend. Such methods offer more flexibility and potentially better fits, but the medium-term cycles would potentially be eliminated or smudged and there would be a lack of consistency in any potentially emerging long cycles. The filters offered too much flexibility and regression analysis, it was felt, more consistency.

The conclusion regarding the 26 year cycle could be said to have been reached by inductive reasoning, in that no theory was hypothesised at the beginning for a 26 year cycle. There was no preconception to look for a 26 year cycle, this is an observation statement induced by the evaluation of the results. However, this conclusion is not unassailable. It would not be especially useful as a reliable predictor because the range from which the observation was induced was so broad, 23-33 years. It has been identified at differing strengths across the data used here, but cannot be legitimately inferred across all economic life. In assessing the degree of corroboration of a 26 year cycle, it will increase with the number of corroborating instances. Its usefulness may be that of a general inference, given past experience, that if there has been no cyclical change after 33 years, one may be looked for, although such change may potentially occur within 23 years of the last cyclical economic change.

Another problem in the conclusion is that of semantics, particularly the observation language and theoretical terms being overdefined by multiple definitions which has had to be weighed against the alternative of fixing the meaning of all terms. The preference though has been for Papineau (1979)'s philosophy which is not to fix all terms because as he argues:

> *"This would fragment into a multitude of distinct generalizations,"*
>
> *Papineau (1979) p 9*

On the one hand, the rationally identified fluctuations in the power spectrums are defined in terms of *Powerfully strong, Strong, Medium, Weak and very weak.* This has necessarily been evaluated relatively within in each dataset. The war and tin data provided stronger observations than the population data, thus expressions needed to be identified relatively within the individual data results in order for a sensible evaluation of the spectral results. On the other hand, in the physical interpretation of the fluctuations in the spectral density estimates there has necessarily been some subjectivity.

Drawing on the falsificationist school to evaluate the spectral results has helped by drawing the spectral results together in some ordered bandwidth for the frequencies. Hanson's (1969) "sense-datum theory" recognises the *awareness* in making sense of the observations. An awareness, not a preconception though. Thus, peaks in the data spectrums at varying degrees, for example, at frequencies equivalent to 22, 23, 25, 26, 27, 29, 30, 31 and 33 years. In drawing the individual peaks together to form a range, then an overall impression is gained. From that, relative differing strengths in the power spectrums can be identified and interpreted in smaller bands at 23-25 years, 23-27 years, 26-30 years etc. The intention being to set some context in order to see and interpret the results in a meaningful way, but not in a preconceived way. However, Hanson's "theory-laden" seeing reminds me that:

> *"Nor is it any wonder that our statements so often fit the facts. They were made for each other."*
>
> *Hanson (1969) page 185*

However, advancements are made by finding order where there is some difficulty in such a situation as this, where other long cycle theorists have arrived at inconclusive or contradictory findings. City practitioners like commodity advisors refer to the practical impact of long cycles as if they are real, when they have only been inconclusively theorised. Long-term technical analysis in the 1990s is spreading in popularity, even into areas traditionally viewed as short-term cyclical investigation, for example, forecasting exchange rates, where long-term waves are looked for in underlying the floating exchange rates, without necessarily identifying any underlying causal mechanism. This thesis, by delving into the facts, that is, the spectral results, for data series which are only approximations of the changing economic environment, namely, tin production and war (battle fatalities), and population, then some Kondratieffs are evidenced in the first two but not in the last series. However more strongly than that, something else, a 26-year fluctuation is found, albeit with some deviancy in all the data series.

9.4 The future

Future research potential is identified, firstly, in obtaining further corroborative evidence of a 26 year cycle; secondly, the underlying causal mechanism could be hypothesised given any further evidence found, and so investigated, and identified; thirdly, if the underlying causal mechanism could reliably be identified, then a more predictive framework could be modelled rather than relying on a somwhat approximate predictor. These are now discussed in more detail.

Firstly, although the research centred on long cycles, the spectral analysis approach has allowed an important induced observation regarding a long-intermediate cycle of 26 years to be made. Whether the 26 year cycle is a fluctuation in its own right, or the first harmonic of the weakly found Kondratieffs, the implication to analysts is thus: demographic economists and commodity analysts associated with the construction industry, and metal commodities, can look for a change in the economic condition somewhere between every 23 to 33 years, averaging every 26 years, which will affect their customary seasonal variations.

Further research on the claim of 26 year cycle can be undertaken in order to falsify or corroborate it. As Feyerbend (1970) argues:

> *"Different experimenters are liable to make different errors and it usually needs considerable time before all experiments are brought to a common denominator."*
>
> *Feyerbend (1970) p 204*

However, to undertake corroboration of the finding, more very long time series have to be gathered or identified. If a sufficient number of very long time series are identified, and display a characteristic 26 year cycle, then further modelling could be undertaken for leads and lags in the data to see if there is any synchronicity across socio-economic data which displays such a characteristic fluctuation. This may aid the further research into identifying the underlying causal mechanism. The data gathered should be non-price data preferably, but given the problem of identifying data of longevity, allow the drawing in of some value and price data. The value and price data will likely require a different approach to the first stage trend elimination, but the problem of filters should still be uppermost in the researcher's mind regarding the potentiality to engineer or remove cycles.

Further, very recently, chaos theorists at New York University also mooted an unsubstantiated and as yet, unpublished, 26 year cycle and this development needs monitoring in the future. Therefore, the initial focus of future research should look for corroborative evidence of the 26 year cycle and which is going to particularly require the development and/or identification of more very long data series for spectral modelling. The spectral approach offers such flexibility to social scientists prepared to adopt the technique, that it is worth exploring and developing long data runs.

Secondly, Kondratieff postulated and empirically found a long cycle, but provided no explanation regarding any causal affect. Similarly, the 26 year cycle cannot readily be identified in nature, apart from the unsubstantiated chaos finding. The 26 year movement is not a regularly occurring one, which would help in the attribution of the underpinning causal mechanism, the fluctuation ranges 23-33 years. But the induced observation of such a frequency lends itself to further research, as Popper would argue, it contains sufficient informative content to be made falsifiable by making its definite claim. The physicist Eddington argued in reference to making claims without the causal affects being yet identified:

> *"some of the greatest triumphs of physical prediction have been furnished by admittedly statistical laws which do not rest upon a basis of causality."*
>
> *Eddington "The Nature of the Physical World", p 298*

Then again, Chalmers (1982) referring to bold conjectures which prove later to be falsifiable states:

> *"all that is learnt is that yet another crazy idea has been proved wrong."*
> *Chalmers (1982) p 55*

Lakatos's view is that all theories are equally conjectural:

> *"Science cannot prove any theory .... it can disprove "*
> *Lakatos (1974, 1978) p 96*

Thirdly, with the identification of the underlying causal mechanism(s), then a more reliable predictive framework could be modelled for analysts rather than a somewhat approximate predictor or indicator, of an economic change every 26 years or at most within 33 years, thereby affecting any general seasonal variations. However, as already referred to (p 9.16), some technical analysts are seemingly less concerned with identifying the underlying *theory* or *causality* (Eiteman, Stonehill & Moffet (1995))[2]. As long as long-term movements are identifiable, characterised as up and down trends under say, floating exchange rates, then the long-term estimate is still useful. For example, for the analyst's client such as a multinational corporation, planning (long-term) direct foreign investment, or proposing to raise long-term foreign-denominated funds. It is sufficient that a long-term movement underlying the shorter-term rates is estimated, for long-term planning purposes only.

With the increased interest in long-term technical analysis, and in areas traditionally associated only with shorter cycles, the underlying causal mechanism of the long-intermediate cycle has more hope of being identified with the future research of further corroborative evidence in other data series. Thereby producing a predictor with some reliability rather than an approximator.

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[2] "Multinational Business Finance" pp132-133.

BIBLIOGRAPHY

Akerman, Johan (1932), "Economic Progress and Economic Crises" (1932, reprinted 1979), Porcupine Press, Philadelphia.

American Economic Association (1944), "Readings in Business Cycle Theory", The Blakiston Company.

American Economic Association (1966), "Readings in Business Cycles", George Allen & Unwin Ltd, London

Annual Abstract of Statistics (1939-93), Central Statistical Office sourced from Dept of Trade & Industry, Table for Non-ferrous Metals- Tin Ore (Metal Contents) Production, white tin. The Newport Central Statistical Office provided the updated 1991, and 1992 figures.

Ashton, T S (1955), "An Economic History of England: the 18th Century", Methuen & Co. Ltd, London.

Ashton, T S (1959), "Economic Fluctuations in England 1700-1800", Oxford at the Clarendon Press.

Ashton, T S (1966), "The Industrial Revolution 1760-1830", Oxford University Press.

Baker, A R H (1966), "Evidence in the Nonarum Inquisitiones of contracting arable lands in England during the early fourteenth century", Economic History Review, 2nd ser, **19**. Cited by Miller & Hatcher (1978).

Baker, R (1976), "New and Improved - Inventors and Inventions that have changed the Modern World", British Museum Publications Ltd.

Bazeley, M L (1921), "The extent of the Royal Forest in the thirteenth century", Transaction of the Royal Historical Society, 4th Ser, **4**.

BBC (1988), "Inside Science", BBC Books.

Bechtel, William (1988), "Philosophy of Science - An Overview for Cognitive Science", Lawrence Erlbaum Associates, Publishers, New Jersey, Hove & London.

Bernstein, E M (1940), "War and the Pattern of Business Cycles", American Economic Review, **30**, pp 524-535.

Beveridge, W A (1920), "The World's Gold Supply", Review of Economic Statistics, **11** pp 181-184.

Beveridge, W A (1921), "Weather and Harvest Cycles", Economic Journal, December.

Beveridge, W A (1929), "A Statistical Crime of the Seventeenth Century", Journal of Economic and Business History, **I**, No.4, August.

Beveridge, Sir William (1939), "Prices and Wages in England from the Twelfth to the Nineteenth Century", Vol 1, Longmans, Green & Co.

Bogdanov, V (1928), "On the Question of the Regularity of the Historical Evloution of Capitalism" Pod Znamenem Marksizma (June 1928), pp 80-98. Cited by Garvy (1943) p 212, 215.

Brandon, P F (1971), "Demesne arable farming in coastal Sussex during the later

Middle Ages", Agricultural History Review, **19**.

Breach, R W & Hartwell, R M (1972), "British Economy and Society 1870-1970" Oxford University Press.

Broun, J A (1878), Nature, vol xvi, pgs 62-64, p 63. Reprinted in Transactions of the Royal Society of Edinburgh, vol xxvii, pp 563-594.

Brown, Henry Phelps & Hopkins, Sheila V (1981), "A Perspective of Wages and Prices", Methuen & Co. Ltd at Cambridge University Press.

Burt, R (1969), "Cornish Mining: Essays on the organisation of Cornish Mines and the Cornish Mining Economy" ed, David & Charles, Newton Abbot.

Cajori, Florian (1930), "An Historical And Explanatory Appendix" pp 627-680 in Newton's Principia (1947 edn).

Cambridge Illustrated Thesarus of Science & Technology (1985), Cambridge University Press.

Capie, F & Webber, A (1985), "A monetary history of the UK, 1870-1982" Vol **I**, George Allen & Unwin pubrs

Carne, Joseph (1839), "Statistics of the Tin Mines in Cornwall, and of the Consumption of Tin in Great Britain", Journal of the Statistical Society of London, **2**, pp 260-268, Table No.1 Produce of the Tin-Mines of Cornwall in each Year from 1750 to 1837.

Carnap, R (1956), "The Methodological character of Theoretical Concepts" pp 38-76 in Minnesota Studies in the Philosophy of Science" eds Fiegl H & Scriven M, volume **1**. Cited by Feyerabend (1970) in Feyerabend (1978) p 225.

Carrington, R C (1863), "Observations of the Spots on the Sun from November 9th 1853, to March 24th 1863", Williams & Norgate.

Caws, P (1965), "The Philosophy of Science - A Systematic Account", D Van Nostrand Co.Inc.

Chalmers, A F (1982), "What Is This Thing Called Science?", 2nd edn, Open University Press.

Chatfield, C (1989,1992), "The Analysis of Time Series", 4th edn, Chapman & Hall.

Chatterjee, S & Price, B (1977), "Regression Analysis by Example", John Wiley & Sons.

Chowdury, A (1987), "Are causal relationships sensitive to causality tests", Applied Economics, vol **19**, pp 459-465.

Clark J, Freeman C & Soete L (1981-1983), "Long Waves, Inventions and Innovations", based on the Futures article 13, no.**4**, August 1981 of the same name, updated as Chapter 6 in Freeman (1983).

Coleman, D C (1978), "The Economy of England 1450-1750", Oxford University Press.

Cournot, A (1897), "Researches into the Mathematical Principles of the Theory of Wealth", English translation of "Recherches sur les principes mathematiques de la theorie des riches" (1838) Paris.

CPSU: publications of the Communist Party of the Soviet Union:
CPSU (1974a), "The Russian Social Democratic Labour Party : 1898-October 1917", Volume 1, ed. Elwood. English translation of "Resolutions & Decisions of the Communist Party of the Communist Party of the Soviet Union", University of Toronto Press.

CPSU (1974b), "Resolutions of the VII Conference 24-29 April 1917" reported in "The Russian Social Democratic Labour Party : 1898-October 1917", Volume **1**, ed. Elwood, pp 217-226. English translation of "Resolutions & Decisions of the Communist Party of the Communist Party of the Soviet Union", University of Toronto Press.

CPSU (1974c), "Resolutions of the XV Party Congress 2-19 December 1927" reported in "The Early Soviet Period : 1917-1929" Volume **2**, ed. R Gregor (1974) pp 309-337. English translation of "Resolutions & Decisions of the Communist Party of the Communist Party of the Soviet Union", University of Toronto Press.

CPSU (1974d), "Joint Plenum of the Central Committee and Central Control Commission" 16-23 April 1929, meeting in order to prepare for the XVI Party Conference April 1929 reported in "The Early Soviet Period : 1917-1929" Volume **2**, ed. R Gregor, (1974) pp 341-5. English translation of "Resolutions & Decisions of the Communist Party of the Communist Party of the Soviet Union", University of Toronto Press.

CPSU (1974e), "Resolutions of the XVI Party Congress 23-29 April 1929" reported in "The Early Soviet Period : 1917-1929" Volume **2**, ed. R Gregor, (1974) pgs 345-65. English translation of "Resolutions & Decisions of the Communist Party of the

Communist Party of the Soviet Union", University of Toronto Press.

CPSU (1974f), "The Stalin Years : 1929-1953" Volume 3, ed. R McNeal. English translation of "Resolutions & Decisions of the Communist Party of the Communist Party of the Soviet Union", University of Toronto Press.

Crawshay-Williams, Rupert (1957), "Methods And Criteria of Reasoning", Routledge & Kegan Paul, London.

Daily News, 14th January 1879 and 21st September 1885.

Danson, J T (1948), "Periodic changes in the Condition of the People and the Variations in the Prices of the Necessary articles of food", Journal of the Statistical Society, **xi**, pp 101-40.

Deane, P & Cole, W A (1969), "British Economic Growth 1688-1959, Trends and Structure", Cambridge University Press.

Dewey, E R & Mandino, O (1971), "Cycles", Hawthorn Books Inc., New York.

Dupuy, R Ernest & Dupuy, Trevor (1977), "The Encyclopaedia of Military History: from 3500BC to the present", Macdonald and Jane's, London.

Eddington (1930), "The Nature of the Physical World" in Newton's Principia (1947 edn) University of California Press, Berkeley.

English Historical Documents c.500-1042, pp 853-4, the Abbot Aelfric of Eynsham.

Ernle, Lord (1912),(1922),(1961), "English Farming Past and Present" 1st,2nd,6th edns, Heinemann.

Feinstein, C H (1972), "National Income, Expenditure and Output of the United Kingdon 1855-1965", Cambridge University Press.

Feinstein, C H & Pollard S (1988), "Studies in Capital Formation in the United Kingdom 1750-1920", Clarendon Press Oxford.

Feyerabend, Paul K (1975), "Against Method: Outline of An Anarchistic Theory of Knowledge", New Left Books, London.

Feyerabend, Paul K (1970), "Consolations for the Specialist", pp 197-230 in "Criticism And The Growth of Knowledge" (1978), eds Lakatos I & Musgrave A, Cambridge University Press.

Feyerabend, Paul K (1978), in "Criticism And The Growth of Knowledge" (1978), eds Lakatos I & Musgrave A, Cambridge University Press.

Feyerabend, Paul K (1981), "Problems of Empiricism - Philosophy Papers", Volumes **1 & 2**, Cambridge University Press.

Fisher, F J (1965), "Influenza and Inflation in Tudor England", Economic History Review, 2nd Ser. **XVIII.**

Floud, R & McCloskey, D (1981), "The Economic History of Britain Since 1700 (Vol 1. 1700-1860)", Cambridge University Press.

Forrester, J (1978), "Innovation and Economic Change" in Freeman (1983), as Chapter 10.

Forrester, Graham, Senge & Sterman (1983) "Implications for National and Regional Economic Policy" Conference Proceedings on Long Waves, Depression and Innovation, Siena, Florence October 1983 cited by Kleinknecht (1987) p5.

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

Freeman C (1983), "Long Wave in the World Economy", Butterworths.

Freeman C (1986), "Design, Innovation and Long Cycles in Economic Development, ed, Frances Pinter, London.

Fuller, Wayne A (1976), "Introduction to Statistical Time Series", John Wiley Series in Probability & Mathematical Statistics.

Galileo, Paolo Sarpi (1604), x, reprint (1953) Opere, Milano. Cited by Hanson (1961) p 11.

Garvy, George (1943), "Kondratieff's Theory of Long Cycles", Review of Economic Statistics, November 1943, pp 203-220. Reprinted in "Readings in Business Cycles and National Income" ed. Hansen & Clemence, George Allen & Unwin Ltd (1953).

Gayer A D, Rostow W W & Schwartz A J (1975a), "The Growth And Fluctuations of the British Economy 1790-1850", Volumes **I**, The Harvester Press, Brighton.

Gayer A D, Rostow W W & Schwartz A J (1975b), "The Growth And Fluctuations of the British Economy 1790-1850", Volumes **II**, The Harvester Press, Brighton.

Gerzstein, A (1928), "Do Long Waves in Economic Life Exist?" Mirovoe Khoziaistvo i Mirovaia Polotika, vol **III**, No.8/9, pp 3-42 and No 10 pp 13-35. Cited by Garvy (1943) pp 213-215.

Getty, J Arch (1985), "Origins of the Great Purges", Cambridge University Press.

Goldstein, Joshua S (1988), "Long Cycles: Prosperity and War in the Modern Age", Yale University Press.

Granger, C W J & Hatanaka, M (1971), "Spectral Analysis of Economic Time Series", Princeton University Press.

Granger, C W J & Newbold, Paul (1986), "Forecasting Economic Time Series: Economic Theory, Econometrics & Mathematical Economics", 2nd edn, Academic Press.

Granvosky, E (1929), "On the Business Cycle Theory of the Soviet Bourgeois Economists" Vestnik Kommunisticheskoi, vol **30** (6) p94. Cited by Garvy ibid (1943) pp 213-215.

Gras, Norman Scott Brien (1915), "The Evolution of the Corn Market from the Twelfth to the Eighteenth Century" (1915, Harvard University Press, reissued 1967 Russell & Russell New York).

Greenstein, B (1935), "Periodogram Analysis with Special application to Business Failures in the United States 1867-1932", Econometrica, April.

Haberler, Gottfried (1937,1958), "Prosperity and depression" 4th edn, (League of Nations Economic Intelligence Service) George Allen & Unwin Ltd, London.

Hansen, A (1925), "Factors Affecting the Trend of Real Wages", American Economic Review, pp 27-42.

Hansen, A (1951), "Business Cycles and National Income", W W Norton & Co, New York.

Hansen, A H & Clemence, R V (1953), "Readings in Business Cycles and National Income", George Allen & Unwin.

Hanson, N R (1961), "Patterns of Discovery - An Inquiry into the Conceptual Foundations of Science", Cambridge University Press.

Hanson, N R (1969), "Perceptions And Discovery - An Introduction to Scientific Inquiry", Freeman, Cooper & Co., USA.

Harbottle, Thomas B (1904), "Dictionary of Battles from the Earliest Date to the Present Time", London.

Harvey, Andrew C (1993), "Time Series Models", 2nd edn, Harvester Wheatsheaf.

Hatcher, J (1973), "English Tin Production and Trade before 1550", Clarendon Press Oxford, and Appendix A (1198-1549), pp 152-163.

Hedges, E S (1964), "Tin in Social and Economic History", Clarendon Press, Oxford.

Herschel, Sir William (1801), "Philosophical Transactions", **xci**, pp 265-318.

Holmes, G (1970), "The Later Middle Ages 1272-1485", Sphere Books Ltd, London.

Hume, D (1939), "Treatise on Human Nature", Part 3, Dent, London. Cited by Chalmers (1982) p 19.

Hutchinson, T W (1953), "A Review of Economic Doctrines, 1870-1929", Oxford University Press.

Hyde Clark, Dr (1838), in Herapeth's Railway Magazine (1838), a commercial journal-cum-scientific review, published only from May 1835-1840. The publication later became the Railway Magazine, issued from May 1835-1903.

Hyde Clark, Dr (1847), "Physical Economy - a Preliminary Inquiry into the physical Laws governing the Periods of Famines and Panics" Railway Register (1847). Published only from 1844-1847.

Imbert, Gaston (1956) "Des mouvements de longue duree Kondratieff" thesis cited by Goldstein (1988), pp 36-39. Imbert, Gaston (1959) p 86,93 cited by Reijnders (1990) p 87.

Jasny, N (1972) "Soviet Economists of the Twenties-Names to be Remembered", Cambridge University Press.

Jevon, William Stanley (1879), "The Theory of Political Economy", 2nd edn, Macmillan & Co Ltd.

Jevons, W S, (1862), Paper entitled "On the Study of Periodic Commercial Fluctuations",paragraph 4, p 4, presented to British Association, Cambridge University and reported in The Times, 8 October 1862. (Reprinted Jevons 1884, Ch 1).

Jevons, W S, (1875), Paper entitled "The Solar Period and the Price of Corn" presented to British Association, Bristol. (Reprinted Jevons 1884, Chapter VI).

Jevons, W S (1878a), "The Periodicity of commercial Crises and its Physical Explanation" presented to British Association, Dublin, and published in the Journal of the Statistical And Social Inquiry Society of Ireland, Aug 1878, **vii**, pp 334-42.

Jevons, W S (1878b), "Commercial Crises and Sunspots", Nature, November 14th, (1878) **xix**, pp 33-37 and April 1879. Combined in "Nature" as "The Solar Commercial Cycle" **xxvi**, pp 226-8, 6 July 1882. Combined article reprinted in "Papers & Correspondence of W S Jevons" ed. R D Collinson Black, Vol **VII**, pp 108-112, Chapter XIV, Papers on Political Economy, Macmillan Press (1981).

Jevons, W Stanley (1884), "Investigations in currency and finance", Macmillan & Co, London.

Jewkes J, Sawers & Stillerman (1969), "The Sources of Invention" (1969 revised, 1958), Macmillan.

Journal (Royal, after 1827) of the Statistical Society of London, from 1838 (for population, copper, tin).

Juglar, Clement (1851-52), Journal des Economistes, 1851-52, cited in Juglar "Des Crises Commerciales"(1889).

Juglar, Clement (1860,1889), "Des Crises Commerciales", premiere (1860), deuxieme (1889), Librairie Guillaumin et C.

Jung, C G (1986), "The Structure and Dynamics of the Psyche" The Collected Works, Volume **8**, (1977, reprint 1986) Routledge & Kegan Paul.

Kershaw, I (1973), "The Great Famine and Agrarian Crisis in England, 1315-22", **59**, Past and Present.

Keynes, John Maynard (1930), "Treatise on Money", Vol **II**, Harcourt, Brace & Co, New York.

Keynes, John Maynard (1936), "General Theory of Employment, Interest and Money", Harcourt, Brace & Co, New York.

Kindleberger, C P (1989), "Manias, Panics and Crashes - A History of Financial Crises", Macmillan Press Ltd.

Kitchin, Joseph (1923), "Cycles and Trends in Economic Factors" The Review of Economic Statistics, January, pp 10-16.

Kleinknecht, Alfred (1981), "Observations on the Schumpeterian Swarming of Innovations" Futures **13**, no.4, August 1981 and reprinted as Chapter 3 in Freeman (1983).

Kleinknecht, Alfred (1987), "Innovation Patterns in Crisis and Prosperity", Macmillan Press.

Kondratieff, N D (1919-22): Other papers on agricultural economics and conjunctures: (1919) "Production and Marketings of Oilseeds in Relation to the Interests of the Peasant Economy, Moscow; (1922a) "The Grain Market and its Regulation during the War and Revolution", Moscow; (1922b) "The World Economy . and its Conjunctures During and After the War", Vologda. Papers cited in Kondratieff (1935) below and Kuznets (1930).

Kondratieff, N D (1924), "The Major Economic Cycles" in the Russian periodical, the Problems of Economic Conditions, (supplement to the Monthly Economic Bulletins of the Conjuncture Institute, Voprosy Conjunktury, Volume I, Issue 1, (1925) pp 28-79. Re-presented in "The Static and the Dynamic View of Economics" Quarterly Journal of Economics, **XXIX**, August 1925, pp 575-583. The original based on 1924 investigations, initially verbally presented, and from which the well-known 1925 paper was developed.

Kondratieff, N D (1925), "The Major Economic Cycles" in the Russian Periodical, The Problems of Economic Conditions, (supplement to the Monthly Economic Bulletins of the Conjuncture Institute, Voprosy Conjunktury, Volume I, Issue I, (1925) pgs 28-79. The 1925 results which are translated in German in 1926:

Kondratieff, N D (1926), "Die Lange Wellen der Konjunktur", Archiv fur Sozialwissenschaft und Sozialpolitik,(Archives of Sociology & Social Legislation) **56**, heft 3, December (1926), pp 573-609.). Then into English in 1935:

Kondratieff, N D (1935) refers to (1935/25), "The Long Waves in Economic Life", Review of Economic Statistics, **XVII**, no.6, November 1935, pages 105-115. Translated from German by W F Stolper, Harvard. Reprinted Readings In Business Cycle Theory, Selected by a Committee of The American Economic Association, (1944) Blakiston Company, pages 20 -42. Reprinted later in Lloyds Bank Review, July 1978, No.129, pages 41-60. The 1935-of-1925 results paper. The best known paper in the West.

Kondratieff, N D (1927), "Plan and Perspective" No2.(1927) and "Critical Remarks on the Plan for the Development of the National Economy" No.3 (1927) translated in Spulber (ed) pgs 438-451.

Kondratieff, N D & Oparin, D T (1928) refers to (1928/26), "Major Cycles of Conjuncture", Moscow, Ranion 1928. The 1928-of-1926 results paper. Part of this is translated into English in 1984:

Kondratieff, N D (1984), "The Long Wave Cycle" (1984), Richardson & Snyder, New York. English translation by Guy Daniels extracting 1928-of-1926 results paper.

Kondratieff, N D (1928b), "Dynamics of Industrial and Agricultural Prices" in Voprosy Conjunktury, **IV**, 1928, pages 5-85. German translation in Archiv fur Sozialwissenschaft und Sozialpolitik, Vol 60, (1928), pgs 1-85. The final 1928 paper.

Krige, J (1980), "Science, Revolution and Discontinuity" (1980) Harvester Press, Sussex.

Kuhn, T S (1970), "The Structure of Scientific Revolutions", University of Chicago Press.

Kuznets, Simon S (1930), "Secular Movements in Production and Prices - Their Nature and Their Bearing Upon Cyclical Fluctuations" (1930) Boston: Houghton Mifflin Co., (The Riverside Press) and reprinted 1967 by Augustus M Kelley, New York.

Kuznets, Simon S (1940), "Schumpeter's Business Cycles" (1940) American Economic Review, **30**, no.2 pp 257-71.

Kuznets, S S (1974), "Technological Innovations and Economic Growth" reprinted in Kuznets's "Growth, Population and Income Distribution" (1979),pp 56-99, W W Norton & Co.

Kuznets, S S (1979), "Growth, Population, and Income Distribution", W W Norton & Co.

Lakatos, Imre & Musgrave, Alan (1978a), "Criticism And The Growth of Knowledge", eds, Cambridge University Press. Reprinted and revised 1974 edn.

Lakatos, Imre (1978b), "Falsification and the Methodology of Scientific Research Programmes", pp 91-196 in "Criticism And The Growth of Knowledge" (1978) Cambridge University Press.

Lakatos, Imre (1978c), "The Methodology of Scientific Research Programmes", ed. Worrall J & Currie G, (1978) Cambridge University Press.

Lancaster, H O (1990), "Expectations of Life - A study in the Demography, Statistics and History of World Mortality", Springer-Verlag, London-New York.

Lemon, Sir Charles (1838), "The Statistics of the Copper Mines of Cornwall", Journal of the Statistical Society of London, **1**, pp 65-84.

Lenin, V I (1917), "Imperialism, the Highest Stage of Capitalism" in H M Christman's (ed) "Essential Works of Lenin" (1966), Bantam Books, pp 177-270.

Levy, Jack S (1983), "War in the Modern Great Power System, 1495-1975", University Press of Kentucky.

Lewis, G R (1903), "The Stannaries: A Study of the Medieval Tin Miners of Devon & Cornwall", Harvard Economic Studies, iii, Cambridge, Mass, Appendix J (1553-1749).

Link, R G (1959), "English theories of economic fluctuations 1815-1848", Columbia University Press.

Lovell, M C (1975), "Macroeconomics: Measurement, Theory & Policy", John Wiley, pp 450-456.

Loyn, H R (1977), "Anglo-Saxon England and the Norman Conquest", Longman Group Ltd, pp 92-7.

Luard, Evan (1986), "War in International Society- A study in International Sociology", IB Tauris & Co.Ltd, London.

McKeown, T (1976), "The modern rise of population", London.

MacFarlane, A (1970), "The Family Life of Ralph Josselin", Cambridge.

Mahdavi, K B (1972), "Technological Innovation. An Efficiency Investigation", Beckmans, Stockholm cited by Kleinknecht (1981).

Mandel, E (1980), "Long Waves of Capitalist Development - The Marxist interpretation", Cambridge University Press.

Matthews R C O, Feinstein C H & Odling-Smee J C (1982), "British Economic Growth 1856-1973", Clarendon Press.

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

Michelson, N F (1990), "Tables of Planetary Phenomena", ACS Publications Inc.

Miller, E & Hatcher, J (1978), "Medieval England - Rural Society and Economic Change 1086-1348", Longman Group Ltd.

Mills, J S (1868), "On Credit Cycles, and Origin of Commercial Panics" Transactions of the Manchester Statistical Society 1867-8, pp 5-40 referred to by Jevons (1884) p215.

Milyutin (1930), "On Counter-revolutionary sabotage in Agriculture", Paper presented to the Agrarian Institute of the Communist Party, October 1930, p9. (Kondrat'evshcina - The Collection of Reports and Speeches of the Communist Party's Agrarian Institute, 1 October 1930).

Miskimin, H A (1964), "Monetary Movements in the fourteenth and fifteenth-century England", Journal of Economic History, **24**.

Mitchell, Wesley C (1951), "What happens during business cycles", National Bureau of Economic Research.

Mitchell, Wesley C (1941,1959), "Business Cycles and Their Causes" (1941, 1959), National Bureau of Economic Research, University of California Press.

Moore G H (1961), "Business cycle indicators", Vol I, National Bureau of Economic Research, Princeton University Press.

Moore, Henry Ludwell (1917), "Forecasting the Yield and the Price of Cotton" (1917, Macmillan, reprinted 1967 by Augustus M Kelley).

Moore, Henry Ludwell (1923), "Generating Economic Cycles", Columbia University.

Moore P (1989), "Sky at night", Harrap.

Motyleff W E (1923), "The Accumulation Theory of Rosa Luxemburg" Vestnik Sotsialisticheskoi Akademii, vol 4, pp 156-57 cited by Garvy ibid (1943) p 212.

National Bureau of Economic Research publication (1951), "Conference on Business Cycles".

Newton, Sir Isaac (1947), "Principia - Sir Isaac's Mathematical Principle of Natural Philosophy and His System of the World" (1686, 1713, 1726). Translation by Andrew Motte (1729), published (1947), University of California Press, Berkeley.

Oman, Charles (1898), "A History of the Art of War- The Middle Ages", Methuen & Co, London.

Oman, Charles (1937), "A History of the Art of War in the Sixteenth Century", New York.

Oxford Readings in Philosophy (1981), "Scientific Revolutions" ed. Hacking I, Oxford University Press.

Pallant, D (1991), "Stock Market Forecasting", Money Management, March, pp 42-45.

Papineau, David (1979), "Theory & Meaning", Clarendon Press, Oxford.

Papineau, David (1987), "Reality & Representation", Basil Blackwell Ltd.

Parvus, A (1896), "Sachsische Arbeiterzeitung" and "Die kapitalistische Produktion und das Proletariat", cited by van Duijn (1983) p 72.

Peters, Edgar E (1991), "Chaos & Order in the Capital Markets", John Wiley & Sons, Inc.

Petty, Sir William (1662), "Treatise on Taxes and Contributions". Reprinted in "The Economic Writings of Sir William Petty" (1899), Vol I, Ch.IV, pp 1-97, Cambridge at the University Press.

Pigou, A C (1927), "Industrial Fluctuations", Macmillan Co., London.

Popper, K R (1980), "The Logic of Scientific Discovery" revised edn, 10th impression, Hutchinson.

Popper, K R (1983), "Realism And The Aim of Science", Hutchinson.

Postan, M M (1950), "Some Evidence of Declining Population in the Later Middle Ages", Economic History Review, 2nd ser, **2**, pp 221-240.

Postan, M M & Titow, J Z (1959), "Heriots and prices on Winchester manors", Economic History Review, 2nd ser, 11.

Postan, M M (1972), "The Medieval Economy and Society: An Economic History of Britain in the Middle Ages", Wiedenfeld & Nicolson.

Price, L L (1891), "West Barbary or Notes on the System of Work and Wages in the Cornish Mines", Oxford University Press. Published in full in Burt (1969) pp 111-206.

Rees, G L (1972), "Britain's Commodity Markets", Paul Elek.

Registrar-General's Statistical Reviews of England & Wales, (1801-1992), "Census of England & Wales", the General Reports and the Decennial Reports on the Census.

Reijnders, J (1990), "Long Waves in Economic Development", Edward Elgar Publishing, London.

Richardson, Lewis F (1960) "Statistics of Deadly Quarrels", London.

Rich, E E & Wilson, C H (1967), "Cambridge Economic History of Europe" eds, iv, Cambridge.

Rose, A (1941), "Wars, Innovations & Long Cycles", American Economic Review, **31**, pp 105-7.

Rostow, W W (1948), "The British Economy of the Nineteenth Century", Oxford Clarendon Press.

Rostow W W (1975), "Kondratieff, Schumpeter and Kuznets: trend periods revisited", Journal of Economic History, **35**, pp 719-53.

Russell, J C (1948), "British Medieval Population", University of New Mexico Press, Albuquerque.

Russell, J C (1961), "Late Ancient & Medieval Population" Transactions of the American Philosophical Society, **48**, part 3 (1958, reprint 1961).

Ryan Bob, Scapens Robert & Theobold Michael (1992), "Research Method And

Methodology in Finance and Accounting", Academic Press Ltd.

Samuelson, P A (1980), "Economics", McGraw-Hill, 11th edn, draws on earlier article "Interactions between the Multiplier Analysis and the Principle of Acceleration" Review of Economics Statistics, (1939), **21**, pp 75-78.

Schumpeter, Joseph A (1939a), "Business Cycles: a theoretical, historical and statistical analysis of the capitalist process", Volume I, McGraw-Hill Book Co.

Schumpeter, Joseph A (1939b), "Business Cycles: a theoretical, historical and statistical analysis of the capitalist process", Volume II, McGraw-Hill Book Co.

Schuster, A (1877), "Nature", May 17th, **xvi**, p 45.

Searle, E (1974), "Lordship and Community: Battle Abbey and its banlieu", Toronto, cited in Miller & Hatcher (1978).

Shearer, Peter (1994), "Business Forecasting and Planning", Prentice Hall.

Sheehan, R G & Grieves, R (1982), "Sunspots and cycles: a test of causation" Southern Economic Journal, January, pp 775-777.

Silberling, N J (1943), "The Dynamics of Business: An Analysis of Trends, Cycles, and Time Relationships in American Economic Activity since 1700 and Their Bearing upon Governmental and Business Policy", McGraw Hill.

Singer, J David & Small, Melvin (1972), "The Wages of War 1816-1965 - A Statistical Handbook", John Wiley & Sons.

Singer, David J & Cusack, Thomas (1982), "Periodicity, Inexorability, and Steermanship in International War", pp 404-422 in Merritt R & Russett B (eds) "From National Development to Global Community" (1982) George Allen & Unwin, London.

Slutsky E (1937), "The Summation of Random Causes as the Source of Cyclic Processes", Econometrica **5**, pp 105-46.

Small, Melvin & Singer, David J (1982), "Resort to Arms", Sage, Beverly Hills.

Solomou, S (1987), "Phases of Economic Growth, 1850-1973", Cambridge University Press.

Solzhenitsyn, A (1974), "Gulag Archipelago 1918-1956", Collins & Harvill Press, Vols I-II.

Solzhenitsyn A (1978), "Gulag Archipelago 1918-1956", Collins & Harvill Press, Vols V-VII.

Sorokin, Pitirim (1937,1933) "Social and Cultural Dynamics: "Fluctuations of Social Relationships, War, and Revolution", vol III (1937) American Book Co., New York)

Soviet Russian Encyclopaedia, (1929), Volume IV, p 133, Moscow.
Soviet Russian Encyclopaedia, (1937), 2nd edn, Volume V, pp 743-4, Moscow.

Stamper, Richard (1994), of the Solar Terrestrial Physics, Rutherford Appleton Laboratory, Didcot (1994 Internet e-mail response to request for sunspot data, providing data for period 1988-1993).

Stillwell, J & Scholten, H J (1989), "Contemporary Research in Population Geography

- A comparison of the UK and the Netherlands", Kluwer Academic Pubrs.

Sukhanov, N (1926), "Long Waves in Economic Life", p 161, cited by Garvy (1943).

Taylor, J (1814), "On the Economy of the Mines of Cornwall and Devon", Transactions of the Geological Society, **12** pp 309-327.

Taylor, J (1837), "On the Economy of Mining", Quarterly Mining Review, **10**, pp 261-272.

Taylor, Stephen (1994), "Modelling Financial Time Series" (1986, reprint 1994) John Wiley & Sons.

Thomson, R J (1907), "An Inquiry into the Rent of Agricultural Land in England and Wales during the Nineteenth Century", **LXX**, Journal of the Royal Statistical Society. Cited by Kondratieff (1928) and Kondratieff (1984) p76.

Thompson, William R (1988), "On Global War: Historical-Structural Approaches to World Politics", University of South Carolina Press.

Thorold Rogers, James E (1882,1876) "A History of Agriculture and Prices in England from the Year after the Oxford Parliament (1259) to the commencement of the Continental War, 1793. Compiled entirely from original and Contemporaneous Records" Oxford at the Clarendon Press Vols I-II (1876), Vols III & IV (1882).

Thorold Rogers, James E (1886), "Work And Wages - Six Centuries of Work and Wages", Swan Sonnenschein & Co., London.

Tinbergen, J & Polak, J J (1950), "The dynamics of business cycles", Routledge &

Kegan Paul Ltd

Tinbergen, J (1981), "Kondratiev Cycles and So-Called Waves", Futures, reprinted in Freeman (1983) as Chapter 2.

Trotsky, L & Varga, Prof E (1921), "The International Situation - A Study of Capitalism in Collapse" (Presented to the Moscow Congress, 1921). English translation published by Communist Party of Great Britain, Covent Garden, London, price 3d.

Trotsky, L (1923), "The Curve of Capitalist Development", in Trotsky's "Problems of Everyday Life" (1973) Monad Press, New York, pp 273-80.

"The World Economy and its Conjunctures During and After the War," Vologda, 1922, in Russian only, p 242 reported in Kuznets S "Secular Movements in Production and Prices" (1930) p 262.

Valentine, L M & Ellis, D F (1991), "Business cycles and forecasting", South-Western Publishing Co, USA.

Van Duijn, J J (1983), "The Long Wave in Economic Life", George Allen & Unwin, London.

Van Gelderen, J (1913) "Springvloed. Beschouwingen over industriele ontwikkeling en prijsbweging", De Nieuwe Tijd, (1913) (pp 253-77/369-84/445-64), p 268. The "Springtide", a monthly review of the Dutch Social-Democrats, cited by various.

Varga, E (1924), "Decline of Capitalism", Communist Party of Great Britain, Covent Garden, London.

Von Ciriacy-Wantrup, S (1936),"Agrarkrisen und Stockungsspannen", Paul Parey, cited by Hansen A (1951) p 65.

Wardwell, C A R (1927), "An Investigation of Economic Data for Major Cycles", Philadelphia, cited by Schumpeter (1939 p 165) and Kuznets (1930 p 265).

Wei, William S (1993), "Time Series Analysis: Univariate & Multivariate Methods", Addison-Wesley Publising Co. Inc.

Wilson, James (1840), "Fluctuations in of Currency, Commerce and Manufacture", pamphlet referred to by Jevons (1884) p 223.

Wittgenstein, Ludwig (1953), "Philosophical Investigations", translation by G Anscombe, Macmillan Press cited in Hanson (1969).

Woodford, M (1987), "Three questions about sunspot equilibria as an explanation of economic fluctuations" American Economic Review, May 1987, Conference Paper pp 93-98.1)

Woods, F & Baltzly, A (1915), "Is War Diminishing? A Study of the Prevalance of War in Europe from 1450 to the Present Day", Boston.

Wright, J N (1991), "Science and the Theory of Rationality", Avebury Academic Publishing Group.

Wright, Quincy (1965), "A Study of War", University of Chicago Press.

Wrigley, E A & Schofield, R S (1981), "The Population History of England 1541-1871", Edward Arnold (for Cambridge Group).