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THE LONG WAVE – A REAL PHENOMENON?

BY

C. VAN EWIJK*

1 INTRODUCTION

Nowadays most economists agree that the downturn in economic growth which started about a decade ago has a structural character. Present economic problems cannot adequately be understood within the narrow framework of the mainly static neoclassical-Keynesian analysis of short-term economic (dis)equilibrium. Therefore a more dynamic theory of the process of economic growth is being sought. To provide such a theoretical framework several authors have reverted to the theory of the long wave. This concept of 40-to 60-year-long business cycle is generally, following Schumpeter, named after the Russian economist, Kondratieff, despite Tinbergen's justifiable reservations.[1]

In The Netherlands the "long wave" tradition was, in recent years, taken up by Broersma, Van Duyn, Van der Zwan[2] and others. In other countries, publications by Mandel, Mensch, Freeman, Rostow[3] and many others testify to an increasing interest in the long wave.

The renewed interest in the Kondratieff cycle is, for a great part, due to actual economic events. For did not the present recession set in approximately fifty years after the great crash of 1929, which started off the severe depression of the 1930s? And did not the rapid expansion after World War II last for some 25 years, the length of half a Kondratieff cycle? It therefore seems worthwhile to take the hypothesis of the long wave seriously and to subject it to an inquiry.

* University of Amsterdam, The Netherlands. I wish to thank W. Driehuis and H.A.A.M. Thoben for their comments on an earlier draft of this article.

1 "The Dutch may perhaps put in some reservations with respect to the name given by Schumpeter to the long waves; these waves were described by two Dutch authors (Van Gelderen and De Wolff) before they were discovered by the Russian economist Kondratieff." Tinbergen and Polak (1950), p. 61.

2 Broersma (1978), Van Duyn (1977, 1979), Van der Zwan (1978).

3 Mandel (1972), Mensch (1979), Freeman (1979), Rostow (1978).

Unlike short business cycles, the long wave has never been generally accepted by economists. In economic textbooks, the Kondratieff cycle is, at best, mentioned as an interesting but unproved curiosity. There are several reasons for this neglect of the long wave. In the first place, none of the supporters of the long wave has succeeded in showing convincingly that the long wave appears not only in prices and monetary variables, but also in real variables. In the second place, the first generation of long-wave authors, De Wolff, Kondratieff, Schumpeter[4] and others, was not able to give a coherent and convincing explanation of the endogenous, cyclical character of the long wave.

Recently, some important contributions to the theory of the long wave have been made by Forrester, Mensch and Rostow.[5] These theoretical contributions will, however, not be discussed here. In Section 3 only the essence of the main theories is given. This article concentrates on the empirical tests of the existence of the long wave. Important contributions on this subject were recently made by Broersma, Van der Zwan, Van Duyn and Van Paridon.[6] These authors, however, come to contradictory conclusions. From an extensive statistical analysis of time-series of real variables, especially series of industrial production, Van Duyn concludes: "The picture . . . is in all respects the one which can be expected if the long wave exists."[7] Also Broersma comes to a positive conclusion: "It appears that most of the variables, which we have investigated, show a wave with a long duration."[8] Van der Zwan, however, states: "The overall picture that can be derived from the statistical testing is one that does not support the hypothesis of a long wave in the Kondratieff sense."[9] Van Paridon shares this negative judgement.[10]

In Section 4 these investigations, as well as the important previous investigations by Kondratieff[11] and Imbert,[12] will be discussed briefly. Then in Section 5 the long wave hypothesis will be subjected to a new statistical test. First, however, we have to discuss the nature and empirical features of the long wave, on the basis of which it should be tested.

4 De Wolff (1929), Kondratieff (1926. 1928, 1935), Schumpeter (1939).
5 Forrester (1977), Mensch (1979), Rostow (1978).
6 Broersma (1978), Van der Zwan (1978), Van Duyn (1979), Van Paridon (1979).
7 Van Duyn (1979), p. 125, (translation CvE).
8 Broersma (1978), p. 128, (translation CvE).
9 Van der Zwan (1978), p. 22.
10 "Er viel een golfbeweging waar te nemen in alle onderzochte landen, die duidelijk niet de regelmaat van een Kondratieff-golf vertoonde," Van Paridon (1979), p. 292.
11 Kondratieff (1926, 1935).
12 Imbert (1959).

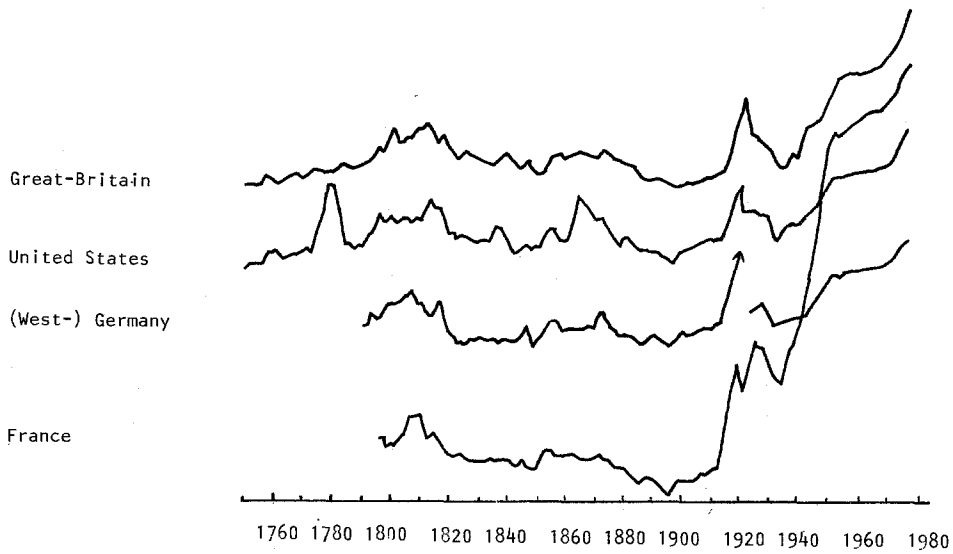

Figure 1 – Wholesale prices in Great Britain, France, (West-)Germany and the United States 1750–1977 (halflog. scale).

Sources: see appendix.

2 THE LONG WAVE IN PRICES AND PRODUCTION

Kondratieff is convinced that economic growth in industrialized countries is characterized by a 40- to 60-year-long cycle. He bases this conviction on the remarkable pattern in time-series of prices during the eighteenth, nineteenth, and the first decades of the twentieth centuries. In Figure 1, price movements from 1750 to the present for the so-called "core-countries" of the industrialized world, Great Britain, France, (West-) Germany and the United States, are shown.

From these price series and some other almost exclusively monetary and nominal series, Kondratieff derives the following periodization of the phases of the long wave[13]:

Peak	1810–1817	1870–1875	1914–1920
Trough	1789–1790	1844–1851	1890–1896

That Kondratieff, like his Dutch forerunners, Van Gelderen and De Wolff,

13 Kondratieff (1935), p. 111.

bases his thesis almost exclusively on price movements does not mean that he considers the long wave to be restricted to the monetary sphere. On the contrary, in his opinion, the long wave is "a factor the effects of which can be found in all the principal fields of social and economic life."[14] Moreover, the ultimate mechanism behind the cycle is in Kondratieff's theory a purely real phenomenon: the periodic re-investment of means of production with a duration of 40 to 60 years. Most well-known long-wave authors share this real conception of the long wave, although they disagree on the ultimate cause of the cycle (see Table 1).

TABLE 1 – CAUSES OF THE LONG WAVE[16]

Author	Cause
De Wolff Kondratieff	Periodic reinvestment of "basic capital" with an average duration of 40 to 60 years.
Schumpeter Mensch	Periodic clusters of basic innovations.
Forrester	Lagged adjustment in production of capital goods.
Rostow	Lagged adjustment in primary production.

Because of lack of statistical data, Kondratieff and other long-wave supporters of the first generation are not able to test the real aspect of the long wave satisfactorily. Kondratieff nevertheless concludes that "on the basis of the available data, the existence of long waves of cyclical character is very probable."[15]

Apparently, he assumes that long movements in prices give a good representation of the long movements in real variables. A solid argumentation for this assumption cannot be found in the publications of any of the well-known long-wave supporters. It seems that it has been directly and uncritically taken from the theory of the normal, short business cycle of that time. With respect to this cycle it is generally assumed that prices and volumes move together in the cycle.[17] Tinbergen states this explicitly: "Cycles in the

14 Kondratieff (1935), p. 115.

15 Kondratieff (1935), p. 115.

16 Other authors also mention periodic recurrence of wars or enlargement of gold- and money-stock as possible causes. See Van Duyn (1979), p. 40.

17 See, e.g., Hablerer (1941), p. 115.

most important economic series are on the whole if not exactly at least approximately simultaneous. This applies in particular to cycles in the general level of prices and in the general level of activity."[18] It is, however, not at all sure or even plausible that this also applies to economic movements of long duration. The theories of the long wave contain many elements which could explain a lagging or even a contrary cycle in prices and volumes. For example, technical progress, which is generally supposed to be more rapid in the upswing than in the downswing of the long wave,[19] causes a tendency of prices to fall in the upswing because of cost reductions owing to faster productivity growth.

In this connection it is worth noting that Rostow, unlike all other long-wave authors, assumes a contrary movement of prices and volumes in the long wave. This emerges from his theory, according to which the downswing of the long wave is characterized by a scarcity of primary products (in the present cycle, especially energy and raw materials), which causes rising prices. This situation is, according to Rostow, caused by neglect of the primary sector during the expansion phase of the cycle.[20]

In order to test the relation between prices and volumes we have made a regression analysis of fluctuations in wholesale prices and industrial production (volume) in the four "core countries" for the period 1750 to 1930. This period roughly corresponds to the observation period of De Wolff, Kondratieff, and Schumpeter. To avoid trend correlation, all series have been transformed into growth rates, computed as first differences of the logarithms of the original data (see Table 2).

Because we are especially interested in the correlation between long movements in prices and production, the regression has also been done for the growth rates of the series after smoothing with a simple nine-year moving average (transformation B) and again after further smoothing of the resulting series by means of a five-year moving average (transformation C).

It is remarkable that the coefficients of determination (R^2) turn out to be very low for almost every regression. This indicates that in general price movements badly correspond to movements in production. Only in Germany do the fluctuations in prices appear to be to some degree a reflection of the real fluctuations. For the series converted in simple growth rates (transformation A) only a very weak positive correlation is found for each country. For France, this correlation is not even significant. If the dominance of short-

18 Tinbergen and Polak (1950), p. 63.
19 See, e.g., Kondratieff (1935), Schumpeter (1939), Van Duyn (1977, 1979).
20 Rostow (1978), pp. 20–37.

TABLE 2 – A REGRESSION ANALYSIS OF WHOLESALE PRICES (DEPENDENT VARIABLE) AND INDUSTRIAL PRODUCTION

	Transformation	Regression coefficient		Coefficient of determination (R^2)
Great Britain	A	0.24	(0.12)	0.03
1763–1930	B	−0.80	(0.19)	0.11
	C	−1.04	(0.18)	0.18
France	A	0.14	(0.14)	0.01
1828–1930	B	−0.64	(0.23)	0.07
	C	−0.95	(0.27)	0.11
Germany	A	1.89	(0.45)	0.26
1863–1930	B	6.88	(0.82)	0.59
	C	4.06	(0.43)	0.64
United States	A	0.46	(0.16)	0.12
1873–1930	B	0.28	(0.39)	0.01
	C	0.09	(0.46)	0.00

Explanation: The equation $P = a + b \cdot Q$ (P = prices, Q = production) has been estimated for the transformed data by the method of least squares method. Behind the regression coefficients (b) the standard deviation is given between brackets.

Transformation A: rate of growth $\left(Y_t = \ln \frac{X_t}{X_{t-1}}\right)$

Transformation B: rate of growth of 9-year moving averages

$$\left(Y_t' = \ln\left[\sum_{t-4}^{t+4} X_i \Big/ \sum_{t-5}^{t+3} X_i\right]\right)$$

Transformation C: 5 year moving averages of the series resulting from transformation B

$$\left(Y'' = \frac{1}{5}\sum_{t-2}^{t+2} Y_t'\right)$$

Sources: see appendix.

term fluctuations is reduced by means of a moving average (transformations B and C), the correlation for the United States becomes still weaker and for Great Britain and France even *significantly negative* regression coefficients are found.

From this analysis we can conclude that with respect to the long movements, prices are an unreliable mirror of simultaneous movements in production. Therefore price series cannot be used in the way Kondratieff and others did. On the basis of this analysis the possibility cannot be ruled out, however, that fluctuations in prices and production do correspond but with a time-lag. Therefore, we have also made a regression analysis for the smoothed series (transformation B) with several lags, which range from −15 years to +15 years with five-year intervals. This range corresponds to half a Kondratieff cycle. This is long enough to draw a reliable conclusion. The results of this analysis are summarized in Table 3.

The results of this analysis are rather mixed. For Great Britain, the unlagged series produce the highest coefficient of determination (R^2). Again, the correlation for these series turns out to be significantly negative. Also at a production lag of five years a significantly negative correlation is found. In all other cases there is hardly any correlation to be found. For France, significantly positive regression coefficients are found at a production lag of ten years and at price lags of ten and fifteen years. As in Table 2, the unlagged series produce a significantly negative correlation. For each combination of series the correlation is very weak. On the whole no evident lag structure can be inferred from this simple analysis. The results for Germany are in accordance with our earlier assertion that in this country price fluctuations reasonably reflect simultaneous fluctuations in production. The unlagged series produce best regression results: the coefficient of determination is relatively high ($R^2 = 0.65$) and the regression coefficient firmly positive. For the United States, the regression fits best at a production lag of five years. The correlation is significantly negative then. For the unlagged series, as in Table 2, a non-significant positive correlation is found.

On the whole, this analysis confirms our earlier conclusion that prices are a poor mirror of long-term fluctuations in production, even when possible lags are taken into account. Only in Germany do fluctuations in prices and production correspond reasonably well.

These results have important consequences for the statistical analysis of the long wave, for they indicate that movements in prices cannot be used to test the existence of the long wave in real variables. Also periodizations which have been derived from price statistics appear to be of little use for analysis of long-term movements in real economic growth. This conclusion is all the

TABLE 3 – REGRESSION ANALYSIS OF PRICES (P) AND INDUSTRIAL PRODUCTION (Q) WITH VARIOUS TIME LAGS

	Great Britain 1779–1930			France 1844–1930			Germany 1879–1914			United States 1889–1930		
	b		R^2	b		R^2	b		R^2	b		R^2
$P_t \quad Q_{t-15}$	0.00	(0.19)	0.00	1.48	(0.52)	0.08	−0.19	(0.20)	0.02	1.21	(0.47)	0.13
$P_t \quad Q_{t-10}$	0.17	(0.20)	0.00	1.01	(0.42)	0.06	−0.42	(0.20)	0.11	−0.33	(0.49)	0.01
$P_t \quad Q_{t-5}$	−0.16	(0.20)	0.00	−0.59	(0.31)	0.04	0.09	(0.21)	0.01	−0.12	(0.45)	0.00
$P_t \quad Q_t$	−0.79	(0.18)	0.11	−0.83	(0.24)	0.11	1.14	(0.13)	0.65	0.33	(0.44)	0.01
$P_{t-5} \quad Q_t$	−0.45	(0.18)	0.04	0.13	(0.25)	0.00	0.42	(0.22)	0.09	−1.06	(0.36)	0.16
$P_{t-10} Q_t$	−0.03	(0.18)	0.00	0.69	(0.18)	0.14	−0.72	(0.18)	0.29	−0.90	(0.38)	0.11
$P_{t-15} Q_t$	−0.11	(0.12)	0.01	−0.09	(0.09)	0.01	−0.11	(0.23)	0.01	−0.24	(0.26)	0.02

Explanation: All series have been transformed in growth-rates of 9-year moving averages (transformation B). The symbol b is again the regression coefficient (the slope).
These results are not strictly comparable to the results in Table 2 because many observations had to be deleted in order to get comparable results for each country in this table.

Sources: see appendix.

more justified if one realizes that all historical periods of rising prices happen to coincide with periods of war. This was already noticed by Kondratieff and also by Tinbergen: "The first peak comes shortly after the period of the Napoleonic wars, the second after the Franco-German War and the American Civil War, and the third one after the First World War."[21] This coincidence should make us even more suspicious of the foundation of the long wave on prices and monetary variables.[22] For a well-founded judgment about the existence of a long wave, therefore, an investigation of the long movements in real variables is indispensable.

3 TESTING THE LONG WAVE

3.1 *Characteristics of the Long Wave*

Testing the long wave as an empirical phenomenon has to be distinguished from testing the theory of the long wave. In this article we confine ourselves to the first. Not until the empirical existence and features of the long wave have been established can the different theories be put to test meaningfully. In order to be able to test the long wave, the characteristics of this wave should be known. Although there are many different descriptions and definitions of the long wave, the following characteristics are generally accepted:

(a) the long wave is a fairly *regular* sequence of periods of rapid and periods of slow economic growth;
(b) the long wave has a *duration of 40 to 60 years* per cycle;
(c) the long wave is *general*: it manifests itself in monetary- and price variables as well as in real economic variables;
(d) the long wave is *international*: it manifests itself simultaneously in the principal industrialized capitalist economies.

As a fifth generally accepted characteristic may be mentioned the periodization of the long wave by Kondratieff. We shall not test the long wave on this

21 Tinbergen (1950), p. 35.
22 Kondratieff was well aware of this criticism and replied that also the occurrence of wars could be explained by the long wave theory: "Much more probable is the assumption that wars originate in the acceleration of the pace and the increased tension of economic life, in the heightened economic struggle for markets and raw materials." Kondratieff could not foresee that World War II would follow the long recession of the 1920s and 1930s. Kondratieff (1935), p. 113.

characteristic, because we have already shown that this periodization, which is mainly based on prices, is unreliable.

Before presenting our new investigation, we will first discuss some methods and difficulties of statistical analysis of long waves. Next the important investigation by Kondratieff, Imbert, and Van Duyn will be discussed critically.

3.2 *Some Statistical Problems of Testing the Long Wave*

One of the greatest difficulties in testing the Kondratieff cycle is the lack of sufficient statistical data. Because one cycle takes about fifty years, it is necessary to go back far in history to be able to observe several cycles. However, we cannot go back too far, for the Kondratieff cycle is generally held to be restricted to the capitalist, and in any case to the industrialized, economies. To demarcate the observation period we can use the take-off periods of industrial development which have been established by Rostow. For the four "core countries" Rostow suggests the following dates of the "take off"[23]:

Great Britain:	1783–1801
France:	1830–1860
Germany:	1850–1873
United States:	1843–1860

The take-off in Great Britain coincides with the expansion phase of the first Kondratieff cycle. In the other countries, the industrialization did not start until the end of the first cycle and the rising phase of the second. Thus, demarcating the observation period, not more than about four cycles for Great Britain and three cycles for the other countries can be studied. This is hardly sufficient because economic growth in the twentieth century has been strongly dominated by the two World Wars. For that reason we have to be very careful with the use and the interpretation of the statistical data.

The process of economic growth is the resultant of many different cycles, shocks, random fluctuations and secular changes. As will be clear, it is very difficult to isolate one particular cycle out of this complex interaction of forces. The main statistical problems of testing a cycle of a particular length are:

23 Rostow (1971), p. 38.

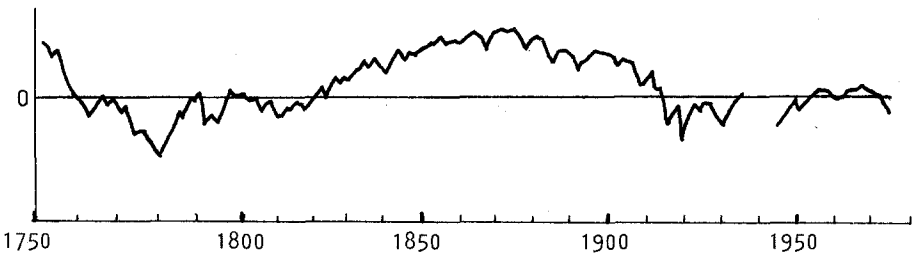

Figure 2 – Industrial production in Great Britain; deviations from a loglinear trend

Explanation: Estimated trend: $\ln y = 16.2 + 0.025t$ $(R^2 = 0.99)$

Sources: see appendix.

(a) how to eliminate the trend and the cycles of longer duration;
(b) how to eliminate short fluctuations and cycles;
(c) how to determine peaks and troughs of the cycle in question.

Ad a: If time series contain a falling or rising trend, cycles will appear as an oscillation around this trend. In case of a rising trend, the variable does not have to decline absolutely in the contraction phase; only growth will be less than in the rising phase. In most cases, it is necessary to eliminate the trend in order to bring out clearly the features of the cycle. Trends can be eliminated in several ways. A very common method is fitting a curve by the method of least squares. The deviations from this trend are then used for further analysis. The form of the curve is completely arbitrary. Unfortunately, the choice of the curve strongly influences the resulting pattern in the deviations. Often a loglinear trend is estimated with the idea that economic growth is constant in the long run. However, this trend seldom gives satisfactory results, because long-term economic growth is not stable at all. This is illustrated in Figure 2, where deviations from a loglinear trend are shown for industrial production in Great Britain. The resulting picture is dominated by short fluctuations and an ultra-long swing around the trend with a duration of more than 100 years. It is impossible to infer from this chart something of the existence of a 50-year-long Kondratieff cycle.

Because of the disappointing results, it is tempting to use other curves. However, if the series are relatively short in comparison with the length of the cycle, the use of other curves is rather dangerous because it can create long movements in the deviations from the trend which were not present in the original series.

The way Kondratieff processes the data concerning coal consumption in France (1830-1910) is a good illustration of this. Kondratieff fits a third-order polynominal to the original series and examines the deviations from this trend after smoothing by means of a 9-year moving average.[24] The deviations are shown in Figure 3 (solid line).

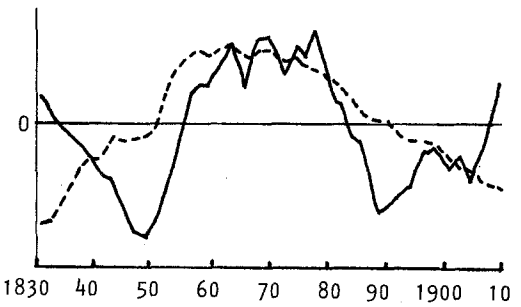

Figure 3 – Consumption of coal in France; deviations from the trend

Explanation: ——— deviations from the third order polynomial:
$y = 539.21 + 15.90t + 0.1326t^2 - 0.00026t^3$
------ deviations from the loglinear trend:
$\ln y = -59.4 + 0.03623t \quad (R^2 = 0.95)$
Both series are smoothed by means of a 9-year moving average. The deviations from the loglinear trend have been computed on the basis of Kondratieff's data.

Source: Kondratieff (1926), pp. 607, 608.

Kondratieff concludes that this series presents a long wave with a trough in 1849, a peak in 1873, a trough in 1896 and again a peak in 1914. This is one of the main proofs in support of the long wave in real variables put forward by Kondratieff. However, when inspecting the original series or the deviations from a loglinear trend (dotted line in Figure 3) nothing remains of the alleged long wave. In the deviations from the loglinear trend no long-term trough appears at all. Only a structural decline in the expansion of coal consumption is found.[25] So the contraction until 1849 and the rise after

24 Kondratieff (1935), p. 109 and Kondratieff (1926), pp. 607, 608.

25 This conclusion is confirmed when average growth per alleged phase is computed for the series after smoothing in the same way as Kondratieff does, with a 9-year moving average. For example average growth in the alleged downward phase 1831–1849 is 5.3% and this is more rapid than growth in the following upward phase (4.7%).

1896 which Kondratieff found should be entirely attributed to his choice of trend curve.

A second common method to eliminate a trend is to transform the series in first differences or relative first differences (rates of growth). This is comparable to eliminating a linear respectively loglinear trend. Without further manipulations, this method proves to be not very useful for investigations of the long wave because short fluctuations mostly dominate longer movements. Hence this method can only be used in combination with some kind of filter which dampens short fluctuations. In Section 5 we will return to this problem.

Ad b: In order to reduce the influence of short fluctuations and cycles, several methods can be used. It is very common to apply a moving average for smoothing the series. This method, however, is not without risks, for it may create waves which were not present in the original series. Adelman and others criticize Kuznets' analysis of the 15- to 30-year "long swing" on this point.[26] To avoid this danger, a short moving average, relative to the length of the cycle under investigation, should be chosen.

A second method to eliminate short cycles is to select comparable observations of each successive short cycle. Usually peaks and/or troughs are chosen. Then longer movements can be established by computing average growth rates between peaks or between troughs of the short cycles. There are several difficulties with respect to this method. First, in most series it is difficult to determine peaks and troughs of one particular cycle, because the economic process consists of many different cycles and irregular movements. If the Kondratieff cycle is investigated, several short cycles are to be eliminated. According to Schumpeter, the following cycles shorter than the Kondratieff cycle can be distinguished: the Kitchin cycle (3 to 4 years), the Juglar cycle (7 to 12 years) and the Kuznets' cycle (15 to 25 years). It is hardly possible to select observations in such a way that all these cycles are eliminated simultaneously. Another difficulty in the method of selecting peaks or troughs is that the number of observations is strongly reduced. That makes this method very liable to statistical errors. In addition to these errors, also errors in the selection of peaks and troughs may have important consequences.

A last method to establish the existence of a cycle with a particular length is spectral analysis. This is statistically the most advanced method, but it has not yet been applied to the Kondratieff wave. From the discussion of applications of spectral analysis to the Kuznets cycle it is apparent that this method requires very long series. According to Soper in his survey of spectral analyses

26 See especially Adelman (1965), pp. 444–463.

of the long ("Kuznets") swing, series of at least ten times the length of the cycle are needed to be able to draw a reliable conclusion about the existence of the cycle.[27] For the Kondratieff cycle only series of three to four cycles are available (see Section 3.2).

Ad c: In order to determine peaks and troughs of a cycle, several difficulties must be overcome. A peak or trough can be defined as the observation which deviates most from the trend in a certain period of time. In determining peaks and troughs especially the following difficulties arise:

(a) Should the maximal deviation be determined before or after smoothing of short fluctuations?
(b) With respect to what trend should the deviations be determined?

For both problems no general theoretically justified solution exists. However, we cannot avoid them. "By refusing to accept peaks and troughs as guides in the determination of cycles, one scorns the help provided by that statistical characteristic of cycles in time series," Kuznets rightly remarked.[28] At the presentation of our new investigation of the long wave in Section 4, we shall return to these problems.

Here we leave it at this brief enumeration of difficulties of statistical testing of the long wave. We do not regard one method as the only right one. In our opinion the best procedure is to use several methods together.

4 PREVIOUS INVESTIGATIONS OF THE LONG WAVE

It is far beyond the scope of this article to give a full discussion of all earlier investigations of the long wave. We will restrict ourselves to a schematic presentation and discussion of the three most important investigations of Kondratieff, Imbert, and Van Duyn respectively.[29] Special attention will be paid to (a) the statistical data, (b) the method, and (c) the conclusions.

4.1 *Kondratieff's Investigation*

(a) Because of the long duration of the cycle in comparison to the available

27 Soper (1975), p. 575.
28 Kuznets (1940), p. 116.
29 An excellent survey of the extensive Russian discussion of the long wave can be found in Garvy (1943). This discussion, however, concentrates on the interpretation of the results of Kondratieff's investigations and the theoretical underpinnings of the long wave.

TABLE 4 – SERIES ANALYSED BY KONDRATIEFF ARRANGED ACCORDING TO LENGTH AND SORT OF VARIABLE

Sort of variable	Length in cycles				Unknown[a]	Total number of series
	2½	2	1½	1		
Nominal, monetary	4	4	3	3	1	15
Real (volume)	–	–	3	8	10	21
Total	4	4	6	11	11	36

[a] Neither Garvy nor Kondratieff give the length of the series in which Kondratieff did not find a long wave.

Source: Garvy (1943), p. 443.

time series, it is important to consider how many series are analyzed and what length these series have (see Table 4). This survey shows that Kondratieff disposes only a few and exclusively nominal and monetary series with reasonable lengths. With respect to the real economic development, the longest series available to Kondratieff are only 1½ cycles long.

(b) If series are dominated by trends, Kondratieff computes deviations from the trend by fitting a trend by the method of least squares. Next, the deviations are inspected for long waves. As far as we know, Kondratieff does not follow a fixed procedure in choosing the specification of the trend curves. In some cases he uses a loglinear trend and in other cases some sort of polynomial. We have already criticized the use of higher order polynomials if the series are relatively short. In paragraph 3.2 we have demonstrated that for this reason his positive conclusion with respect to a long wave in the series of French coal consumption is very questionable.

In order to dampen the short fluctuations, Kondratieff smoothens the deviations from the trend by means of a simple 9-year moving average. In "Long Waves in Economic Life" Kondratieff derives the turning points of the long wave from the smoothed series.[30] In other articles, Kondratieff uses also unsmoothed series for this purpose.[31] Kondratieff does not argue which method is to be preferred: "The problem of the most accurate method for the determination of the maxima and minima would deserve a special analysis; at present we leave this question open."[32]

30 Kondratieff (1935).
31 See Garvy (1943), p. 442.
32 Kondratieff (1935), pp. 109, 110 (footnote).

(c) The results of Kondratieff's investigations, as far as they have been published, support, in his opinion, the existence of a long wave in prices as well as in real variables. We do not disagree with respect to the price wave, but his evidence for the real aspect of the wave can not withstand a critical evaluation; in only 11 out of 21 real series has Kondratieff found a long wave. In addition to this, it should be remembered that all these are very short, which makes his method of trend elimination unreliable. Hence we must conclude that Kondratieff's assertion that the long wave is "very probable" has been argued very weakly.

4.2 *Imbert's Investigation*

(a) The French economist Imbert[33] concentrates especially on statistical testing of the long wave in real variables. For that purpose he analyses 80 time series relating to the real economic development in Belgium, Great Britain, France, Germany, the United States, and some world series, covering a period from 1780 till 1950. Of these series, 13 refer to the general level of production, 33 refer to the volume of production in particular industries, and 34 series refer to agricultural production. Table 5 gives a survey of the length of the series of general industrial production and of the series of production of particular industries. From this table it is evident that Imbert too disposes of mainly short series.

TABLE 5 – THE LENGTH OF THE SERIES REFERRING TO INDUSTRIAL PRODUCTION ANALYSED BY IMBERT

Sort of variable	Length in cycles				Total
	3	2½	2	1½	
Indicators of general industrial production	2	2	8	1	13
Indicators of production in particular industries	3	7	16	7	33
Total	5	9	24	8	46

Source: Imbert (1959) tableau 6, pp. 104, 105 and tableau 7, pp. 114, 115.

(b) Imbert starts his statistical investigation of the real long wave from a given dating of phases of the long wave, which was derived from series of prices and monetary variables. On the basis of this predetermined periodization, Imbert tests the long wave in real variables. This method is sometimes

33 Imbert (1935).

referred to as the method of "split halves."[34] According to this method, the data are divided into two parts, in this case prices and monetary variables on the one hand and real economic variables on the other. Then the first part is used for identification of the cycle. The features of the cycle which are established in this way can then be tested with the second part of data.

Using the given periodization of the long-wave phases, Imbert tests the existence of the real long wave with the criterion that average real growth during a Kondratieff rising phase should exceed average growth during the preceding Kondratieff declining phase, and growth during a Kondratieff declining phase should be lower than during the preceding Kondratieff rising phase. If the criterion for a particular phase is satisfied, Imbert speaks of "concordance."[35] In that case, the movements in real growth conform to the pattern in prices and thus also the Kondratieff pattern. Imbert derives average growth from the slope of a loglinear curve fitted to the series for each Kondratieff phase by the method of least squares.

(c) Imbert concludes that 9 out of the 13 series which refer to general industrial production show a "*concordance perfecte*." For 18 out of the 33 series of particular industries he finds very good ("*très bonne*") results. The overall conclusion of Imbert is that the outcome of his statistical analysis confirms Kondratieff's hypothesis of the long wave: "*les resultats d'ensemble obtenue pour les séries industrielles paraissent très satisfaissants et montrent l'impact profond des mouvements longs sur l'évolution industrielle.*"[36]

If the results of his investigations are critically examined, however, a very different conclusion is reached. In addition to Imbert's arrangement of the results, we have determined the degree of concordance for each alleged turning point seperately. We have expressed the degree of concordance in the percentage of observations, in this case series, which satisfy the criterion of concordance for that turning point. For example, a degree of concordance of 100 percent means that in all series, average growth per Kondratieff phase rises after a trough or declines after a peak. A concordance of 0 percent indicates that the real movements around that turning point are exactly contrary to the Kondratieff pattern. The expected value of concordance for stochastic series is 50 percent. The outcome of this rearrangement of Imbert's results is presented in Table 6. From this table it is clear that only a few of the alleged turning points are confirmed by the real economic development. For the Kondratieff peak of 1814 and the trough of 1849, even an evident contrary

34 See, e.g., Van der Zwan (1978), p. 11.

35 This definition of "*concordance*" corresponds much to the "conformity index" of Burns and Mitchell. See Burns and Mitchell (1947), p. 31.

36 Imbert (1929), p. 116.

real movement is found. Also the evidence for an upward turn after 1896 is very weak. So for only half of the Kondratieff turning points (1873, 1920 and 1933) is the outcome clearly positive.

TABLE 6 – DEGREE OF CONCORDANCE FOR EACH TURNING POINT OF THE KONDRATIEFF CYCLE FOR INDICATORS OF GENERAL INDUSTRIAL PRODUCTION AND PRODUCTION OF PARTICULAR INDUSTRIES

		Series of general industrial production		Series of production in particular industries	
Peak	1814	0	(0)	6	(0)
Trough	1849	0	(0)	50	(36)
Peak	1873	100	(75)	97	(83)
Trough	1896	69	(54)	76	(64)
Peak	1920	89	(77)	80	(78)
Trough	1933	100	(100)	91	(73)

Explanation: Between brackets the degree of concordance is given if the more stringent requirement is made that the average rate of growth has to change at least 1/10 in the direction predicted by the Kondratieff pattern.

Sources: Calculated from tableaux 6 and 7, Imbert (1959), pp. 104, 105 and 114, 115.

These results lead to the conclusion that the long movements in real economic growth do not conform to the Kondratieff pattern. For the period until 1930, which corresponds to the observation period of Kondratieff, only two of the five alleged turning points are confirmed by the results of Imbert's investigation.

4.3 *Van Duyn's Investigation*

Recent contributions to the statistical testing of the long wave are made by the Dutch authors Broersma, Van Duyn, Van Paridon, and Van der Zwan. Broersma[37] graphically analyses the long fluctuations in several economic time series from 1889 till 1976 for the United States. This period of not even the length of two full cycles, is, however, much too short to draw a well-founded conclusion about the existence of the Kondratieff cycle. Van Paridon's[38] investigation mainly consists in the visual inspection of graphically represented series of industrial production after elimination of a loglinear

37 Boersma (1978), pp. 99–129.
38 Van Paridon (1979), pp. 279–290.

trend. Like Broersma, he makes no attempt to support his (negative) conclusion in a more explicit way.

Van der Zwan gives a detailed statistical analysis of movements in economic growth between 1855 and 1930 for several series of production and real income in the United Kingdom, the United States, Germany and some series of world production. Van der Zwan's method of testing corresponds with the method of Imbert. Using the periodization of Kondratieff he compares trend growth in upward and downward Kondratieff phases. His analysis concentrates on the alleged upward turn after 1896. From this analysis Van der Zwan concludes that the "rise during 1890-96 till 1914-20 that (has) been so strikingly inferred from prices and monetary variables, appears not to be reflected in the volume of production."[39]

Full discussion of these contributions is beyond the scope of this article. Therefore we shall focus on the most extensive and systematic investigation of the long wave by J.J. van Duyn in "*De lange golf in de economie*."[40]

(a) Van Duyn concentrates his statistical analysis on series of industrial production for Great Britain (1782-1973), France (1815-1973), Germany (1850-1973), and the United States (1860-1973).[41]

(b) Van Duyn argues that long movements in production series can best be established by computing average growth rates between peaks of the 7- to 12-year-long Juglar cycle. These growth rates he uses for further analysis. The dating of the Juglar peaks Van Duyn adopts from Burns and Mitchell,[42] who have extensively investigated short business cycles. However, Van Duyn is not consistent in this: "when it was evident that the turning points given by Burns and Mitchell did not reflect peaks in the series of industrial production" Van Duyn departed from the dating of these authors.[43] Which criterion he uses for this he does not mention. In addition to this vague method of selection, it is very questionable if the turning points of the "reference cycle" of Burns and Mitchell may be used for this purpose. In the first place, the "reference cycle" is derived from many economic indicators, including price- and monetary indices, whereas Van Duyn specifically needs the peaks in the series of industrial production. In the second place, the reference cycle has a duration of 4 to 5 years, which is much shorter than the duration of the Juglar cycle, which Van Duyn tries to eliminate. And finally Van Duyn does not take into account the very important consequences of the existence of

39 Van der Zwan (1978), p. 22.
40 Van Duyn (1979), especially pp. 115-150.
41 For these series he uses the same sources as we do in our analysis (see appendix).
42 Burns and Mitchell (1946), table 46.
43 Van Duyn (1979), p. 125 (translation CvE).

TABLE 7 – AVERAGE GROWTH IN THE PHASES OF THE KONDRATIEFF CYCLE ACCORDING TO VAN DUYN

	Great Britain		France	
First Kondratieff				
rise	1782–1825	3.2	(1815–1824	1.4)
decline	1825–1845	3.5	1824–1847	1.3
Second Kondratieff				
rise	1845–1873	3.0	1847–1872	1.7
decline	1873–1903	1.5	1873–1903	1.4
Third Kondratieff				
rise	1903–1913	2.3	1903–1913	3.5
decline	1920–1928	2.8	1920–1929	8.1
	1929–1948	2.1	1929–1948	−0.9
Fourth Kondratieff				
rise	1948–1973	3.2	1948–1973	6.1
	United States		**(West) Germany**	
Second Kondratieff				
rise	(1864–1973	6.2)	(1850–1872	4.3)
decline	1873–1895	4.7	1872–1890	2.9
Third Kondratieff				
rise	1895–1913	5.3	1890–1913	4.1
	1920–1929	4.8	1920–1929	·
decline	1929–1948	3.1	1929–1948	·
Fourth Kondratieff				
rise	1948–1973	4.7	1948–1973	9.1

Explanation: The periods between brackets do not cover a full Kondratieff phase.

Source: Van Duyn (1979), p. 126.

medium-long cycles of 15 to 25 years, which were found by Kuznets, O'Leary, and Lewis[44] and others, and which, for the United States, have been confirmed by spectral analytic tests.[45]

Using observations selected in this manner, Van Duyn establishes long movements by computing average growth from peak to peak of the short cycles. The most explicit test of Van Duyn corresponds with the tests of Imbert and Van der Zwan. Also Van Duyn adopts the periodization of Kondratieff, but instead of computing average growth as the slope of the trend curve, Van Duyn computes average growth between the selected

44 Kuznets (1930), O'Leary and Lewis (1965).

45 See, e.g., Dowling and Poulson (1974), Soper (1975).

observations (peaks of the Juglar cycle) at the beginning and the end of a Kondratieff phase. So Van Duyn, too, implicitly assumes that price movements are a good reflection of the long movements in production.

(c) The main results of Van Duyn's investigation are presented in Table 7. The degrees of concordance which can be derived from this table for each country are remarkable high: Great Britain, 66 percent; France, 100 percent; (West-) Germany, 100 per cent; and the United States, also 100 percent. Only long movements in production in Great Britain before 1873 do not fully correspond with the long wave hypothesis.

Because this method of analysis is very sensitive to the selection of peaks, we have checked the dating of the peaks by means of the simple criterion of Lewis,[46] according to which production has to exceed the level of production in preceding years, and growth after the peak has to be less than average for at least two years. Checking this for Great Britain, 4 out of the 8 peaks cannot stand this test, *viz.* 1788, 1873, 1903 and 1948. For France, only one peak satisfies the criterion (1872); for the United States, two (1929, 1973); and for Germany, also two (1890, 1973).

Because of this outcome we have repeated Van Duyn's test of the long wave with a selection of peaks which corresponds better with the fluctuations in industrial production[47] (see Table 8). These results, as summarized in the

TABLE 8 – AVERAGE GROWTH IN THE PHASES OF THE KONDRATIEFF CYCLE

Great Britain		France		United States		(West) Germany	
1789–1819	3.3						
1819–1845	4.0	1824–1846	1.6				
1845–1872	2.9	1846–1872	1.6	(1860–1872	5.7)	1850–1874	4.5
1872–1899	2.2	1872–1899	1.7	1872–1892	5.0	1874–1890	2.5
1899–1913	1.6	1899–1912	2.8	1892–1929	4.4	1890–1912	4.2
1920–1929	2.8	1920–1929	8.1				
1929–1937	3.3	1929–1937	0.4	1929–1943	5.6	1927–1938	3.2
1951–1973	3.0	1951–1972	5.7	1943–1973	3.2	1951–1973	6.3
"*Concordance*"							
	17%		50%		25%		100%

Sources: see appendix.

46 Lewis (1978), p. 20.

47 These peaks have been derived from the series of industrial production and all of them satisfy the criterion of Lewis.

degree of concordance for each country, sharply contrast with Van Duyn's results. For Great Britain and the United States, degrees of concordance result which indicate rather a contrary movement of prices and production than a movement corresponding to the Kondratieff pattern. For France, we find a concordance of 50 percent, exactly the expected value for stochastic series. Only the German production series show a pattern in accordance with the Kondratieff thesis. The overall conclusion with respect to the real long wave is, in contrast with Van Duyn's conclusion, clearly negative.[48]

4.4 *Conclusion*

In contrast to their own positive conclusions, careful examination of the results of the investigations of Kondratieff, Imbert and Van Duyn led us to clearly negative conclusions with respect to the existence of a long wave in real variables. However, we cannot yet attach far-reaching consequences to this outcome. Even if we assumed that these results falsify the long wave as it is described by Kondratieff, it will not be possible to conclude that no long wave exists at all. For, all these investigations were based on a specific periodization and have therefore no validity for long waves in general. Notwithstanding the negative results it is still possible that a long wave in real variables exists, but with a different timing.

In the following section we shall discard Kondratieff's periodization and offer a new test of the long wave and a new periodization of long movements in economic growth.

48 In an appendix, Van Duyn presents an alternative test which leads also to a positive conclusion. Van Duyn adduces this as an extra support of his conclusion. However, a simple mathematical derivation shows that the alternative test is not independent of the main argument, but only computes in a roundabout way average growth again between the same selected peaks.

The alternative test is based on the test-statistics, T, where

$$T = \sum_{t=t^1}^{t^2} (e_t - e_{t-1}) \qquad (1)$$

where: t^1 and t^2 are the two turning points at the beginning and the end of the Kondratieff phase;

$$e_t = \ln Q_t - \ln Q'_t \; ; \qquad (2)$$

with: Q_t = production in year t, Q'_t = trendvalue of production in year t.

If the statistic (T) is positive for a rising phase or negative for a declining phase, the Kondratieff thesis is, according to Van Duyn, confirmed.

Substitution of equation (2) in equation (1) results in:

5 A NEW TEST OF THE LONG WAVE

5.1 *Method of Testing*

In order to perform a general test of the existence of a long wave the help of a predetermined periodization of the phases of the long wave must be rejected. This makes the analysis much more complex. We will start with a visual inspection of the series. This, however, is a rather subjective way of testing and moreover it will appear to be very difficult to draw any conclusions directly from the graphs of the series. Therefore more manipulations will be necessary to come to a more explicit test of the long wave. First, we will establish the intervals during which long term growth exceeds 'normal' economic growth and the corresponding intervals of below-normal growth. The pattern in these intervals is an indication of the long movements in economic growth. From a comparison between this pattern and the Kondratieff pattern some conclusions can be drawn with respect to the existence and timing of a long wave. However, this is a rather crude test because despite smoothing the series still contains fluctuations shorter and longer than the Kondratieff cycle, which blur the picture. Especially a rather irregular 12 to 25 year long medium wave dominates the longer movements including a possible Kondratieff cycle. This medium cycle corresponds, in certain periods and countries, to the 'long swing' which is often called after Kuznets. For a more exact identification of long movements this intermediate wave must be eliminated. This will be done by computing average growth between the successive peaks and between the troughs of this wave. This method is preferred to Van Duyn's method of using Juglar peaks, because by that method all fluctuations with a duration between the length of the Juglar cycle and the Kondratieff cycle are left in the series. The precise way of determining the turning points and computing average growth will be discussed later.

We will first deal with problems concerning the graphing of the time-series and the interpretation of these graphs.

48 – *continued*

$$
\begin{aligned}
T &= \Sigma (\ln Q_t - \ln Q_{t-1} - \ln Q't + \ln Q'_{t-1}) \\
&= \Sigma (\ln Q_t - \ln Q_{t-1}) - \Sigma (\ln Q'_t - \ln Q'_{t-1}) \\
&= \ln (Q_{t^2}/Q_{t^1}) - \ln (Q'_{t^2}/Q'_{t^1}) \ .
\end{aligned}
$$

T proves to be simply total growth between the selected observations t^1 and t^2 minus total trendgrowth during that period. Hence it is not surprising that this test comes to the same results as Van Duyn's main analysis. The outcome of this test hinges also completely on the selection of the peaks t^1 and t^2.

5.2 *Visual Inspection of the Series*

Our investigation is restricted to the four main industrialized countries: Great Britain, France, (West-) Germany and the United States. For each country the long movements in five indicators of general economic activity are analysed. Table 9 gives a survey of these series.

TABLE 9 – TIME SERIES USED IN THE INVESTIGATION OF THE LONG WAVE IN REAL VARIABLES

	Great Britain	France	(West-) Germany	United States
Industrial production (volume)	1750–1977	1815–1977	1850–1977	1860–1977
National income (volume)	1830–1977	1901–1977	1850–1977	1889–1977
Investment (volume)	1830–1977	1896–1977	1850–1977	1889–1977
Exports (volume)	1796–1977	1896–1977	1836–1977	1879–1977
Imports (volume)	1796–1977	1919–1977	1836–1977	1879–1977

Sources and composition of these series are given in the appendix.

All these series are characterized by heavy short fluctuations and a trending mean. This makes visual inspection of the original series very difficult. Hence the series must be transformed to eliminate trend and short fluctuations. As concluded in section 3.2, the elimination of the trend by estimating a certain trend curve seldom produces satisfactory results. Moreover, the specification of the trend curve is very determining for the outcome. For these reasons, we have chosen to eliminate the secular rise in the series by converting them into growth rates. This is comparable to the elimination of a loglinear trend but has the advantage that it brings out medium and long fluctuations better, provided that short fluctuations are in some way dampened. A second advantage of conversion into growth rates over fitting a trend curve is that growth rates have a direct and substantive economic meaning. It should, however, be taken into account that phases and turning points in the series of growth rates do not directly correspond with phases and turning points in the original series. A relative extremum in the series of growth rates, if computed on a continuous basis, corresponds with an inflection point in the logarithms of the original data; a zero rate of growth corresponds with an extremum in the original series. We shall return to this problem presently.

First, however, a second problem must be dealt with. After conversion into rates of growth, the result for most series is dominated by short

fluctuations. Without further manipulations, long movements are difficult to diagnose then. For that reason smoothing is necessary. In most investigations of the long wave, a simple 9-year moving average is chosen. For the original series or the deviations from the trend, this yields satisfactory results, as appears from the analyses by Broersma, Van Paridon, and others. We have tried this method of smoothing on the rates of growth. However, as short fluctuations still appeared to dominate longer movements in economic growth, further smoothing proved necessary. After experimenting with combinations of the 9-year moving average with several other moving averages, we have decided to apply a 5-year moving average on the growth rates in addition to the smoothing of the original data by means of a 9-year moving average.[49] This way of smoothing appeared a reasonable compromise between the wish to eliminate short fluctuations and the statistical need to use a short moving average relative to the length of the Kondratieff cycle. The results of this transformation for the series of industrial production are shown in Figures 4 to 7. For the sake of brevity, the graphs for the other variables have not been presented here. As can be seen from the graphs of the transformed series of industrial production, this method of smoothing brings out medium- and long-term fluctuations reasonably well. Further smoothing does not improve the results significantly and makes the analysis less precise and less reliable, because of the loss of more observations and the danger of creating false long movements. Therefore we have decided not to use further smoothing.

In addition to simple visual inspection, we have, on the basis of these graphs, established the long movements in a more objective way by determining the intervals during which growth was above "normal" growth. Because we are interested in the long movements, we have derived these intervals from the smoothed series which were presented in the foregoing graphs. A possible interpretation of the Kondratieff thesis is that growth is above "normal" growth during the rising phases and below normal during the falling phases.[50] By examining the pattern in intervals of above-normal growth, some conclusions can be drawn with respect to the existence of a long wave. Furthermore, by comparing these intervals with the periodization of Kondratieff, this periodization can be tested.

49 The formula for this transformation is

$$g_t = \frac{1}{5} \sum_{j=t-2}^{t+2} \left(\ln \sum_{i=j-4}^{j+4} x_i - \ln \sum_{i=j-5}^{j+3} x_i \right)$$

where x_i = original observation.

50 See e.g. Van Duyn (1979), p. 146.

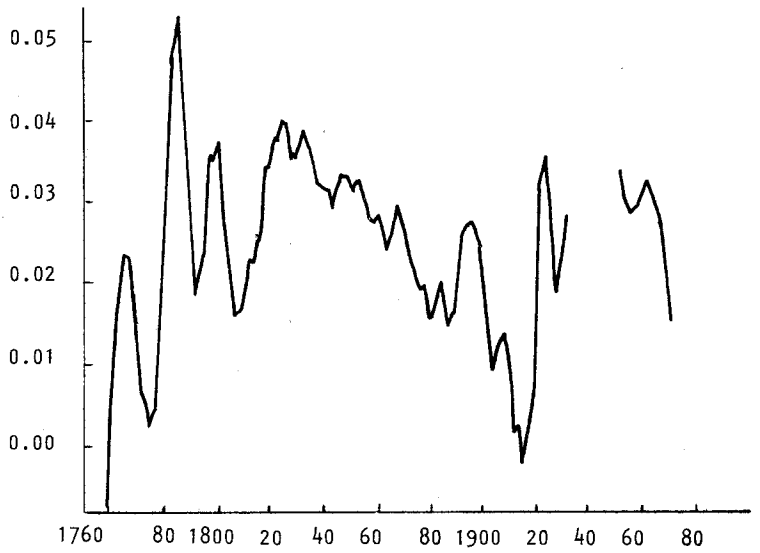

Figure 4 – Great Britain, growth of industrial production, smoothed by means of a moving average.*

$$* \quad g_t = \sum_{j=t-2}^{t+2} \left(\ln \sum_{i=j-4}^{j+4} x_i - \ln \sum_{i=j-5}^{j+4} x_i \right)$$

where x_i = original observation.

Sources: see appendix.

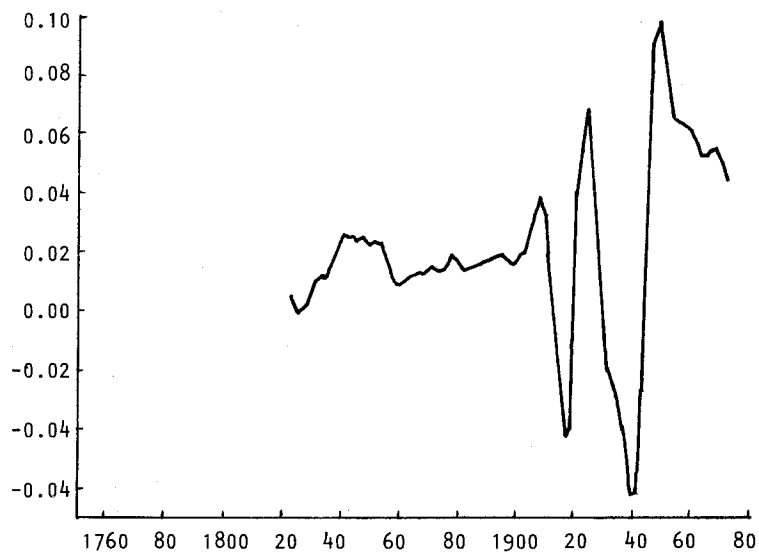

Figure 5 – France, growth of industrial production, smoothed by means of a moving average.

Explanation: see Figure 4.

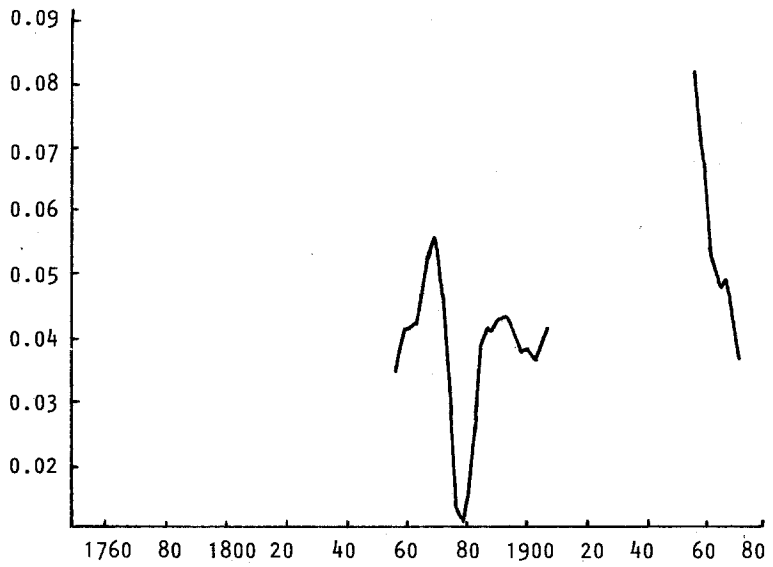

Figure 6 – (West-)Germany, growth of industrial production, smoothed by means of a moving average.

Explanation: see Figure 4.

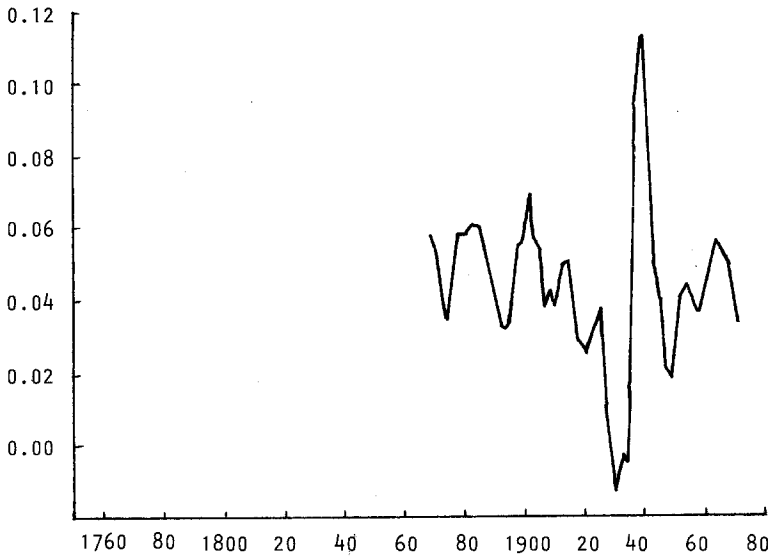

Figure 7 – United States, growth of industrial production, smoothed by means of a moving average.

Explanation: see Figure 4.

It is not clear what rate of growth should be regarded as "normal." It may be interpreted as the average rate of growth in each country during the whole period of observation. However, for a better diagnosis, it is preferable to establish intervals of above-normal growth for more hypothetical normal rates of growth. In Figure 8 this is done for average growth and two other rates of growth within the same range, 0.5% above and 0.5% below the average growth rate, except for Germany where the other growth rates have been chosen 0.5% and 0.10% above the average rate of growth because average growth has been negatively biased by the wars.

In Section 5.4, Figures 4 to 7 and these diagrams will be thoroughly examined with respect to the long wave. At this stage it is important to recognize that it turns out to be very difficult to draw conclusions from the graphs and diagrams, because a rather vehement and irregular medium wave blurs the picture. Further analysis is therefore necessary. This medium wave must be eliminated in some way before we can draw conclusions about the existence of a long wave in real variables.

5.3 *Eliminating the Medium Wave*

As already stated, it is not statistically justified to eliminate the medium wave by means of further smoothing. For that reason, we have chosen to eliminate the influence of the medium wave by computing average growth from peak to peak and from trough to trough of this wave. This method is comparable to Van Duyn's but differs in the following respects:

(a) Average growth is computed not only between successive peaks but also between successive troughs in order to get more comparable observations and thus a more complete picture of long term movements in economic growth.
(b) The turning points of *medium wave* are selected instead of the peaks of the Juglar cycle.
(c) The long wave is not tested on the basis of Kondratieff's periodization but on the basis of a description of the movements in economic growth with a longer duration than the medium wave.
(d) The turning points of the medium wave are determined for each series separately. The method by which this is done is rather complex and we will deal with it first.

In order to reduce the influence of incidental factors and to eliminate cycles and fluctuations shorter than the medium wave, all series are smoothened by a simple 9-year moving average. The turning points have been derived from

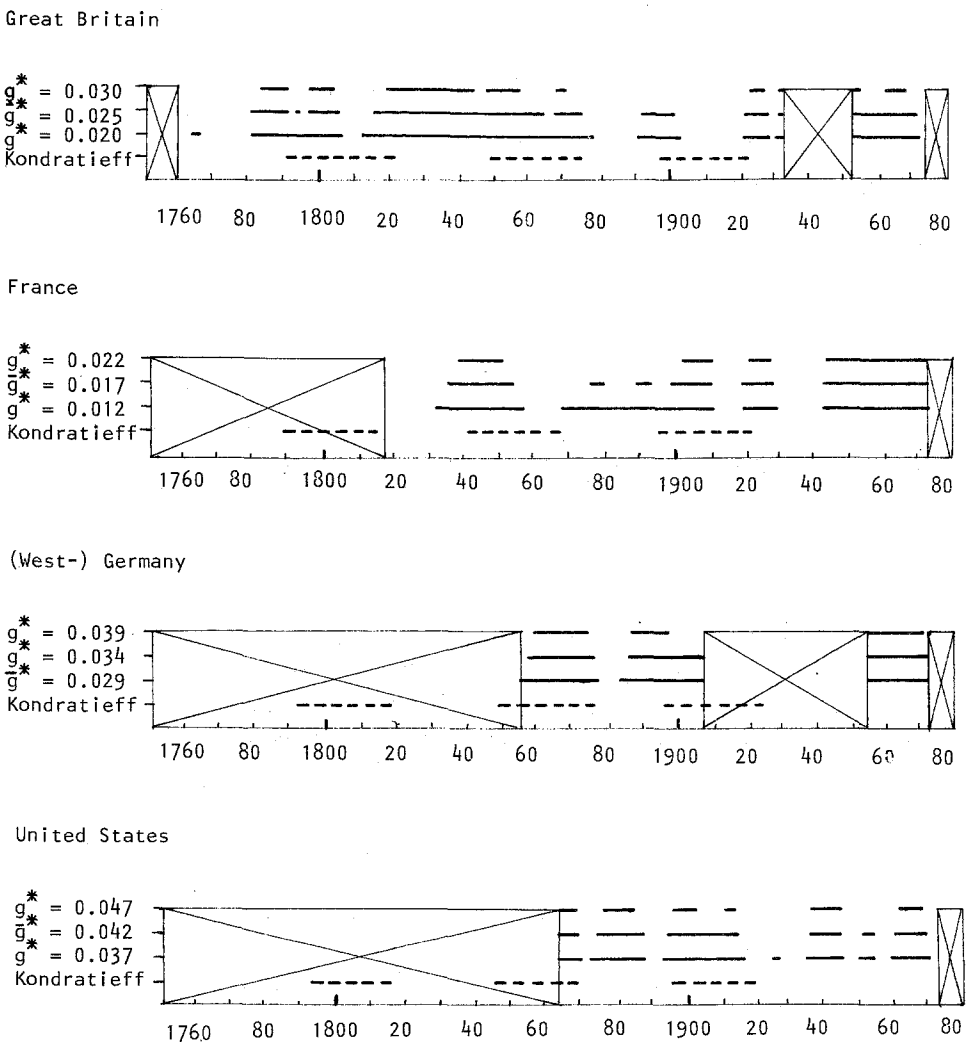

Figure 8 – Intervals of above-normal economic growth of industrial production in Great Britain, France, (West-)Germany and the United States.

Explanation: The solid lines represent the intervals during which the smoothed rate of growth (see also Figures 4 to 7) is above average growth (g^*) or another hypothetical "normal" rate of growth (g^*). The intermitted lines represent the rising phases according to Kondratieff's thesis. The dating of these phases is taken from Burns and Mitchell (1946), p. 432.

Sources: see appendix.

these smoothed series. If we hold on to the definition of a turning as a maximum in deviation from the trend in a certain interval, we have to determine the trend for every interval in some way. As already stated,[51] it is in most cases unsatisfactory to estimate one trend for the whole period, because in that way waves longer than the medium wave and structural changes in the process of economic growth are insufficiently taken into account. This is important for the medium wave because it oscillates around a trend which is far from stable. Schumpeter rightly points out that the trend of a particular cycle consists of all cycles and fluctuations with a longer duration than the cycle in question.[52] For that reason it is preferable to establish trends for shorter periods of time, for instance for each cycle or half cycle. To delimit these intervals the inflection points can be used, for these points may be conceived as comparable observations of the structural development. The inflection points in the series (after conversion in logarithms) are already known as relative minima or maxima in the rates of growth of these series. Because we are interested in the long-term movements, we have derived the inflection points from the graphs of the smoothed growth rates (like the Figures 4 to 7 for industrial production). Using the inflection points, trend growth for every half cycle can be determined by computing average growth between the observations corresponding with the inflection points.

This method is illustrated in Figure 9. This figure shows the series of industrial production in the United States, which is smoothed by a simple 9-year moving average. The trend curves for every half cycle of the medium wave are shown as loglinear curves between the inflection points (dotted lines). Peaks and troughs are determined as maxima in deviation from these trend curves. The solid lines indicate average growth between the successive peaks and the successive troughs of the medium cycle and thus show the outlines of the long-term movements in economic growth.

The results of this analysis are presented in the Tables 10 to 13. This rather complex way of establishing the long-term movements must be preferred to, for instance, the use of arbitrary observations from smoothed series, like the common method of comparing growth rates between successive 5-year or decade averages.[53] In that way, medium-term fluctuations are

51 See section 3.2.

52 ". . . for every time series the sweep of any cycle is the trend of the cycles of next lower order" Schumpeter (1939), p. 173.

53 See e.g. Kuznets (1930) and Van Paridon (1979).

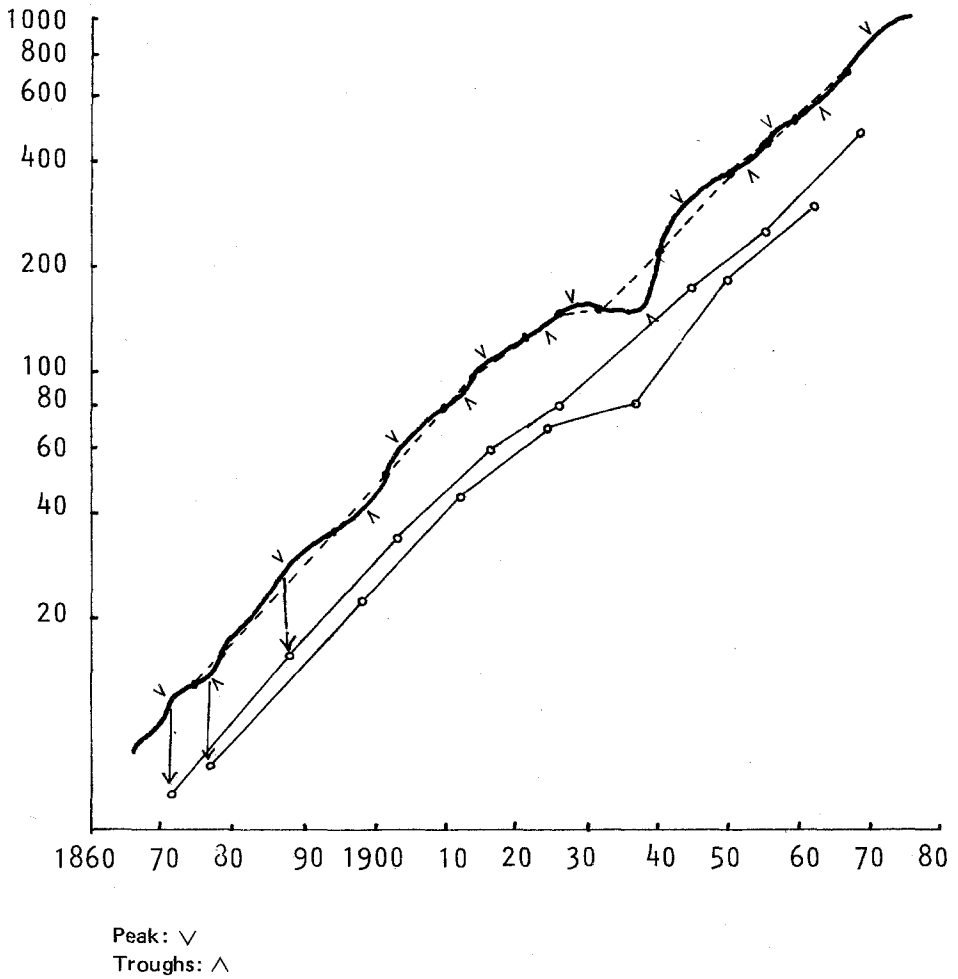

Figure 9 – Inflection points, peaks and troughs in the series of industrial production of the United States (halflog. scale).

Explanation: The series is smoothed by a 9-year moving average. For every cycle-half trend-growth is determined and shown by the intermitted lines (- - - -). With the peaks and troughs the outlines of long-term economic growth are established. These are shown by the solid lines between peaks and between troughs (—o—o—), which are shifted vertically downwards for graphic reasons.

not adequately taken into account. A decade average can accidentally cover the depression years of a medium wave and the following decade average the

boom. In such a case, growth between the decade averages indicates medium-term fluctuations rather than longer movements. Therefore, we have chosen a more careful way of selecting observations which can be used as indicators of movements longer than the 15- to 25-year-long medium wave. From the results of this analysis and the fore-going graphs and diagrams, we will establish the features of long-term fluctuations in economic growth for each country separately. With the assessment of the chronology of long rising and declining phases as a basis, we will draw our conclusions about the existence and, if it exists, the dating of the Kondratieff cycle.

5.4 *Long-Term Movements in Economic Growth in Great Britain*

From Table 10 and the graphs and diagrams about economic growth in Great Britain, it can be concluded that this country experienced two evident periods of rapid expansion in the eighteenth and nineteenth centuries. The first expansion period was roughly from 1780 until 1800 and the second from about 1820 until 1860. In these periods, long-term economic growth averaged 3.0 to 3.8 percent (see also Figure 4). During the expansion from 1820 till 1860 exports grew even faster, averaging 4.8 to 6.2 percent. After 1860, long-term growth gradually declined to below 2 percent in the 1920s and 1930s. Exports scored even negative rates of growth during that period. After World War II, the British economy grew again at a reasonable pace but it did not achieve the records of the nineteenth century.

What can be concluded about the long wave? With respect to the long wave as described by Kondratieff, the evidence is clear: the long-term pattern in economic growth does not at all correspond with Kondratieff's thesis. What for instance should be a downward phase from 1820 till 1850, according to Kondratieff, turns out to be a period of enormous expansion.[54] Also the Kondratieff upswing after 1896 is not supported by our results. Average growth of industrial production between the peaks of 1902 and 1911 is only 1.2 percent. This is below average growth between the peaks of 1870 and 1902 (2.2 percent). The same is true for Gross National Product and the other variables. Inspecting Figures 4 and 8, we conclude that there was a boom in the 1890s – but far too short to be considered a rising Kondratieff phase.

If Kondratieff's periodization is dropped, little evidence is also found of a more or less regular 40- to 60-year-long wave. We do find long movements, but these do not resemble a wave within the Kondratieff range, but rather

54 According to Garvy, the Russian economist, A. Gerstein uttered the same point of criticism as early as 1928. Garvy (1943), p. 452.

TABLE 10 – AVERAGE GROWTH IN INDUSTRIAL PRODUCTION, NATIONAL PRODUCT, INVESTMENT, EXPORTS AND IMPORTS BETWEEN PEAKS (*P*) AND BETWEEN TROUGHS OF THE MEDIUM WAVE IN GREAT BRITAIN

Interval	Length	Average growth	Interval	Length	Average growth
Industrial production			Exports		
1761[b]–1780	19	1.4	1808–1823	15	3.1
1769–1788 *P*	19	2.5	1818–1842 *P*	24	4.3
1780–1794	14	3.7	1823–1845	22	4.8
1788–1803 *P*	15	3.0	1842–1856 *P*	14	6.2
1794–1817	23	2.6	1845–1865	20	4.9
1803–1837 *P*	34	3.0	1856–1871 *P*	15	3.6
1817–1846	29	3.8	1865–1877	12	3.8
1837–1856 *P*	19	3.2	1871–1886 *P*	15	2.9
1846–1866	20	3.0	1877–1901	24	2.2
1856–1870 *P*	14	2.7	1886–1910 *P*	24	2.3
1866–1889	23	2.1	1901–1919	18	0.1
1870–1902 *P*	32	2.2	1910–1927 *P*	17	−1.1
1889–1908	19	1.5	1919–1943	24	−2.3
1902–1911 *P*	9	1.2	1927–1950 *P*	23	0.8
1908–1919	11	1.4	1943–1963	20	6.6
1911–1926 *P*	15	1.5	1950–1973[a] *P*	23	4.1
1919–1930[b]	11	2.7			
1950–1970	20	3.1[c]			
Gross National Product			Imports		
1835–1849 *P*	14	1.9	1802[b]–1826 *P*	25	1.9
1844–1862	18	2.2	1820–1842	22	3.6
1849–1874 *P*	25	2.3	1826–1850 *P*	23	3.9
1862–1890	28	2.0	1842–1855	23	2.5
1874–1902 *P*	28	1.9	1850–1875 *P*	25	4.4
1890–1910	20	1.9	1855–1884	29	4.0
1902–1915 *P*	13	1.5	1875–1902 *P*	27	2.8
1910–1930	20	0.5	1884–1919	35	1.7
1915–1942 *P*	27	1.3	1902–1930 *P*	28	1.2
1930–1951	21	1.9	1919–1956	37	0.9
1942–1970[b] *P*	28	2.1	1930–1973 *P*	43	2.2

TABLE 10 – *Continued*

Interval	Length	Average growth	Interval	Length	Average growth
Investment					
1836[b]–1850*P*	14	4.7			
1841–1857	16	2.9			
1850–1864 *P*	14	3.0			
1857–1870	13	4.3			
1864–1879 *P*	15	3.3			
1870–1889	19	1.5			
1879–1902 *P*	23	2.8			
1889–1919	30	1.0			
1902–1934 *P*	32	1.2			
1919–1944	25	2.2			
1934–1969[b]*P*	35	3.8			

Explanation: The peaks and troughs of the medium wave are determined as maxima in deviation (in the series of 9-years moving averages) from the trend within a certain period of time. These periods are delimited by the points of inflection of the medium wave, computed as relative extremes in the smoothed series of growth rates. Trend growth per period is determined by computing average growth between the observations in the series of 9-years moving averages.

Symbols: [a] First or last observation of the series.
[b] This peak or trough is determined as maximum deviation from the trend of the adjoining interval, because it was not possible to determine the trend for this interval due to lack of data.
[c] Only a rough indication; for this period no peaks or troughs could be calculated due to lack of data.
P = Average growth between peaks.

a 100- to 140-year-long swing: rapid economic growth from about 1780 till 1860, interrupted by the Napoleonic Wars, and after 1860, gradually declining growth till the 1920s, and again reasonable growth after World War II till the 1970s.

5.5 *Long-Term Movements in Economic Growth in France*

For the diagnosis of long movements in French economic growth, we have to rely almost entirely on the series of industrial production. From this series we can conclude that French economic growth during the nineteenth century and the first half of the twentieth century was very modest. The highest

TABLE 11 – AVERAGE GROWTH IN INDUSTRIAL PRODUCTION, NATIONAL INCOME, EXPORTS AND IMPORTS* BETWEEN PEAKS AND BETWEEN TROUGHS OF THE MEDIUM WAVE IN FRANCE

Interval	Length	Average growth	Interval	Length	Average growth
Industrial production			Exports		
1820[b]–1853 *P*	33	1.6	1930–1951 *P*	21	0.7
1835–1863	18	3.1	1945–1965	20	11.2
1853–1879 *P*	16	2.3	1951–1970[b] *P*	19	8.7
1863–1887	14	2.5			
1879–1896 *P*	17	1.6			
1887–1905	18	1.9			
1896–1912 *P*	16	2.4			
1905–1919	14	0.0			
1912–1930 *P*	18	1.1			
1919–1943	25	−2.2			
1930–1973[a] *P*	43	3.7			
1950–1970	20	6.1[c]			
Net National Product			Imports		
1934–1950 *P*	16	0.5	1934–1950 *P*	16	0.0
1944–1959	15	6.1	1943–1958	15	8.5
1950–1969 *P*	19	5.3	1950–1970[b] *P*	20	8.7

Explanation: See Table 10.

* Because of lack of data no results for investment can be given.

growth is recorded in the second quarter of the nineteenth century (3.1 percent between the troughs of 1835 and 1863) and the first decade of the twentieth century (2.4 percent between the peaks of 1896 and 1912). During the intermediate period, growth was very slow and quite stable, averaging 1.2 to 1.9 percent. France did not see any really fast expansion until the period after 1945, when it reached long-term growth rates of over 5 percent for each variable.[55]

55 For industrial production in the 19th and 20th centuries in France, an alternative source is available. Markovitch (1966) provides data for average growth per decade from 1780 till 1960. These growth figures are sometimes rather different from those of Crouzet, which are used in our analysis. According to the data of Markovitch, the first expansion period was from about 1820 till 1840. According to Markovitch, the acceleration of industrial growth at the end of the 19th century began earlier and was much weaker than can be inferred from the series of Crouzet. This again illustrates how careful one has to be when using economic time series.

With respect to the long wave according to the periodization of Kondratieff, our conclusion is the same as for Great Britain: long-term movements in real economic growth do not resemble the Kondratieff pattern (see especially Figure 8). With respect to the long wave, without a given dating our conclusion is less firm. With good will, a certain periodicity with a frequency in the Kondratieff range can be observed. If intervals of above-normal growth are established with average growth as a criterion, we find periods of rapid growth in industrial production roughly from 1835 till 1854 (19 years), from 1899 till 1909 (10 years) and from 1942 till 1973 (31 years). Shortly after World War I also a period of rapid expansion can be observed but this period is rather short for a long wave rise. Moreover it is obviously caused by non-economic events, i.e., recovery from the war. Therefore this period should be disregarded when establishing the long-term pattern in economic growth. The intermediate intervals are respectively 45 and 33 years long. To some extent this pattern resembles a long wave. However, if another "normal" rate of growth is chosen, little of this seeming long wave pattern remains (see Figure 8).

Summarizing, it can be assessed that the Kondratieff scheme of long waves clearly does not correspond with the facts and that the evidence for a long wave in general is inconclusive.

5.6 *Long-Term Movements in Economic Growth in Germany*

For Germany no series of production growth before 1850 are available. After 1850 the economic growth led to an evident peak in 1874. Thereafter, as in Great Britain, a sharp contraction followed. After the recession, growth of industrial production regained its former rapid pace till 1913. The same pattern can be found in the graphs of the other variables. From 1913 until 1950, long-term economic growth was strongly dominated by the two wars. After 1950 West Germany experienced an unprecedented rapid expansion, reaching an average rate of industrial growth of 6 percent during the period 1954–1970. These relatively short and blurred series make it difficult to decide on the existence of a long wave. During the period 1850–1913, for industrial production, national product and investment, and during the period 1830–1913, for imports and exports, the pattern of economic growth resembles to some extent the Kondratieff wave. However, this resemblance hinges essentially on the interpretation of the contraction from 1874 till 1884. In our opinion, this contraction is a phase of the medium wave and strongly influenced by incidental factors. In the first place, this contraction has a duration of only ten years, which is too short for a Kondratieff phase. In the second place, this contraction seems to be caused by a temporary,

strong decline in two principle determinants of effective demand: exports and investment. If this interpretation is accepted, little evidence for a long wave remains. Table 12 shows that, disregarding this contraction, long-term economic growth of industrial production is fairly constant from 1875 till 1909: 4.0 percent between the peaks of 1875 and 1896 and also 4.0 percent

TABLE 12 – AVERAGE GROWTH OF INDUSTRIAL PRODUCTION, NATIONAL PRODUCT, INVESTMENT, EXPORTS AND IMPORTS FROM PEAK TO PEAK AND FROM TROUGH TO TROUGH IN (WEST-) GERMANY

Interval		Length	Average growth
Industrial production			
1855[b]–1884		19	5.6
1875–1896	*P*	17	4.0
1884–1906[b]		22	4.1
1896–1909[a]	*P*	13	4.0
1928–1934		6	2.1[c]
1954–1970		16	6.0[c]
Net National Product			
1867–1884		17	2.4
1874–1896[b]	*P*	22	2.5
1884–1909[a]		25	3.0
1929–1934		5	3.2[c]
1954–1970		16	5.4[c]
Investment			
1864–1874	*P*	10	4.2
1869–1883		14	2.5
1874–1896	*P*	22	3.4
1883–1905[b]		22	4.3
1929–1934		5	7.0[c]
1954–1970		16	5.7[c]
Exports			
1848–1862		14	5.7
1857–1875	*P*	18	5.0
1862–1895[b]		33	3.7
1875–1909[a]	*P*	34	3.8
1929–1940		11	−4.0[c]
1954–1970		16	10.7[c]
Imports			
1843[b]–1858	*P*	15	2.8
1850–1866		16	3.9
1858–1875	*P*	17	5.6
1866–1884		18	4.1
1875–1895	*P*	20	3.1
1884–1905[b]		21	4.2
1895–1909[a]	*P*	14	3.6
1929–1940		11	−2.5[c]
1954–1970		16	11.9[c]

Explanation: See Table 10.

from 1896 till 1909. The other variables produce mixed results for this period. Investment and imports correspond reasonably well to the Kondratieff pattern and show a rise from about 1890 till 1910. On the other hand, long movements in National Product and exports do not support the long wave thesis. If we ascribe the boom in investments and imports to the preparation for the war, very little evidence for the long wave will remain.

5.7 *Long-Term Movements in Economic Growth in the United States*

For the United States, no continuous series for industrial production starting from before 1860 are available. Series for the other variables are even shorter. Establishment of long movements requires data for a longer period. Therefore we have also consulted other sources of noncontinuous information. Parker and Warthenby[56] have ascertained that during the period 1799–1830, production grew only at a modest pace (see Table 14). In the 1830s, production accelerated and during the following decades production grew at a rapid and – apart from the Kuznets and shorter cycles – steady pace (see Table 15). The temporary decline in growth between 1855 to 1875 is obviously caused by the Civil War.

When this information is combined with the information for the period after 1870 (see Table 13), it can be concluded that long-term growth of industrial production in the United States was high and stable from about 1830 till 1910, averaging 5 percent per year. After 1910 a gradual decline in economic growth sets in, which culminates in the deep depression of the 1930s. During the following period, which was dominated by World War II, the economy recovered rapidly. After 1950, economic growth slowed down a bit and continued at a reasonable pace till the 1970s. Industrial production grew at about 4.7 percent per year and national income at about 3.8 percent. This is, however, less than the pace of economic growth in the second half of the nineteenth century.

With respect to the long wave, our conclusion is clearly negative: no trace of a 40- to 60-year long wave can be found. Long movements break up in Kuznets waves on the one hand and an ultra-long movement, the outlines of which we have just described, on the other.

5.8 *Is the Long Wave a Real Phenomenon?*

Summarizing the results of this investigation, it can be concluded that the long movements in economic life do not conform to the thesis of the long wave. In Great Britain and the United States fluctuations longer than the

56 Parker and Warthenby (1960).

TABLE 13 – AVERAGE GROWTH IN INDUSTRIAL PRODUCTION, NATIONAL PRODUCT, INVESTMENT, EXPORTS AND IMPORTS FROM PEAK TO PEAK AND FROM TROUGH TO TROUGH IN THE UNITED STATES

Interval		Length	Average growth
Industrial production			
1870–1888	*P*	18	5.3
1875–1897		22	5.1
1888–1903	*P*	15	5.1
1897–1911		14	5.3
1903–1916	*P*	13	4.5
1911–1924		13	3.8
1916–1926	*P*	10	3.2
1924–1936		12	1.9
1926–1944	*P*	18	4.2
1936–1950		14	6.2
1944–1955	*P*	11	3.2
1950–1961		11	4.7
1955–1969[b]	*P*	14	4.7
Gross National Product			
1905–1925	*P*	21	3.1
1918–1936		18	1.7
1926–1941	*P*	15	2.9
1936–1950		14	4.8
1941–1956	*P*	15	3.1
1950–1961		11	3.4
1956–1965[b]	*P*	9	3.8
Investment			
1897[b]–1918		21	1.4
1909–1926	*P*	17	2.7
1918–1935		17	−4.4
1926–1950	*P*	24	3.5
1935–1960		25	6.4
1950–1969[b]		19	3.9
Exports			
1886[b]–1907		21	4.1
1900–1916	*P*	16	3.9
1907–1922		15	3.4
1916–1927	*P*	11	0.6
1922–1935		13	−1.4
1927–1944	*P*	17	3.9
1935–1957		22	5.0
1944–1973[a]	*P*	29	2.0
1950–1970		20	4.8[c]
Imports			
1888–1910	*P*	22	3.4
1897–1917		20	4.0
1910–1926	*P*	16	3.9
1917–1935		18	1.7
1926–1939	*P*	13	0.2
1935–1960		25	3.8
1939–1973[a]	*P*	34	4.4
1950–1970		20	4.8[c]

Explanation: See Table 10.

TABLE 14 – AVERAGE GROWTH IN PRODUCTION IN THE UNITED STATES, 1799–1839

	Private production per head	Total private production	Industrial production
1799–1809	–0.4	2.7	2.1
1809–1819	–1.9	1.0	–1.0
1819–1829	–0.2	2.8	4.1
1829–1839	1.7	3.5	0.7

Source: calculated from data in Parker and Warthenby (1960).

TABLE 15 – AVERAGE GROWTH IN GROSS NATIONAL PRODUCT IN DECADE AVERAGES 1834–1878

1834/43–1839/48	4.4
1939/48–1844/53	5.5
1844/53–1849/58	5.4
1849/58–1869/78	3.4

Source: Gallman (1966).

normal (short) business cycle break up in a rather irregular 10- to 25-year-long medium wave and "trend movements" which cover much longer periods than phases of a Kondratieff wave. With respect to France and Germany, evidence is less clear, but also for these countries it can be concluded that long movements in real economic variables bear no evident resemblance to phases of a Kondratieff cycle.

Our conclusion with respect to the Kondratieff's periodization of long movements in economic growth is firmly negative; it gives a wrong image of movements in real economic life and therefore it is a bad starting point for investigations of long movements on the process of economic growth.

6 SUMMARY AND CONCLUSIONS

Fifty years after Kondratieff concluded from his investigation that the long wave was "very probable," the discussion about the existence of the long wave has been re-opened by four investigations published in 1978 and 1979 by Dutch authors. These investigations, however, do not give a final answer to

the question of existence of the Kondratieff cycle. Their conclusions are contradictory. Broersma and Van Duyn believe that they have ascertained the long wave and Van der Zwan and Van Paridon reject the long wave on the basis of their investigations. This contradictory situation formed the starting point of this article. We have tried to solve it by discussing the major investigations of the long wave by Kondratieff, Imbert and Van Duyn, and by presenting a new test of the long wave.

We started by discussing the use of monetary and price statistics in the identification and tests of the long wave. On theoretical and empirical grounds, it was proved that movements in prices and monetary variables do not reliably reflect movements in the real economic sphere. Therefore series of these variables cannot be used to establish and test long movements in real economic life. On the same grounds, the use of a periodization of phases of a long wave which is based on prices or monetary variables should be rejected. This is an important conclusion because it applies also to the dating of the long wave by Kondratieff, which is used in most investigations of the long wave, including those by Imbert and Van Duyn. In our analysis we have tested the existence of a long wave separately from its periodization.

For our test of the long wave we have assumed the following characteristics, which are generally thought essential for the long wave: (1) it is more or less regular; (2) one cycle has a duration of 40 to 60 years; (3) it is general, which means that it manifests itself in prices as well as in volume series; and (4) it is international, which means that it manifests itself in the important industrialized countries at the same time.

On the basis of these characteristics, the investigations by Kondratieff, Imbert, and Van Duyn have been discussed. It has been ascertained that Kondratieff disposed of too few series of considerable length with respect to the real economic sphere to be able to test the real aspect of the long wave reliably. In addition to that, his method of fitting a higher-order polynomial as trend was criticized, which made the grounds for his positive conclusion about the existence of the long wave even weaker.

Imbert and Van Duyn arrive, after extensive analysis of volume series, at a positive conclusion; they believe that the Kondratieff thesis is confirmed by the results of their investigations. However, after critical examination of their analyses, these conclusions appeared to be badly founded. Following their method of analysis, but reordering their statistical information and repeating their analysis in a more correct way where necessary, we came to exactly the opposite conclusion: long movements in real variables, especially before 1914, badly correspond to Kondratieff's scheme of the phases of the long wave.

Because of the restricted character of the analyses by Imbert and Van Duyn, which stick to one predetermined periodization, this negative conclusion is not sufficient to reject the real long wave in general. For that reason, in Section 4 the Kondratieff periodization was dropped and the real aspect of the long wave was tested in a more general way. By several means, long movements in real economic growth were explored for Great Britain, France, (West-) Germany and the United States. Series of industrial production, national product, investment, exports and imports were subjected to a visual inspection after transformation in rates of growth. Then intervals of "above-normal" growth were established. Finally, average rates of growth between successive peaks and successive troughs of the medium wave were computed. On the basis of the results of these operations, a chronology of long movements in real economic growth was made up. Comparison of the long movements which were thus established with the characteristics of the Kondratieff wave led to conclusions which can be summarized as follows:

1. The periodization by Kondratieff of the phases of the long wave is a bad framework for investigating long movements in real economic life.
2. Although the process of long-term economic growth is far from steady, the long movements do not correspond to a long wave pattern. This applies certainly to Great Britain and the United States. With respect to France and Germany, our conclusion is less firm. However, the long wave is certainly not a general and universal characteristic of growth in the industrialized countries.
3. Long movements in real economic growth are not internationally uniform.
4. If it is concluded that the long wave does not exist in the real sphere, it has to be questioned if the long wave in prices can be regarded as an endogenous cycle.[57]

Forced by the economic events, we have to reflect on the theory of economic growth. The theory of equilibrium or steady growth gives insufficient insight into the structural economic problems in the 1970s and 1980s. A more dynamic theory of structural economic growth is needed. Several economists think that the theory of the long wave offers a better framework for interpreting and explaining the present economic situation. Van Duyn emphasizes that "all insights acquired from the long wave about human

57 In our opinion the long wave in prices and monetary variables may be attributed to the economic consequences of the wars, the occurrence of which cannot be explained adequately by business cycle theories.

behaviour imply a total rejection of thinking in terms of equilibrium."[58] This is, however, only partly true, for in a sense the concept of the long wave also implies a determinism: every rise will, after some time, be followed by a decline, and the other way around. This means that the present economic decline will be followed by a rise after some 20 to 30 years, if governments do not succeed in shortening this interval.

In our opinion the concept of the long wave leads away from the real complex and ever-changing dynamics of the process of structural growth in capitalist economies. In order to get a better insight into the long movements in economic life, it is necessary to drop the long wave concept and to concentrate our scientific energy on the understanding of long movements which can really be found.

APPENDIX

This appendix surveys the composition and the sources of the time series which are used in our analysis of economic growth in Great Britain, France, (West-) Germany and the United States. For each of these countries series are constructed for:

- industrial production, including mining, construction, gas and electricity;
- gross national product, market prices (volume);
- gross investment, including inventories (volume);
- exports (volume);
- imports (volume);
- wholesale prices (general).

In some cases we had to use series with slightly different definitions; those cases will be mentioned.

GREAT BRITAIN

Industrial production

(a)	1750–1855	Hoffmann (1965), p. 285.
(b)	1856–1938, 1946–1952	Feinstein (1972), p. T111.
(c)	1953–1977	International Financial Statistics (IFS) (supplement 1971, may 1979, october 1978).

Ad a: Hoffmann gives only a series of industrial production, including construction which has been smoothed twice by method of a 10-year moving average. For that reason, we used the series of industrial production *excluding* construction which has not been smoothed by Hoffmann.

58 Van Duyn (1979), p. 5.

Gross national product

(a)	1830–1869	Calculated from data in Deane (1967), pp. 104–107.
(b)	1870–1948	Feinstein (1972), p. T8.
(c)	1949–1977	Mitchell (1975), pp. 790–795 (completed with data from Annual Abstract (1979)).

Gross investment

(a)	1830–1856	Deane (1968), pp. 104–107.
(b)	1857–1948	Feinstein (1972), p. T14.
(c)	1949–1977	Mitchell (1975), pp. 790–795 (completed with data from Annual Abstract (1979)).

Exports (domestic) and imports (general)

(a)	1796–1913	Imlah (1958), pp. 96, 205.
(b)	1914–1918	Feinstein (1972), p. T5.
(c)	1919–1933	Deane and Mitchell (1962), p. 329.
(d)	1934–1977	Yearbook of International Trade Statistics (1962, 1977).

Ad a: The missing observations of 1813 are estimated by interpolation.

Wholesale prices

(a)	1750–1796	Deane and Mitchell (1962), p. 469.
(b)	1797–1849	Deane and Mitchell (1962), p. 470.
(c)	1850–1875	Deane and Mitchell (1962), p. 474.
(d)	1876–1955	Mitchell (1975), pp. 736–740.
(e)	1956–1977	Monthly Bulletin of Statistics (june 1975, june 1979).

Ad a: Originally Schumpeter.
Ad b: Originally Gayer, Rostow, Schwartz.
Ad c: Originally Sauerbeck.

FRANCE

Industrial production

(a)	1815–1899	Mitchell (1965), p. 355.
(b)	1900–1977	Annuaire Statistique (1977), pp. 762, 763 (completed with data from Main Economic Indicators, OECD, oct. 1978).

Ad a: Originally Crouset.

Net national product

(a)	1901–1913, 1920–1948	Annuaire Statistique (1977), pp. 762, 763.
(b)	1949–1977	IFS (may 1977, march 1979).

Investment

(a)	1896–1913, 1922–1938	Carré *et al.* (1976), p. 528.
(b)	1949–1977	Annuaire Statistique (1977), pp. 792, 793 (completed with data from Main Economic Indicators, oct. 1978).

Exports

(a)	1896–1913	Carré *et al.* (1976), p. 246.
(b)	1913–1970	Annuaire Statistique (1977), pp. 762, 763.
(c)	1971–1977	IFS (october 1978).

Imports

(a)	1913–1970	Annuaire Statistique (1977), pp. 762, 763.
(b)	1971–1977	IFS (october 1978).

Wholesale prices

(a)	1798–1948	Mitchell (1975), pp. 736–738.
(b)	1949–1977	Annuaire Statistique (1977), pp. 762, 763.

GERMANY (since 1945 West Germany)

Industrial production

(a)	1850–1913, 1925–1938	Calculated from data in Hoffmann (1965), pp. 33, 451.
(b)	1948–1977	IFS (1971 supplement, may 1977, october 1978).

Ad a: Hoffmann's series of industrial production, which excludes mining, is corrected with his series of mining. The weights are derived from the shares in net value added in the years 1882, 1907 and 1932, which are also used as base-years by Hoffmann.

Net national product

(a)	1850–1913, 1925–1938	Hoffmann (1965), p. 825.
(b)	1951–1977	IFS (may 1977, october 1978).

Net investment

(a)	1850–1913, 1925–1938	Hoffmann (1965), p. 825.
(b)	1950–1977	Mitchell (1975), pp. 790–795 (completed with data from Main Economic Indicators, oct. 1978).

Exports and imports

(a)	1836–1913, 1924–1932	Hoffmann, pp. 530–537.
(b)	1933–1977	Yearbook of International Trade Statistics (1962, 1977).

Ad a: Hoffmann warns that these data are unreliable because of many changes in definition and territory.

Wholesale prices

(a)	1792–1921, 1924–1966	Mitchell (1965), p. 737.
(b)	1967–1977	Statistical Yearbook (1977).

Ad a: The observations of 1922 and 1923 are missing because of the hyper-inflation.
Ad b: Index of prices of industrial goods.

UNITED STATES

Industrial production

(a)	1860–1953	Long term economic growth (1965), p. 168.
(b)	1954–1977	Federal Reserve Bulletin (july 1971, november 1978).

Ad a: Excluding construction; originally Nutter.
Ad b: Excluding construction.

Gross national product

(a)	1889–1929	Long term economic growth (1965), pp. 166, 167.
(b)	1930–1977	Survey of Current Business (july 1977, may 1979).

Ad a: Originally Kendrick.

Investment

(a)	1889–1929	Long term economic growth (1965), pp. 170–171.
(b)	1930–1977	Survey of current business (july 1977, may 1979).

Exports (domestic) and imports (general)

(a)	1879–1969	Historical statistics of the United States (1975), pp. 891–893.
(b)	1970–1977	IFS (may 1977, march 1978).

Wholesale prices

(a)	1750–1890	Historical statistics of the United States (1975), pp. 199–202.
(b)	1891–1969	Long term economic growth (1973), pp. 202, 203.
(c)	1970–1977	IFS (may 1977, october 1978).

Ad a: Originally, Warren and Pearson.
Ad b: Originally, Bureau of Labour Statistics.

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Summary

THE LONG WAVE – A REAL PHENOMENON?

To explain the decline in economic growth after the beginning of the 1970s, several authors have reverted to the theory of the 40- to 60-year-long Kondratieff cycle. This article concentrates on the empirical foundations of this cycle. After a critical survey of the important investigations by Kondratieff, Imbert and Van Duyn, the thesis of the long wave is subjected to a new test on the basis of time series of indicators of real

economic growth in Great Britain, France, (West-) Germany, and the United States. The results of this investigation are clearly negative with respect to the existence of a long wave in real variables in these countries.