SERIE RESEARCHMEMORANDA

KONDRATIEFF LONG WAVES IN AGGREGATE OUTPUT?

An Econometric Test

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Researchmemorandum 1983-12 October '83

VRIJE UNIVERSITEIT
EKONOMISCHE FAKULTEIT
AMSTERDAM

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Paper for the Meeting on Long Waves, Depression, and Innovation: Implications for National and Regional Economic Policy, Siena/Florence, Italy, 26-29 October 1983, organized by the International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria, and the Istituto Regionale per la Programmazione Economica della Toscana (IRPET), Florence, Italy.

Acknowledgements

The research underlying this paper has been subsidized by the Dutch Ministry of Science Policy (Wetenschapsbeleid). The authors would like to thank J.B.D. Derksen, P. Nijkamp, F.C. Palm, A. van Ravestein and J. Reijnders for reading and commenting on the first draft of this manuscript. The responsibility for the final version of the text is exclusively that of the authors.

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INTRODUCTION

The performance of most Western economies during the last decade has promoted renewed interest in research on the so-called Kondratieff long waves with a supposed wave length of some 45 to 60 years. According to the time schedule of the Kondratieff wave, the period from the 1890s up to about World War I, as well as that from the late 1940s to the early 1970s would have to be considered as prosperous phases of the long wave, whereas the crisis phenomena of the last decade would be consistent with the Western economies having entered a new downturn of the long wave, comparable with the downturn of the inter-war period. If we extrapolated that scheme in quite a simplistic and mechanistic way, it would be tempting to conclude that a new revival of the world economy is to be expected somewhere between the late 1980s and the middle 1990s. However, it is not our intention to further advance or substantiate such speculations. Neither is it the task of this paper to give an account of the large variety of hypotheses concerning the existence and possible causes of long waves. Nonetheless it has to be mentioned that the concept of long waves it subject to considerable discussion and research effort.[1)] The range of opinions reaches from more or less full acceptance of the hypothesis[2)] through cautiously critical statements[3)], up to outright rejection[4)].

1) See, for example, the discussion between Weinstock, Mensch and Nullau in WIRTSCHAFTSDIENST 56, April 1976, or more recently the contributions in: Schröder/Spree (ed.) (1981), Petzina/Van Roon (ed.) (1981), or in FUTURES (1981).

2) Van Duijn (1979, 1983), Glismann et al. (1978, 1981), Mandel (1973) and (1980).

3) Kuczynski (1978, 1980), Metz (1983), Kleinknecht (1981), Spree (1978), Rosenberg (1983).

4) Weinstock (1964, 1976), Milward (1981), Van Ewijk (1981, 1981a), Van der Zwan (1980).

As in the 1920s, there is again a concentration of long wave research in the Netherlands[5], but there are also some contributors from other countries who deserve to be mentioned[6].

Basically, the discussion centers around the question of whether the alleged long waves do exist, not only in monetary and price series but also in 'real' variables such as industrial output, GNP, etc. Whereas long waves in the former are not seriously questioned, several authors have expressed considerable doubts about long waves in the latter[7]. Moreover, among those who tend to be convinced that a Kondratieff-like pattern of fluctuations does exist, it is still debatable whether to conceive them as being driven by exogenous or by endogenous forces. Assuming exogenous factors behind the long wave is consistent with the waves being historically unique events that are not necessarily to be repeated in the future; an endogenous explanation would imply a regular recurrence of the wave and some prognostic importance of the long wave hypothesis. Only in the latter case can we speak of true cycles.

It might be argued that debating the above points does not make much sense as long as there are serious doubts about whether long waves do exist at all. There is then some need to test the Kondratieff hypothesis more rigorously.

The present paper will be restricted to this task. We shall present a new method for testing whether there are fluctuations over time that fit into the time schedule of Kondratieff long waves, and whether the amplitudes of such fluctuations are strong enough to be considered significant. Our testing method will be applied to series on aggregate

5) Broersma (1978), Van Duijn (1979, 1983), Van Ewijk (1981, 1981a), Kleinknecht (1981a), Van Paridon (1979), Namenwirth (1973), Reijnders (1983), Van der Zwan (1980).
It might be doubted whether Schumpeter did justice to the early Dutch contributors on long waves (Van Gelderen, 1913, De Wolff 1924, 1929) when introducing the term 'Kondratieff long waves'. Given the quality and timing of the Dutch publications we could equally speak of a Van Gelderen or a De Wolff cycle. However, these authors remained less well-known, since they mainly published in Dutch language.

6) Coombs (1983), Forrester (1977), Freeman et al. (1982), Graham/Senge (1980), Ray (1980), Rostow (1978), Rostow et al., (1979), Wallerstein (1979).

7) See, for example, Van der Zwan (1980) or van Ewijk (1981, 1981a) for the earlier discussion, see Garvy's critique of Kondratieff (Garvy, 1943).

industrial production and GNP of several major industrial countries. Not to bother the reader with a lot of details about time series construction, we shall use time series that have already been compiled by others (see table 1). The quality of these series is beyond our judgement.

Table 1. Time Series to be Used for Testing

Country	Variable	Time Coverage	Source
United Kingdom	Industrial Production	1801-1938 1946-1981	Mitchell 1981/OECD 1983
	Gross Domestic Product	1830-1979	Glismann et al. 1981
France	Industrial Production	1815-1913, 1919-1938, 1947-1981	Mitchell 1981/OECD 1983
	Net Domestic Product	1900-1913 1920-1979	Glismann et al. 1981
Germany	Net National Product	1850-1913, 1925-1941, 1948-1979	Glismann et al. 1981
Belgium	Industrial Production	1831-1913 1920-1939 1946-1981	Gadisseur 1979 Mitchell 1981/OECD 1983
U.S.A.	Gross National Product	1889-1979	Glismann 1981
Italy	Gross Domestic Product	1861-1979	Glismann 1981
Sweden	Gross Domestic Product	1861-1979	Glismann 1981
World (1)	Industrial Production (excl. Mining)	1780-1979	Kuczynski 1980/ Haustein et al. 1982
World (2)	Total Industrial Production (incl. Mining)	1850-1976	Kuczynski 1980

OUR MODEL

Research experience until now has shown that spectral analysis is not a very promising method for the analysis of long waves. In general, the available time series as compared with the length of the cycle we are looking for are much too short[8]. Furthermore, the outcomes of spectral analysis are quite sensitive to the method of trend elimination. The latter point also applies to 'classical' methods of separating time series into components as Glisman et al. (1978)[9] have done.

Therefore, we decided to choose a completely different method. We conceive of long waves as a succession of longer periods of accelerated versus decelerated growth. To be more exact, we ought to speak of 'trend periods' or 'mouvements de fonds' (Dupriez), or in Spiethoff's terminology of 'Wechsellagen', instead of using the term 'wave'. In the following, for pure convenience, we shall use the term 'A periods' for periods of accelerated growth, and periods of decelerated growth will be called 'B periods'. If the Kondratieff long wave hypothesis is relevant, it should be possible to demonstrate that the alleged A periods of the long wave have average growth rates that are significantly higher than the average growth rates of the preceding and following B periods and vice versa. The average growth rates will be computed from the time series cited in table 1.

There are two commonly used methods of establishing average growth rates: We can take either the logarithms of the geometric means or the slopes of the log-linear trend curves. Although the geometric means can be computed more easily, they have the disadvantage that the average growth rates depend only on the values of the beginning and end years of the periods. Therefore, we decided to use the slopes of the log-linear

8) See, for example, the experience of Kuczynski (1978).

9) It is possible, however, that a new method of determining trends in time series which has been applied most recently by our German colleague, Rainer Metz (1983), will bring a solution to that problem within reach; cf. for example the papers of Metz, Metz/Spree, Stier and Schulte in: D. Petzina/G. van Roon (ed.) (1981).

trend curves. With this method, the values of each year of the series are used, and the estimation is therefore less sensitive to disturbances in the series.
However, we decided to impose the following restrictions on the trend estimates: in the transition years ('peak' and 'through' years) the estimated values of the trends for the preceding and the following periods have to equal each other. This is consistent with the assumption that the transition from A to B periods and vice versa is not subject to erratic jumps in the absolute level of our variable.

To summarize the model verbally: We estimate log-linear trends for the different A and B periods, whereby the restrictions imposed guarantee a continuous 'zig-zag' pattern. The below defined Y_i are the estimated values in the transition years. Starting from the values in the transition years, we can reconstruct the complete 'zig-zag' line.

Mathematically our model can be written as follows:

T_o is the first year of the series,

T_m is the last year of the series,

$T_1,\ldots,T_{m-1}$ are the transition years ('peaks' and 'troughs' of the long waves)

$\ln y_t = a_i + b_i t$ is the log-linear trend formula for the i-th period consisting of the years: $T_{i-1},\ldots,T_i$
the restrictions for the trend estimates are:

$$a_i + b_i T_i = a_{i+1} + b_{i+1} T_i \quad \text{for } i = 1,2,\ldots,m-1$$

defining $Y_o = a_1 + b_1 T_o$ and

$$Y_i = a_i + b_i T_i \quad \text{for } i=1,\ldots,m$$

the model can be re-written without restrictions as:

$$\ln y_t = Y_{i-1} + (t - T_{i-1}) \left(\frac{Y_i - Y_{i-1}}{T_i - T_{i-1}}\right) \quad \text{with } t = T_{i-1},\ldots,T_i$$

or,

$$\ln Y_t = \frac{T_i - t}{T_i - T_{i-1}} Y_{i-1} + \frac{t - T_{i-1}}{T_i - T_{i-1}} Y_i$$

i.e. y_t is nothing but the weighted sum of the value of the beginning and end years of the period considered. The restriction discussed above requires that all the Y_i be estimated simultaneously.

If we now want to test whether the growth rates of two successive periods are equal we can test whether the slopes b are equal for the two periods.
Therefore the following condition has to be fullfilled:

$$\frac{Y_i - Y_{i-1}}{T_i - T_{i-1}} = \frac{Y_{i+1} - Y_i}{T_{i+1} - T_i}$$

This can be rewritten as:

$$Y_i = \frac{T_{i+1} - T_i}{T_{i+1} - T_{i-1}} Y_{i-1} + \frac{T_i - T_{i-1}}{T_{i+1} - T_{i-1}} Y_{i+1}$$

We need to add a disturbance term ε_t to the model. However, the existence of the medium-term 'classical' business cycle, among other reasons, suggests that the ε_t are autocorrelated. If we took no account of the existence of autocorrelation, the estimates of the Y_i would be unbiased, but their variances are likely to be biased; consequently, the significance levels of our test may be biased. Therefore, we apply the following tentative solution to the autocorrelation problem:
we start with an OLS estimation of the model to obtain the residuals. Then we estimate the autocorrelation pattern using the following formula:

$$\varepsilon_t = \sum_{i=1}^{n} \rho_i \varepsilon_{t-i} + u_t \quad \text{with: } u_t \sim N(0, \sigma^2)$$

(with n indicating the degree of autocorrelation)

Knowing the autocorrelation pattern, we re-estimate the Y_i with GLS (for the mathematical description of that method, see the appendix). Eventually we compare the autocorrelation pattern of the residuals of the GLS estimate with the previously obtained autocorrelation pattern. If both patterns match, we stop iterating ; if they do not, we have to continue the iterating process, taking the last obtained autocorrelation pattern and repeating the GLS estimate, and so on. Thus we actually obtain maximum-likelihood estimates.

DIFFERENCES BETWEEN OUR TEST AND TESTS BY OTHER AUTHORS

The advantage of our approach can be summarized as follows:

- Unlike attempts at applying spectral analysis (cf. Kuczynski 1982), Van Ewijk 1981) the reliability of our test outcomes is not crucially dependent on the mere length of the available time series.
- For our test we use time series from a larger range of countries than was done by Van Ewijk (1981, 1981a) or by Van der Zwan (1980). Whereas most of Van der Zwan's series end during the 1930s, our data also cover the more recent period, for which the long wave hypothesis appears to be most relevant.
- The study of Glismann et al (1981) has the advantage of also using a wider range of data. However, it shares with the Van Ewijk (1981a) study the weakness that the results are crucially dependent on the use of moving average methods, the effects of which are hard to control. Although we also included a nine-year moving average in our graphs for illustrative purposes, the test results on which we concentrate our interpretation do not depend on that method.
- In contrast with the methods of Kuczynski (1980) and Van der Zwan (1980), our estimates of growth rates explicitly take into account the existence of autocorrelation. Furthermore, our estimates are somewhat more 'stable' as we apply the restriction that the values of the estimated trends have to be equal in the transition years for the period preceding and following the transition year. As a consequence, our test is more robust against minor changes in the periodization of long waves.
- As opposed to authors who try to handle chronologies that are better adapted to the pecularities of individual countries (Van Duijn 1979, 1983 , Kuczynski 1980 , Van Ewijk 1981a). We concentrate our interpretation on quite a rigid time schedule that claims a relatively strict regularity and strong synchronization of long

waves in a world market context. This time schedule remains closely within the boundaries of long waves as given by Kondratieff. In the following, this time scheme will be discussed in more detail.

THE PERIODIZATION OF LONG WAVES

Table 2 offers a survey of long wave chronologies as given by Van Duijn (1983) to which we added the chronologies by Bouvier (1974), Amin (1975), and Kuczynski (1980). Given the variety of indicators and methods used by the different authors, it is astonishing that most of the chronologies nonetheless remain within the time schedule given by Kondratieff. Other than the position taken by Rostow for the most recent period, which is based on a different approach[11], important deviations from Kondratieff's chronology occur only in the chronology of Van Duijn and Clark, taking 1929 as the upper turning point of the third Kondratieff. Since we wanted to restrict the bulk of statistical documentation in this paper to a minimum, we did not test all the chronologies in table 2.[12]

Instead we made a selection. In principle, there are six chronologies in tabel 2 that are suitable for testing since they are carried up to the present. Among the latter, we decided to choose the one given by Mandel. The main reasons for this choice are the following. First, Mandels' chronology is closest to the dating of long waves as suggested by Kondratieff, i.e. it is the most 'orthodox'. Secondly, Mandel conceives his chronology as being valid for the Kondratieff wave as a world market phenomenon that can be applied to data on various countries without taking too much notice of national pecularities. Therefore, we can take his time schedule as an example of quite a rigid conception of long waves which claims a strong synchronization of the long wave process between countries in a world market context, besides implying a relatively strict regularity of the long waves.

11) See Rostow (1978); for a clarification, see Wallerstein (1979).

12) Anyone who would like to test a wider range of chronologies or other interesting time series may request the complete computer program (FORTRAN) from the authors.

Table 2 : Long wave chronologies according to various authors

	1st Kondratieff		2nd Kondratieff		3rd Kondratieff		4th Kondratieff	
	lower	upper	lower	upper	lower	upper	lower	upper
Kondratieff (1926)	ca. 1790	1810/17	1844/51	1870/75	1890/96	1914/20	-	-
De Wolff (1929)	-	1825	1849/50	1873/74	1896	1913	-	-
Von Ciriacy-Wantrup (1936)	1792	1815	1842	1873	1895	1913	-	-
Schumpeter (1939)	1787	1813/14	1842/43	1869/70	1897/98	1924/25	-	-
Clark (1944)	-	-	1850	1875	1900	1929	-	-
Dupriez (1947;1978)	1789/92	1808/14	1846/51	1872/73	1895/96	1920	1939/46	1974
Rostow (1978)	1790	1815	1848	1873	1896	1920	1935	1951
Mandel (1973)	-	1826	1847	1873	1893	1913	1939/48	1966
Van Duijn (1983)	-	-	1845	1872	1892	1929	1948	1973
Bouvier (1974)	-	-	1840	1865	1897	1913	-	-
Amin (1975)	1815	1840	1850	1870	1890	1914	1948	1967
Kuczynski (1981)	-	-	1850	1866	1896	1913	1951	1969

Compared with the Mandelian standard, the chronologies by the other five modern authors are certainly not less sophisticated. Actually they are somewhat 'softer', trying to adapt themselves better to the national characteristics of individual countries. Their main differences with Mandel are certainly related to the question of how to treat the two World Wars in a long wave context. In some countries we miss up to eleven year's data around World Wars I and II. In some other countries, the statistical series were continued throughout the war, but we do not know to what extent the data are influenced by pre-war armament booms, by the war economy, or by post-war reconstruction booms. In the case of Germany, it could, for example, be argued that during the first half of the twentieth century the data are biased against as well as in favour of the long wave hypothesis: the reconstruction effect after World War I (the 'golden twenties') as well as Hitler's armament boom caused an 'exaggeration' of growth rates during the interwar B period, whereas the pre-World War I armament race as well as the reconstruction effect of the 1940s and 1950s yield a higher level of growth rates in the A periods of the third and fourth Kondratieff. Under such circumstances, along with missing observations, a somewhat precise demarcation of long wave periods is extremely difficult.

In that situation, the inspection of the GNP series of Sweden may be of some help, since this country did not participate in either of the World Wars. Graph A7 of the appendix covers the Swedish GDP series from which (for illustrative purposes) we substracted a log-linear trend. The Swedish series suggests that the year 1913, as given by Mandel, seems indeed to be the appropriate transition year from the A to the B period of the third Kondratieff, and that the transition to the A period of the fourth Kondratieff should be dated quite closely around World War II. The year 1951 as suggested by Kuczynski is obviously too late. The impression from graphs A1-A11 in the Appendix for the different series and countries is consistent with interpreting the 'golden twenties' primarily in terms of a reconstruction boom, since the peak of 1929 is much stronger in countries that were directly involved in warfare as compared with such sountries as Sweden. Consequently, taking 1929 and/or 1951 as transition years would clearly bias our test against the long wave hypothesis[13].

13) This point is confirmed by a test run on our data using the Van Duijn and Kuczynski chronologies. The test outcomes are not documentated here; they can be requested from the authors.

A first test on the Mandelian scheme quickly revealed that 1966 and 1967 are obviously not adequate transition years to the present B period. It should be mentioned that Mandel's chronology was already developed during the early 1970s, and that today, with roughly a decade more of data, we can judge this point more easily and in a more reliable way. Therefore we changed the original Mandelian scheme, and took 1974 instead of 1966[14].

Furthermore, in contrast to Mandel's rigid time scheme, we used in several cases a 'softer' chronology. The latter was derived from the graphs in the Appendix. As an optical aid we used a nine-year moving average on the residues of the series after substraction of a log-linear trend. The turning point of the smoothed series which was nearest to Mandel's transition year was taken as an alternative transition year. In general, we would expect the 'soft' scheme to yield somewhat better significance levels than the 'hard' scheme of Mandel. This is in the same time to check to what extent our test is sensitive to smaller changes in the demarcation of A and B periods.

REMARKS ON THE INTERPRETATION OF THE TABLES

Before studying the results, four remarks have to be made .

First: For the period from 1974 onwards, all the estimates documented in different tables of this paper have tremendously high standard errors due to the low number of observations. This might explain that, in spite of remarkably declining growth rates in most series after 1974, significance levels remain poor. However, given the actual economic development, it is certainly realistic to expect that significance levels will become increasingly better if in future years we can include more and more data from the 1980s.

14) Other authors might have plausible reasons for taking earlier years such as 1973, the year of the oil crisis. We nonetheless took 1974, since this choice is consistent with Mandel's criterion of taking as an end point of a Kondratieff period the trough year of the last short-term business cycle belonging to the A or B period considered. The first year after that trough year is taken as a starting year of a new A or B period. According to the formal requirements of our test, we only took the trough year as a demarcation point between two periods.

Secondly: A similar problem applies to the beginning periods of the Italian and the Swedish series which start only in 1861 (instead of 1847) or for the NDP series of France, starting in 1900 (instead of 1893). The first estimate for the USA, covers only 4 years (1889-93) and should better not be interpreted.

Thirdly: All the test results documented in this paper are based on the assumption that a second degree of autocorrelation exists in the residues of the series. Given the relatively strong evidence of the 'classical' short-term business cycle from the 1820s-30s onwards, taking no account of autocorrelation is likely to bias our test seriously. In view of the allegedly sinus-shaped pattern of the short-term business cycle, the assumption of a second degree of autocorrelation seems to be most appropriate. To be quite safe, we repeated all the tests, assuming also a first, a third, and a fourth degree of autocorrelation. The results did not substantially differ from those obtained with a second degree of autocorrelation, i.e. the significance levels changed only slightly so that our conclusions would have been the same using a different degree of autocorrelation.

Fourth: There is one point in Mandel's chronology which is not clearly determined: he gives 1939 as well as 1948 as possible transition years to the A period of the fourth Kondratieff. Therefore, we tested all our series with Mandel's chronology, taking both 1939 and 1948. In interpreting the results, one property of our estimates of growth rates has to be kept in mind: We imposed a restriction on the estimation of trends such that the trend values of two subsequent periods are equal in the transition year, i.e. two subsequent trend periods intercept in their common transition year. This creates a kind of 'harmonica' effect: if one transition year is changed, this will influence the trend estimates for all the other A and B periods in the series, with the harmonica effect fading the further we move away from the altered transition year Therefore, taking 1948 instead of 1939 may bring about some change in the outcomes for the entire series. Tentative testing with slightly changed demarcation years showed, however, that, in general, the changes due to the 'harmonica' effect are not dramatic. Only in three out of our eleven series did the substitution of 1948 for 1939 bring notable changes in the significance levels:

- in the series for France, we got contradictory results: depending on whether we look at the GNP or at the industrial output series, or whether we take 1939 or 1948, we get significance levels respectively below and above the 95% level, and vice versa. Due to the unknown influence of World War II, it is hard to say which of the two transition years is more adequate.
- in the USA, World War II brought a strong boom; taking 1948 instead of 1939 would imply that we group this war-boom in the B period. This would obviously be a problematic decision that would bring down one significance level from 99% to 90%, and another from 99.8% to 95.8%.
- in the Swedish series, substituting 1948 for 1939 would have an enormously negative impact for several significance levels. However, from looking at graph A7 we can be safe in saying that 1948 would be much too late as a demarcation year.

Since, in general, 1939 appears to be the more realistic demarcation point, the test results based on Mandel's chronology with 1939 are documented in table 3. A comparable table based on the Mandelian scheme taking the year 1948 can be found in the Appendix. To allow for an illustrative check of the Mandelian periodization, we included in graphs A1-A11 of the Appendix the trend lines estimated with his time scheme (i.e. the trend estimates underlying table 3). It can be seen from these graphs, that in some cases the trend lines could be fitted a bit more perfectly, if we modified the Mandelian chronology so as to move either transition year a bit forward or backward in the series. As mentioned above, we have tried out some dating alternatives using the optical impression from the nine-year moving averages in the graphs of the Appendix. The outcomes from testing this 'softer' scheme are documented in table A2 of the Appendix. It becomes obvious from table A2 that our testing method is relatively robust against deviations from the 'hard' scheme.
Only in the case of Sweden do these changes ledd to a remarkable increase in one significance level (from 85.5% to 96.1%). In all other cases, significance levels are only slightly changed; in most cases this change is in the positive direction. In the following, we will therefore concentrate our interpretation on the results obtained from testing the 'rigid' Kondratieff chronology of Mandel. These results are given in table 3.

Table 3: Average Growth Rates for A and B Periods of the Long Waves, their Approximate Standard Errors, and the Significance of Differences in Average Growth Rates, According to Mandel's Long Wave Chronology

A and B Periods:		Country and Variable: World Ind. Prod. (1)	World Ind. Prod. (2)	Belgium Ind. Prod.	Germany NNP	France Ind. Prod.	France NDP	Sweden GDP	Italy GDP	USA GNP	UK Ind. Prod.	UK GDP
A: 1792-1825	g :	2.63%	-	-	-	0.13%	-	-	-	-	2.64%	-
	SE :	(0.25)	-	-	-	(1.32)	-	-	-	-	(0.25)	-
sign. of diff.:		1.1%	-	-	-	15.4%	-	-	-	-	2.7%	-
B: 1825-1847	g :	3.89%	-	1.99%	-	1.88%	-	-	-	-	3.47%	2.18%
	SE :	(0.35)	-	(0.62)	-	(0.59)	-	-	-	-	(0.23)	(0.42)
sign. of diff.:		34.9%	-	98.4%	-	38.8%	-	-	-	-	11.7%	59.3%
A: 1847-1873	g :	3.66%	2.32%	3.85%	2.52%	1.61%	-	3.02%	0.92%	-	3.00%	2.33%
	SE :	(0.32)	(0.36)	(0.33)	(0.57)	(0.48)	-	(0.57)	(1.21)	-	(0.20)	(0.25)
sign. of diff.:		66.2%	23.3%	99.9%	34.0%	56.9%	-	85.5%	61.1%	-	99.1%	76.9%
B: 1873-1893	g :	3.38%	2.80%	1.46%	2.95%	1.44%	-	2.20%	0.45%	4.27%	2.02%	1.95%
	SE :	(0.42)	(0.37)	(0.41)	(0.61)	(0.62)	-	(0.29)	(0.66)	(2.98)	(0.26)	(0.32)
sign. of diff.:		75.4%	45.8%	99.5%	43.6%	60.3%	-	98.6%	97.0%	46.9%	12.2%	29.7%
A: 1893-1913	g :	3.90%	2.73%	3.48%	2.77%	1.73%	2.81%	3.31%	2.65%	4.01%	1.47%	1.64%
	SE :	(0.42)	(0.36)	(0.44)	(0.63)	(0.60)	(1.87)	(0.26)	(0.62)	(0.53)	(0.26)	(0.32)
sign. of diff.:		99.9%	97.5%	99.9%	97.7%	96.9%	91.0%	96.8%	98.0%	99.0%	16.2%	93.8%
B: 1913-1939	g :	1.95%	1.63%	-0.19%	0.83%	-0.01%	-0.42%	2.55%	0.66%	2.16%	1.88%	0.88%
	SE :	(0.29)	(0.26)	(0.31)	(0.44)	(0.44)	(0.81)	(0.19)	(0.44)	(0.33)	(0.20)	(0.32)
sign. of diff.:		99.9%	99.9%	99.9%	99.9%	99.9%	99.9%	99.9%	99.9%	99.8%	99.9%	99.9%
A: 1939-1974	g :	4.68%	3.53%	3.30%	4.50%	4.83%	4.32%	4.46%	4.29%	3.80%	3.06%	2.52%
	SE :	(0.24)	(0.21)	(0.24)	(0.34)	(0.37)	(0.64)	(0.15)	(0.36)	(0.27)	(0.16)	(0.18)
sign. of diff.:		61.9%	50.8%	79.8%	77.4%	92.5%	52.4%	99.9%	64.3%	74.8%	99.9%	73.0%
B: 1974- ...	g :	3.94%	3.46%	1.95%	2.65%	1.95%	4.04%	-0.14%	3.26%	2.17%	-0.56%	1.64%
	SE :	(2.31)	(3.55)	(1.48)	(2.27)	(1.78)	(4.18)	(1.28)	(2.61)	(2.28)	(1.01)	(1.34)

g = estimated growth rate
SE = standard error of growth rate (calculated by a first-order Taylor approximation).

SUMMARIZING THE RESULTS OF TABLE 3

The results from testing Mandel's 'rigid' chronology can be summarized as follows:

- in Kuczynski's two series on world industrial production, as well as in the series for France, Germany and the USA, significance levels vary between fairly good and excellent from the 1890s up to the the present (with the exception of the most recent period for which we lack sufficient data for reliable testing).
  During the pre-1893 periods, there are no significant differences in average growth rates for the alleged A and B periods, and in several cases the variation of growth rates is even inverse to the one we would expect from a long wave view.
- as opposed to the dichotomy between the pre-1890s and post- 1890s pattern in the above-mentioned series, the Belgian industrial production series of Gadisseur reveals a highly significant long wave pattern from the 1830s up to the present.
- the outcomes of the GDP series for Italy and Sweden show a result similar to that of the Belgian data; i.e. from 1861 onwards growth rates vary in a way consistent with the long wave hypothesis. Only for the 1861 to 1873 period are significance levels below 95%, due to the high standard error of the estimate (incomplete coverage of the 1848 to 1873 period).
- very weak evidence for the existence of long waves comes from the two British series. As can be seen from a look at graphs A10 and A11 of the Appendix, the British series are dominated by a kind of very long-term life cycle of rising (1820s-1870s) and declining (from the 1870s onwards) world market hegemony of British industry. This pattern can also be discerned from the growth rates in the above table. The 'hegemonial' life cycle may have obliterated the Kondratieff long wave. Only from the inter-war period onwards is the British growth pattern consistent with the Kondratieff long wave hypothesis.

CONCLUDING COMMENTS

A comparison of the above results with those from previous studies clearly indicates the importance of testing the long wave hypothesis with time series from a larger range of countries. Kuczynski (1978, 1980) tested the hypothesis exclusively with his world series. Van Ewijk (1981, 1981a) and Van der Zwan (1980) concentrated heavily on British, U.S., French and German data (with Van der Zwan not even covering the post-World War II period). In our test, all these series proved indeed to have no long wave pattern in the pre-1890 period, and, in the British case, this holds even for the entire pre-World War I period. Consequently, the negative conclusions in the above-cited studies are not surprising.

On the other hand, although our outcomes are much more in favour of the long wave hypothesis, they do not allow us to share the full optimism of the study by Glisman et al. (1978). One of us has previously expressed some scepticism about the method of discerning long waves by Glisman et al. (1978) (see Kleinknecht, 1981; for a reply see Glisman et al., 1981). From the viewpoint of our above results, this scepticism is only partially confirmed. With the exception of the British series, we can say that, according to our test, and for roughly the last hundred years, all the series tested show a fairly significant long wave pattern. However, as opposed to the study of Glisman et al., our results remain ambiguous for the pre-1890 period. On the one hand, important series such as those on world production, or the data for Great Britain and France, give no support for long-term fluctuations of the Kondratieff type during the pre-1890 period; on the other hand, the Belgian data show a highly significant long wave pattern from the 1830s onwards; furthermore, evidence for long waves during the pre-1890 period comes from the Italian and Swedish data, although for shorter periods (from 1861 onwards).

There are several possibilities of dealing with the above ambiguity. Adherents of the long wave might argue that, in general, the further we go back in history, the less reliable our data will become. Here, an important argument could be derived from the Schumpeterian tradition, arguing with the role of young, innovative growth industries as a driving force behind the A periods. This Schumpeterian element of growth may be somewhat underestimated insofar as young industries often only draw the attention of statisticians once they have reached a certain minimum size. Naturally, if such as 'anti-Schumpeterian' bias should exist, it would be relevant rather for the 19th than for the 20th century. Still another argument could refer to the fact that only highly aggregated data haven been used for the above tests. A rather smooth pattern in aggregate data could still be consistent with the Kondratieff long wave having a 'primary impact on price, wage, and interest rate trends, on the sectoral composition (rather than volume) of investment, and on regional and international income distribution', as has been emphasized most recently by Rostow (1982, p. 82). However, this possibility, too, can only be mentioned without being investigated in this paper.

Summarizing the above points, three positions appear to be reasonable. One of them could be that the Kondratieff cycle is indeed relevant even before the 1890s, but it does not show up due to biased data, or due to high levels of aggregation, and so on.

A different position could be that it is not only bad data, but also the existence of movements temporarily stronger than the Kondratieff wave, that makes evidence in favour of the latter rather weak. Such an argument could refer to the already mentioned 'hegemonial' life cycle of Great Britain, the shorter-term Kuznets cycle, or the fact that countries entered their rapid growth 'take-off' phase at different times, some of them during the Kondratieff B periods.

Still a different possibility could be that the mechanism bringing about Kondratieff long waves is indeed not relevant for the infant phase of capitalism, and that the system had to reach a certain level of consolidation before it could produce such waves; i.e. the Kondratieff long wave would be <u>primarily</u> important for the era of 'Hochkapitalismus' and 'Spätkapitalismus'. The Kondratieff pattern from the 1830s onwards in the Belgian series does not strongly contradict this argument, since Belgium has been one of the forerunners in the industrialization process of continental Europe.

Principally, the outcomes of this paper are consistent with each of the three above propositions, and it is up to more detailed historical research to decide which is more realistic.

Finally, an important limitation of this paper has to be kept in mind: no evidence has been given for the existence of Kondratieff long waves as true cycles. The above test does give evidence that in several major industrial countries there are - at least since the 1890s - differences in average growth rates for A and B periods which excellently fit into the time schedule of Kondratieff long waves; and these differences are statistically significant. However, as already mentioned in the introduction of this paper, it can still be argued that these fluctuations are due to historically unique causes, and need not necessarily be repeated in the future. This argument is supported by the fact that, up to now, such a low number of A and B periods can be observed that merely quantitative proof of long cycles is just not possible for the time being. Therefore, we fully agree with the point made by Spree (1978) or Rosenberg (1983), that a concept of long cycles can only attain credibility if long cycle theorists develop theoretically convincing endogenous models of the long cycle; i.e. it has to be demonstrated that A periods necessarily develop into B periods, and vice versa.

As can be seen from the references in the above introduction, discussion around this topic has been quite vivid recently. The above results are sufficiently encouraging to continue that type of research work.

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APPENDIX

of the paper:

Long Waves in Aggregate Output?

An Econometric Test

Contents:

Appendix,

Table A1: Average Growth Rates for A and B Periods of the Long Waves, Their Standard Errors, and the Significance of Differences in Average Growth Rates, According to the Long Wave Chronology of Mandel

A and B Periods:		Country and Variable:										
		World Ind. Prod. (1)	World Ind. Prod. (2)	Belgium Ind. Prod.	Germany NNP	France Ind. Prod.	France NDP	Sweden GDP	Italy GDP	USA GNP	UK Ind. Prod.	UK GDP
A: 1792-1825	g :	2.63%	-	-	-	-	-0.001%	-	-		2.64%	
	SE :	(0.25)	-	-	-	-	(1.10)	-	-		(0.26)	
sign. of diff.:		1.1%	-	-	-	-	8.7%	-	-		3.8%	
B: 1825-1847	g :	3.89%	-	1.86%	-	-	1.90%	-	-		3.47%	2.20%
	SE :	(0.35)	-	(0.46)	-	-	(0.44)	-	-		(0.25)	(0.45)
sign. of diff.:		34.2%	-	99.9%	-	-	33.8%	-	-		13.7%	57.7%
A: 1847-1873	g :	3.65%	2.30%	3.86%	2.51%	-	1.61%	3.02%	0.89%		3.01%	2.32%
	SE :	(0.32)	(0.27)	(0.23)	(0.56)	-	(0.35)	(0.78)	(0.73)		(0.21)	(0.27)
sign. of diff.:		62.5%	13.4%	99.9%	33.1%	-	56.9%	78.7%	67.4%		98.5%	74.5%
B: 1873-1893	g :	3.43%	2.85%	1.48%	2.96%	-	1.48%	2.16%	0.45%	4.50%	2.04%	1.96%
	SE :	(0.42)	(0.28)	(0.29)	(0.61)	-	(0.46)	(0.44)	(0.35)	(3.20)	(0.28)	(0.34)
sign. of diff.:		62.5%	33.1%	99.9%	40.4%	-	54.5%	89.8%	99.9%	41.2%	8.6%	23.5%
A: 1893-1913	g :	3.67%	2.64%	3.34%	2.70%	2.91%	1.57%	3.12%	2.61%	3.72%	1.36%	1.52%
	SE :	(0.40)	(0.26)	(0.30)	(0.60)	(1.35)	(0.44)	(0.40)	(0.31)	(0.62)	(0.27)	(0.33)
sign. of diff.:		98.4%	98.1%	99.9%	95.5%	96.4%	91.5%	53.9%	99.9%	90.0%	1.8%	75.8%
B: 1913-1948	g :	2.46%	1.89%	0.35%	1.28%	-0.01%	0.72%	3.06%	1.05%	2.65%	2.15%	1.20%
	SE :	(0.22)	(0.14)	(0.17)	(0.32)	(0.40)	(0.25)	(0.22)	(0.16)	(0.30)	(0.15)	(0.18)
sign. of diff.:		99.9%	99.9%	99.9%	99.9%	99.9%	99.9%	99.8%	99.9%	95.8%	99.9%	99.9%
A: 1948-1974	g :	5.29%	4.12%	4.20%	5.62%	6.02%	6.00%	4.53%	5.55%	3.83%	3.22%	2.83%
	SE :	(0.34)	(0.22)	(0.25)	(0.47)	(0.59)	(0.38)	(0.33)	(0.26)	(0.45)	(0.23)	(0.27)
sign. of diff.:		83.6%	72.3%	99.3%	95.9%	87.2%	99.8%	98.7%	98.8%	67.4%	99.9%	84.4%
B: 1974- ...	g :	2.78%	2.07%	0.75%	1.28%	1.58%	0.74%	0.45%	0.83%	2.55%	-0.72%	1.28%
	SE :	(2.36)	(3.33)	(1.21)	(2.20)	(3.48)	(1.54)	(1.61)	(1.88)	(2.58)	(1.09)	(1.38)

g = estimated growth rate
SE = standard error of growth rate

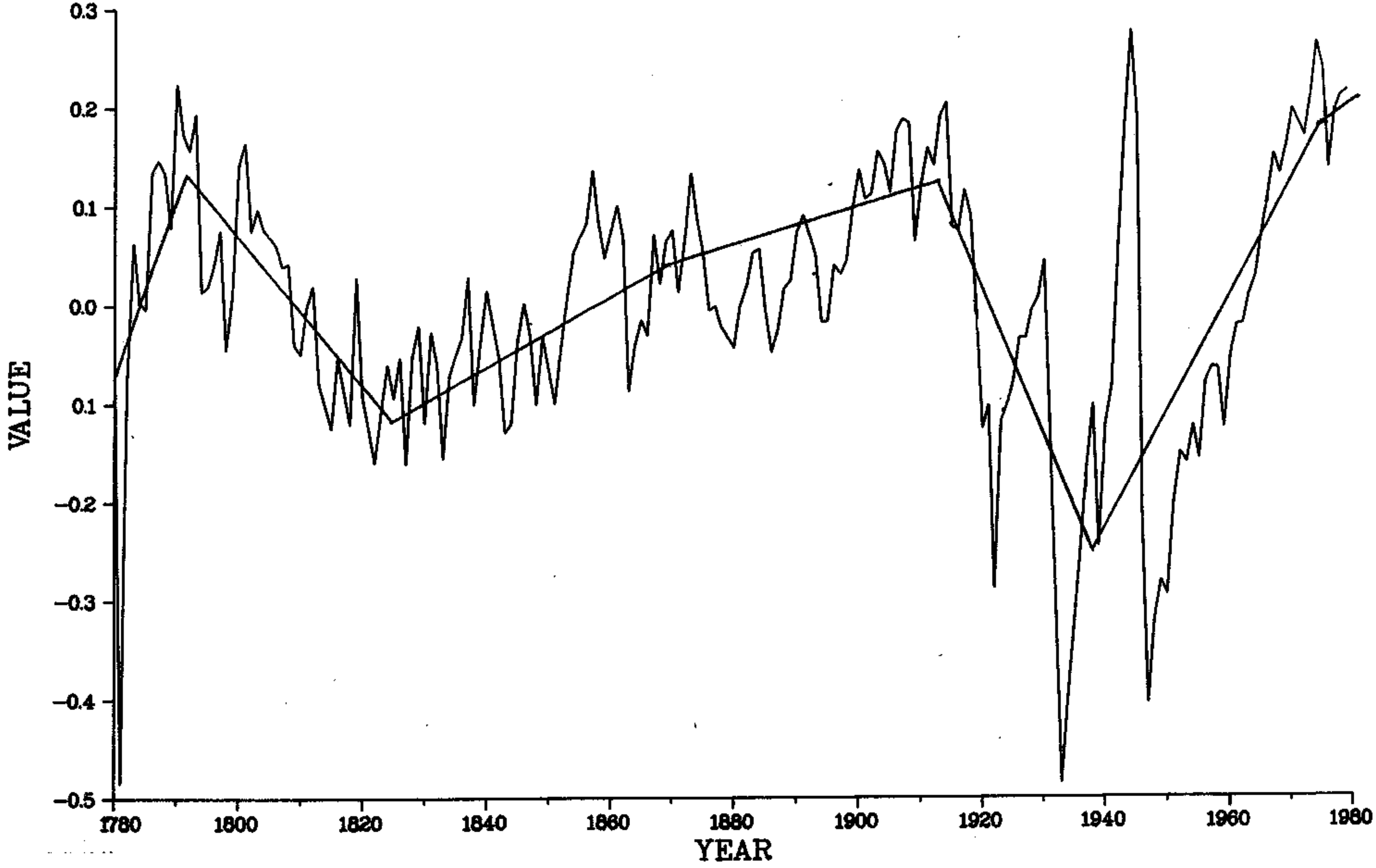
Appendix, Table A2: Average Growth Rates for A and B Periods of the Long Waves, Their Standard Errors, and the Significance of Differences in Average Growth Rates, According to Our 'Soft' Chronology

A and B periods \ Country and Variable:	Belgium (Ind. Production	World Ind. Production (excl. mining)	Germany NNP	Sweden (GDP)	Italy (GDP)	U.S.A. (GNP)
		1792–1825[1]				
A: growth rate :	–	2.63%	–	–	–	–
stand. error :	–	(0.24)	–	–	–	–
sign. of diff. :	–	1.0%	–	–	–	–
	1831–1847	1825–1847				
B: growth rate :	1.84%	3.87%	–	–	–	–
stand. error :	(0.46)	(0.34)	–	–	–	–
sign. of diff. :	9.9%	43.0%	–	–	–	–
	1847–1873	1847–1871	1850–1874	1861–1874	1861–1873	
A: growth rate :	3.92%	3.76%	2.95%	3.11%	0.74%	–
stand. error :	(0.24)	(0.35)	(0.57)	(0.42)	(0.71)	–
sign. of diff. :	99.9%	79.5%	83.0%	96.0%	51.9%	–
	1873–1889	1871–1883	1874–1882	1874–1891	1873–1898	1889–1893
B: growth rate :	1.15%	2.98%	1.24%	2.02%	0.70%	3.43%
stand. error :	(0.36)	(0.68)	(1.39)	(0.26)	(0.28)	(2.85)
sign. of diff. :	99.9%	82.8%	86.9%	99.9%	99.9%	64.9%
	1889–1913	1883–1910	1882–1913	1891–1912	1898–1913	1893–1909
A: growth rate :	3.22%	3.82%	3.09%	3.41%	3.16%	4.67%
stand. error :	(0.25)	(0.28)	(0.39)	(0.20)	(0.43)	(0.61)
sign. of diff. :	99.9%	99.9%	99.8%	99.9%	99.9%	99.9%
	1913–1946	1910–1950	1913–1948	1912–1935	1913–1946	1909–1936
B: growth rate :	0.23%	2.54%	1.18%	2.24%	0.89%	2.03%
stand. error :	(0.17)	(0.17)	(0.31)	(0.16)	(0.18)	(0.28)
sign. of diff. :	99.9%	99.9%	99.9%	99.9%	99.9%	99.9%
	1946–1975	1950–1974	1948–1974	1935–1971	1946–1977	1936–1969
A: growth rate :	3.93%	5.51%	5.65%	4.46%	5.13%	3.85%
stand. error :	(0.22)	(0.35)	(0.47)	(0.11)	(0.22)	(0.24)
sign. of diff. :	96.5%	88.7%	95.9%	99.9%	89.7%	85.1%
	1975–1982	1974–1980	1974–1980	1971–1980	1977–1980	1969–1980
B: growth rate :	1.07%	2.44%	1.33%	1.38%	–0.33%	2.62%
stand. error :	(1.42)	(2.30)	(2.18)	(0.66)	(4.10)	(1.02)

1) the growth rate for the 1740–1792 period is: 5.26 (0.86).

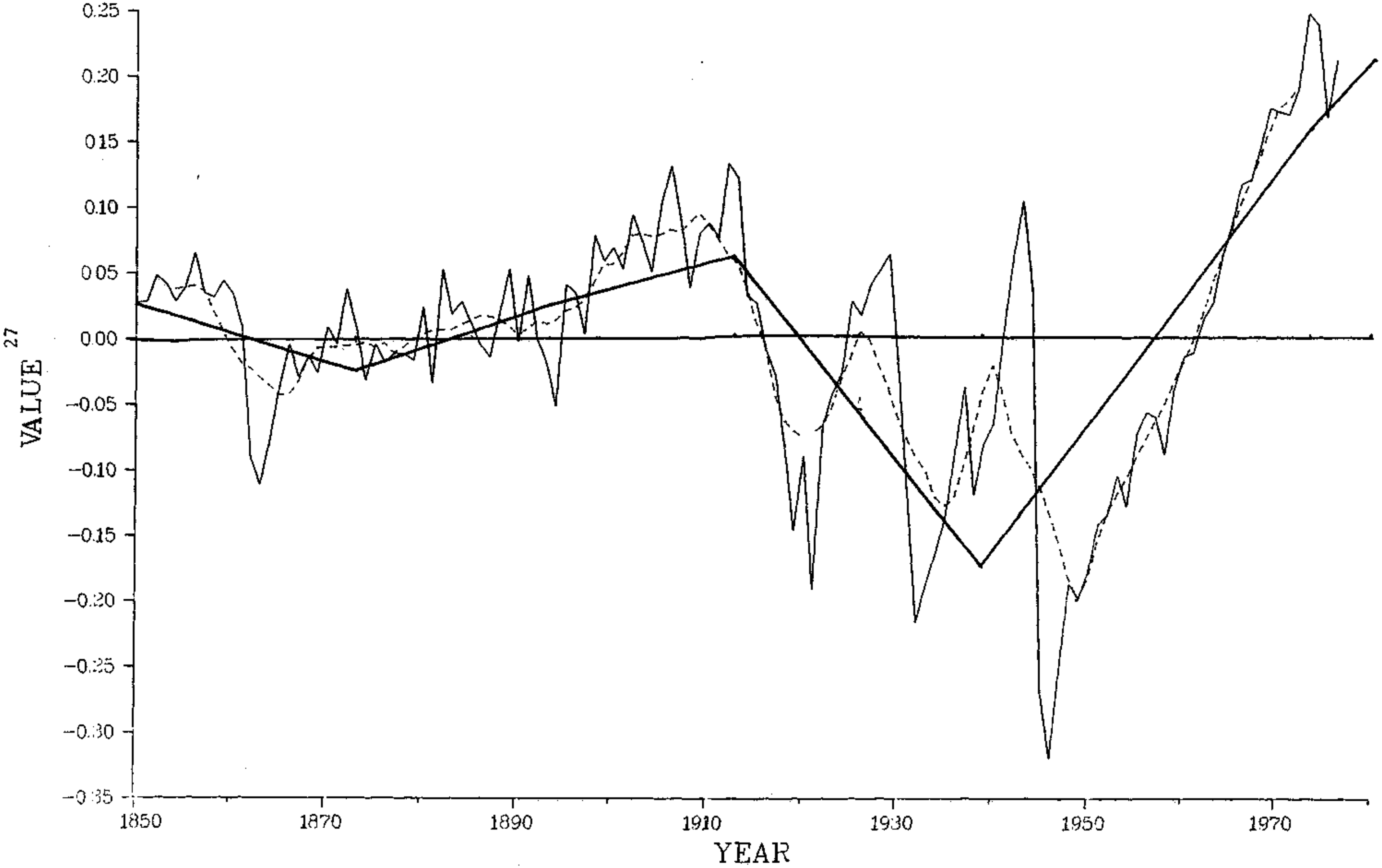
Graph A1 : World Industrial Production (1) (excl. Mining)

DETRENDED WITH −58.76806 + 0.03366 * YEAR



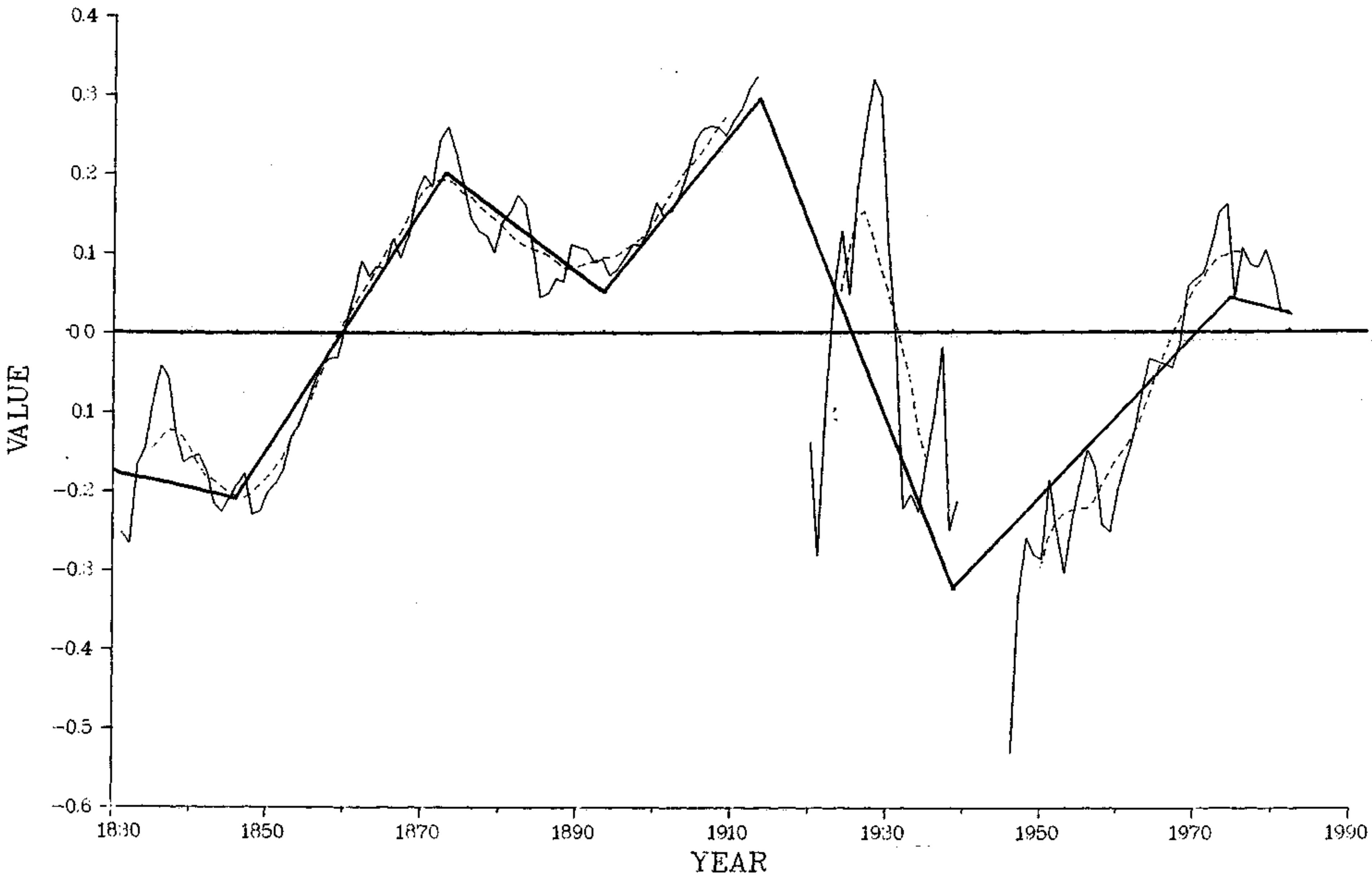
GRAPH A2 : WORLD INDUSTRIAL PRODUCTION (2) (incl. Mining)

DETRENDED WITH −41.62127 + 0.02519 * YEAR



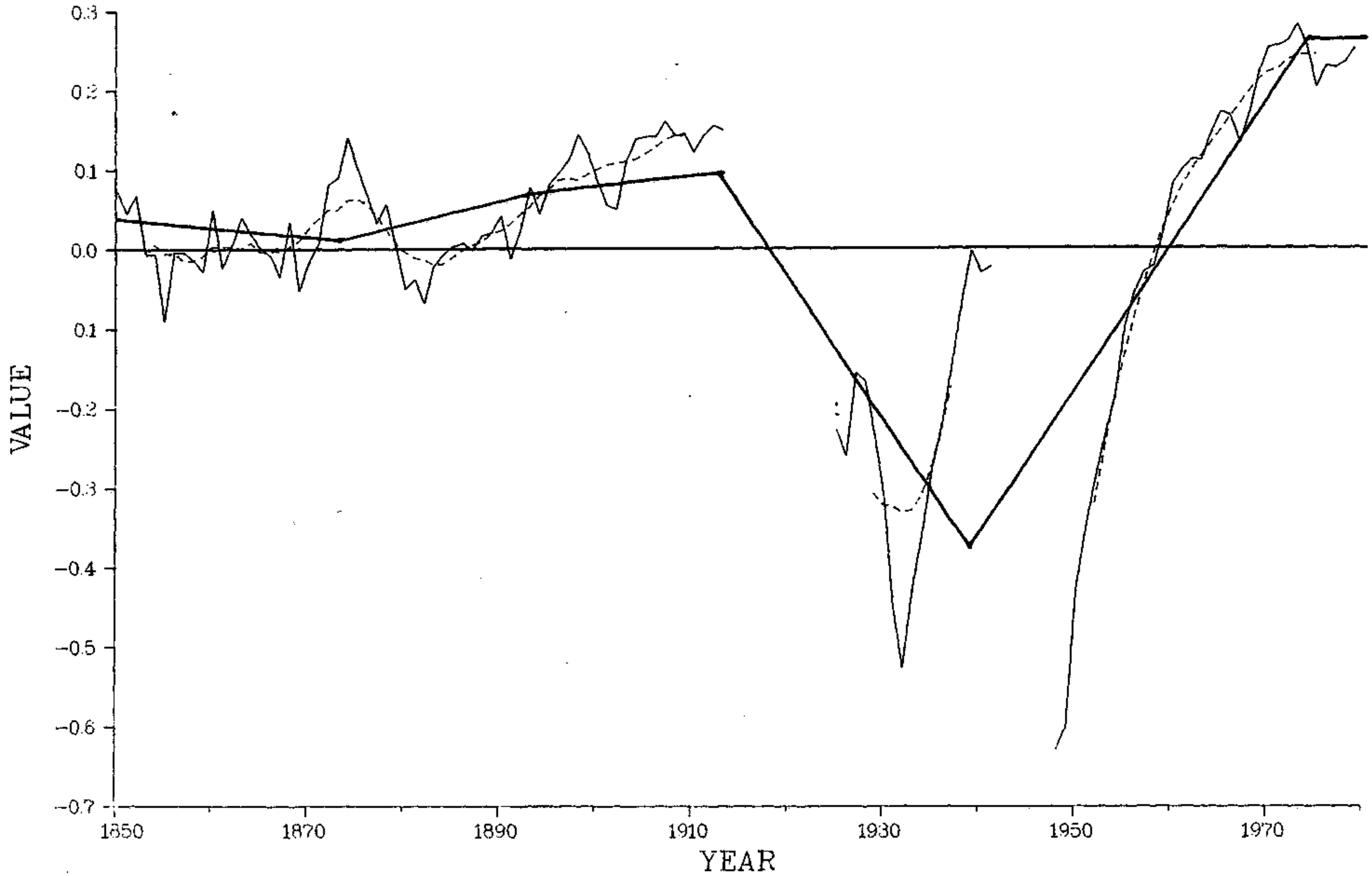
GRAPH A3: MANUFACTURING PRODUCTION OF BELGIUM

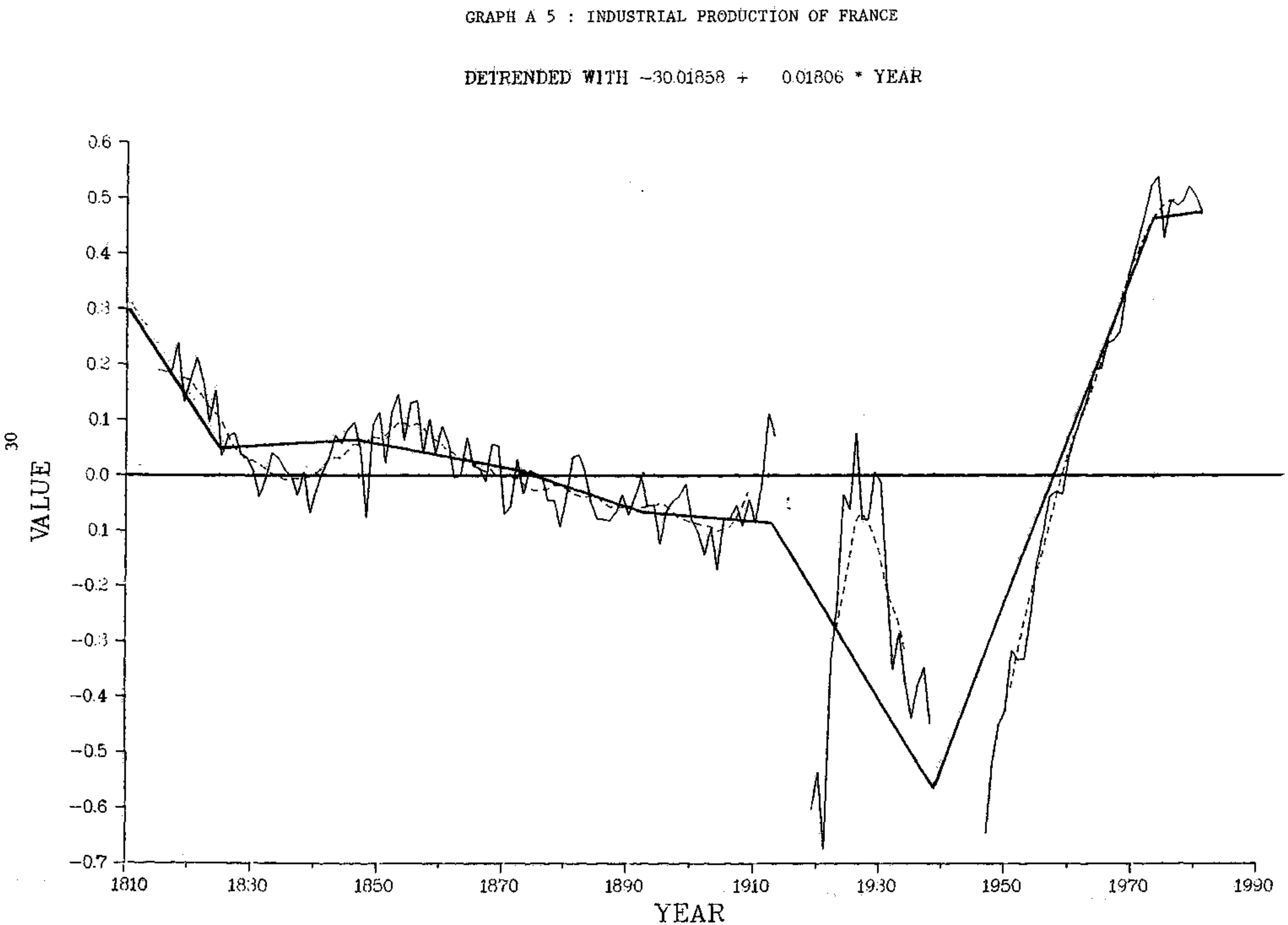
DETRENDED WITH −34.81527 + 0.02196 * YEAR



GRAPH A4 : NET NATIONAL PRODUCT OF GERMANY

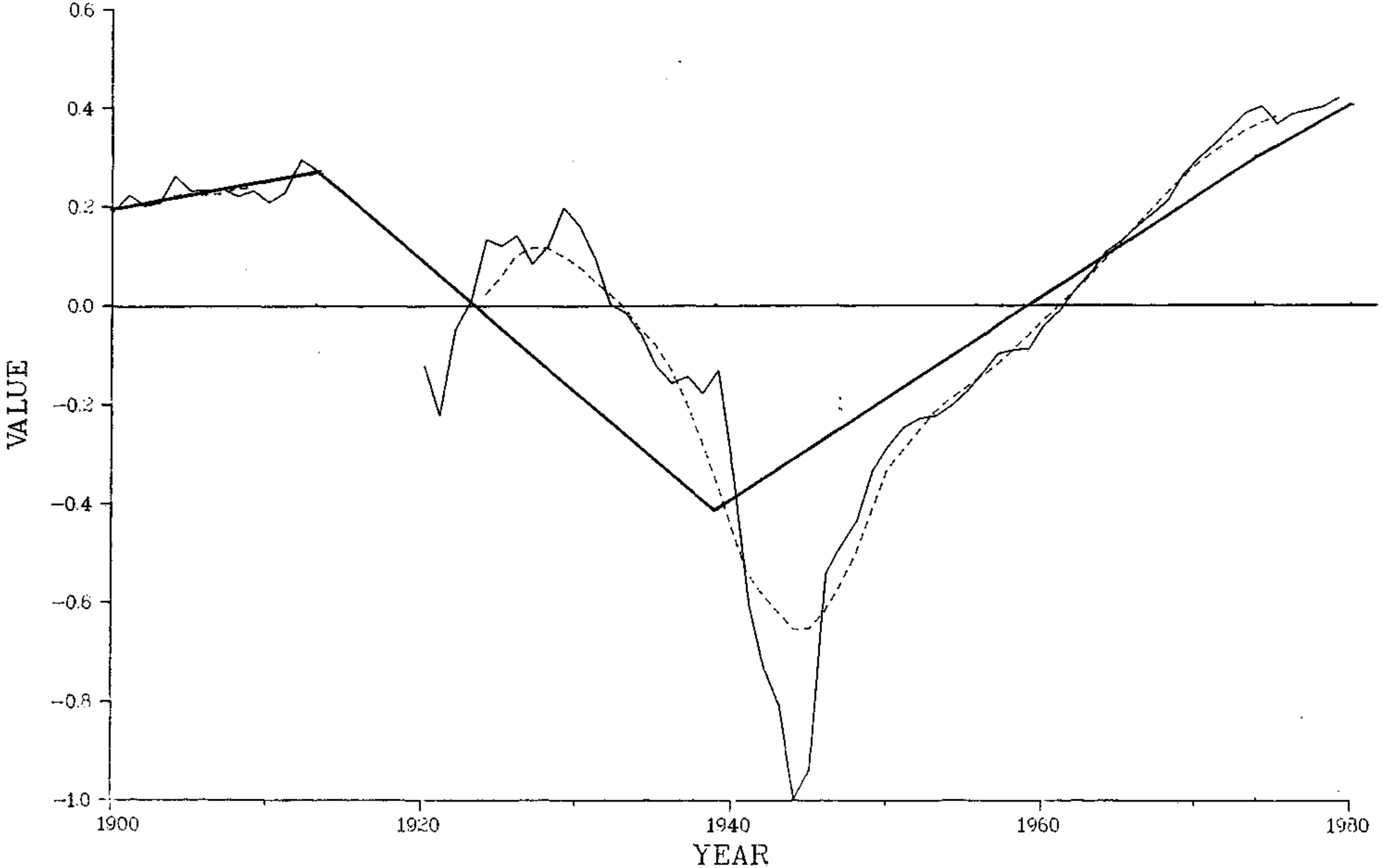
DETRENDED WITH −45.28196 + 0.02611 * YEAR




GRAPH A 5 : INDUSTRIAL PRODUCTION OF FRANCE
DETRENDED WITH -30.01858 + 0.01806 * YEAR
VALUE
YEAR
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
1810
1830
1850
1870
1890
1910
1930
1950
1970
1990

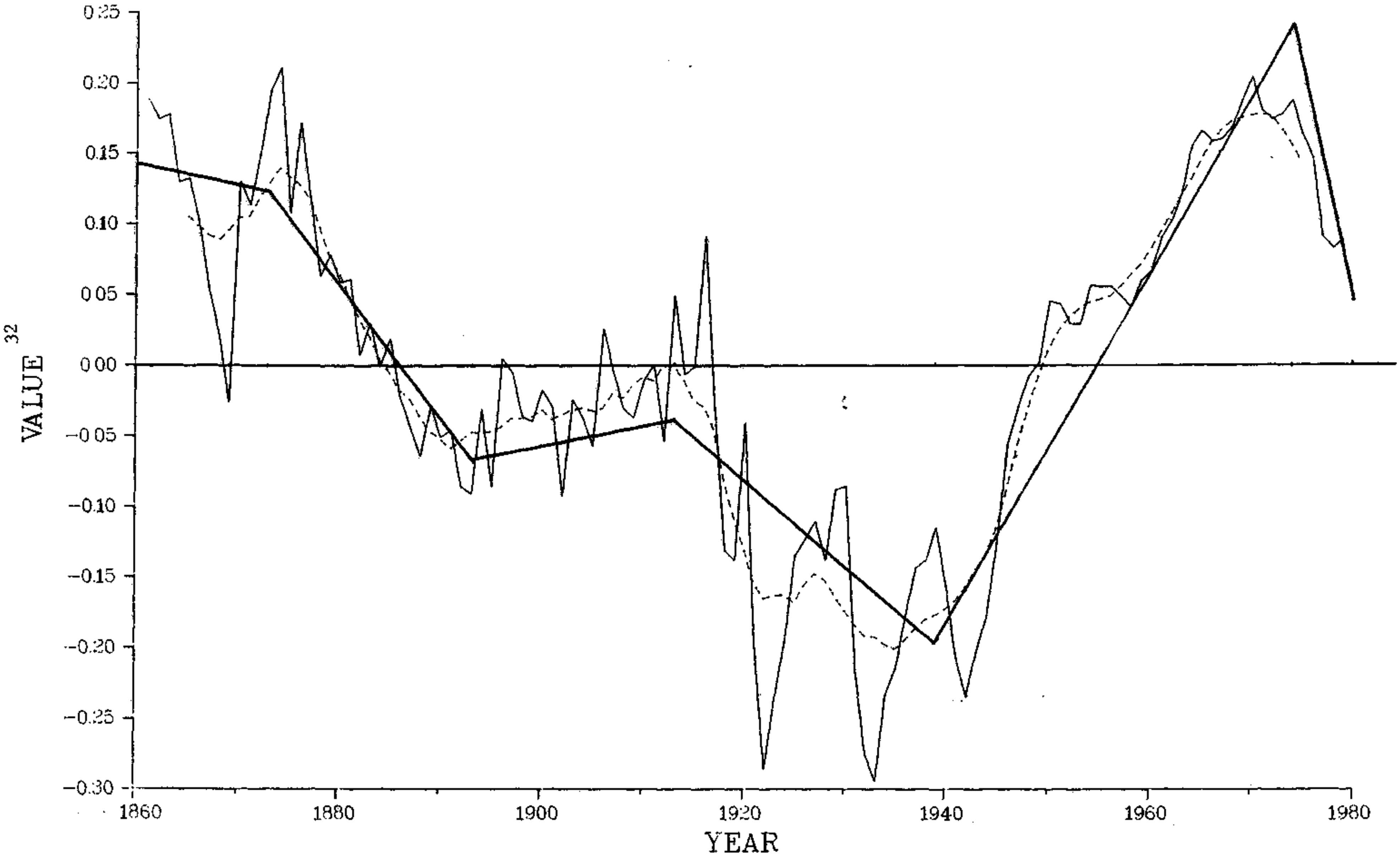
GRAPH A6 : NET DOMESTIC PRODUCT OF FRANCE

DETRENDED WITH −37.03963 + 0.02197 * YEAR



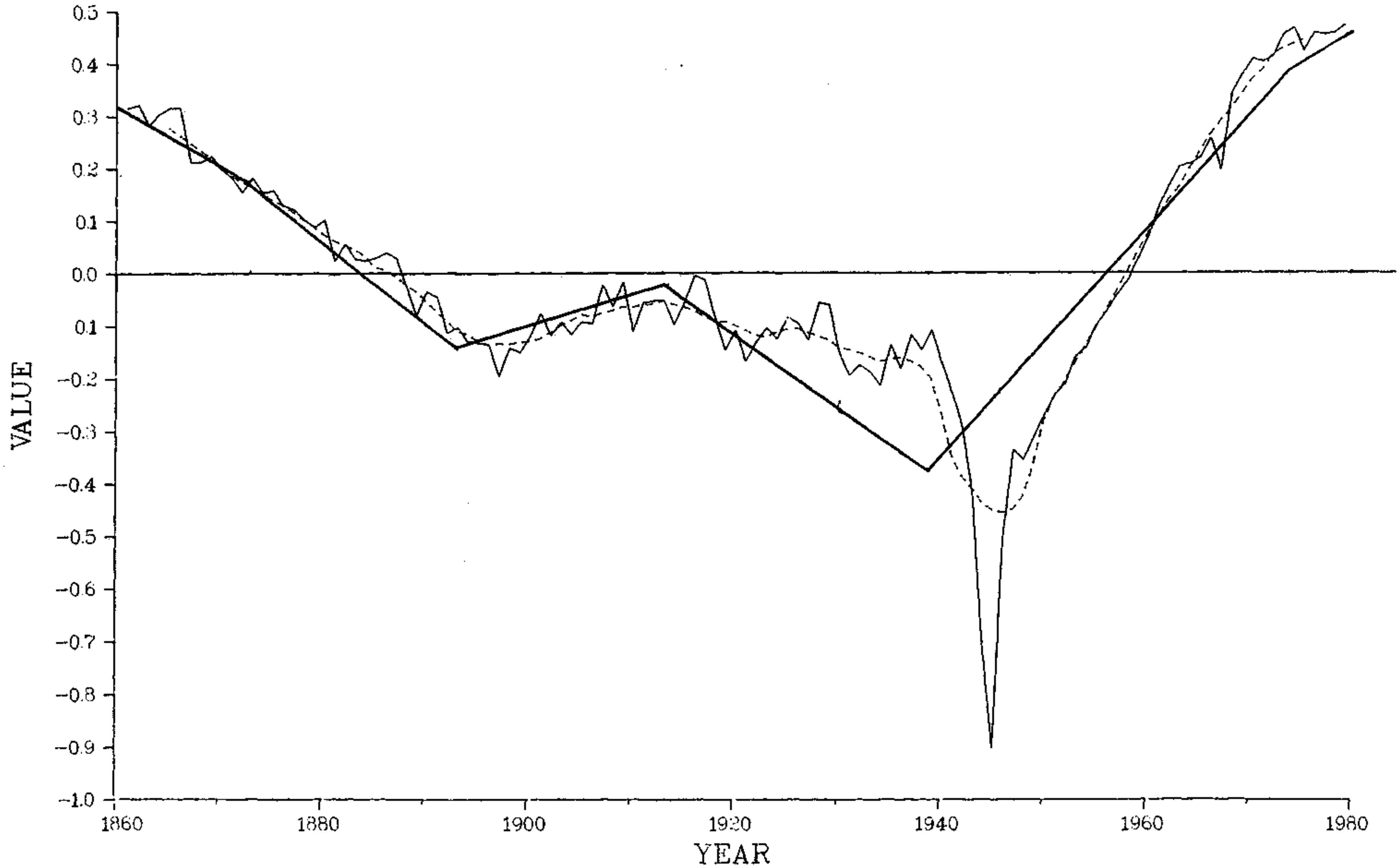
GRAPH A7 : GROSS DOMESTIC PRODUCT OF SWEDEN

DETRENDED WITH −56.54430 + 0.03121 * YEAR



GRAPH A8 : GROSS DOMESTIC PRODUCT OF ITALY

DETRENDED WITH −29.30348 + 0.02024 * YEAR



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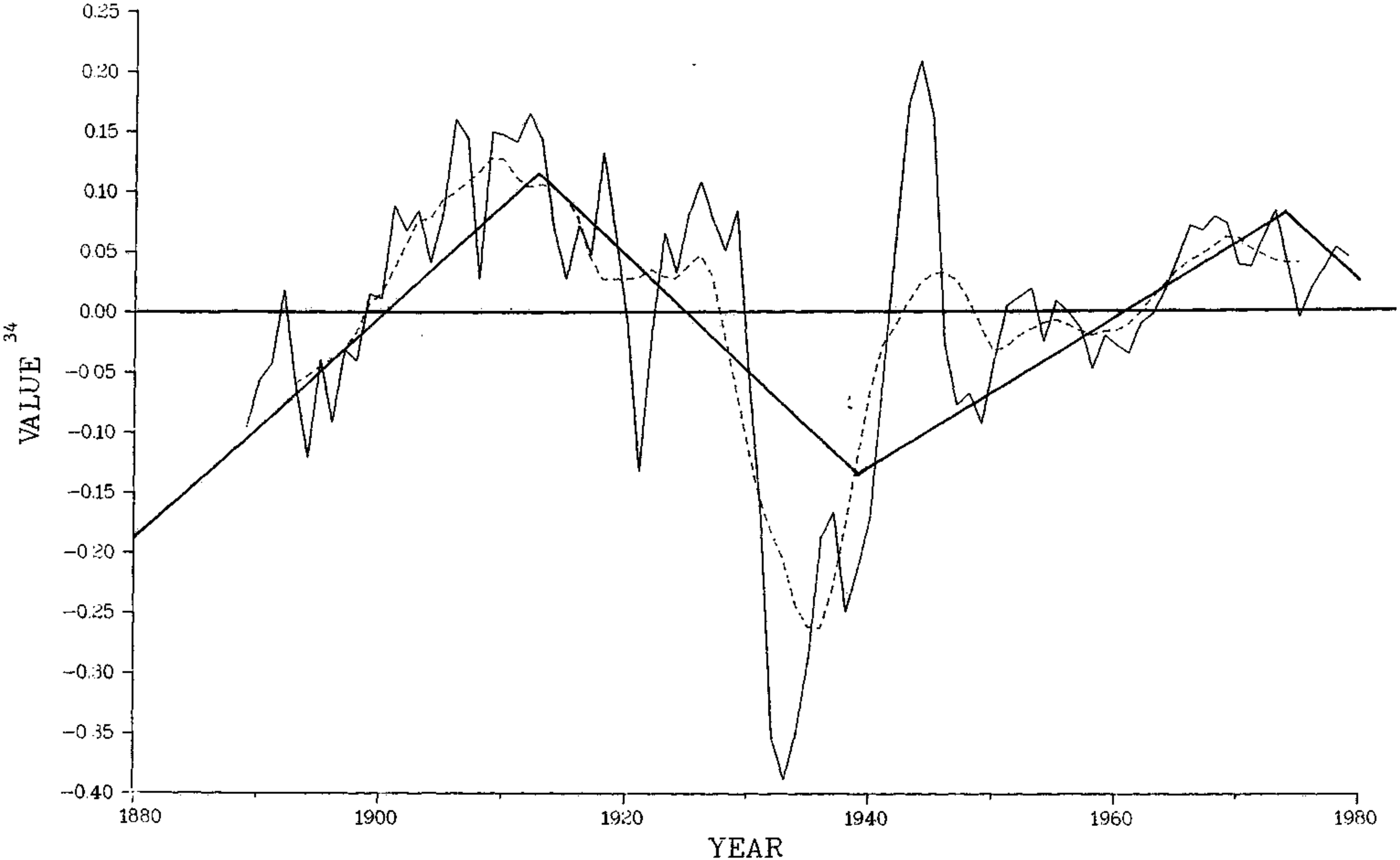
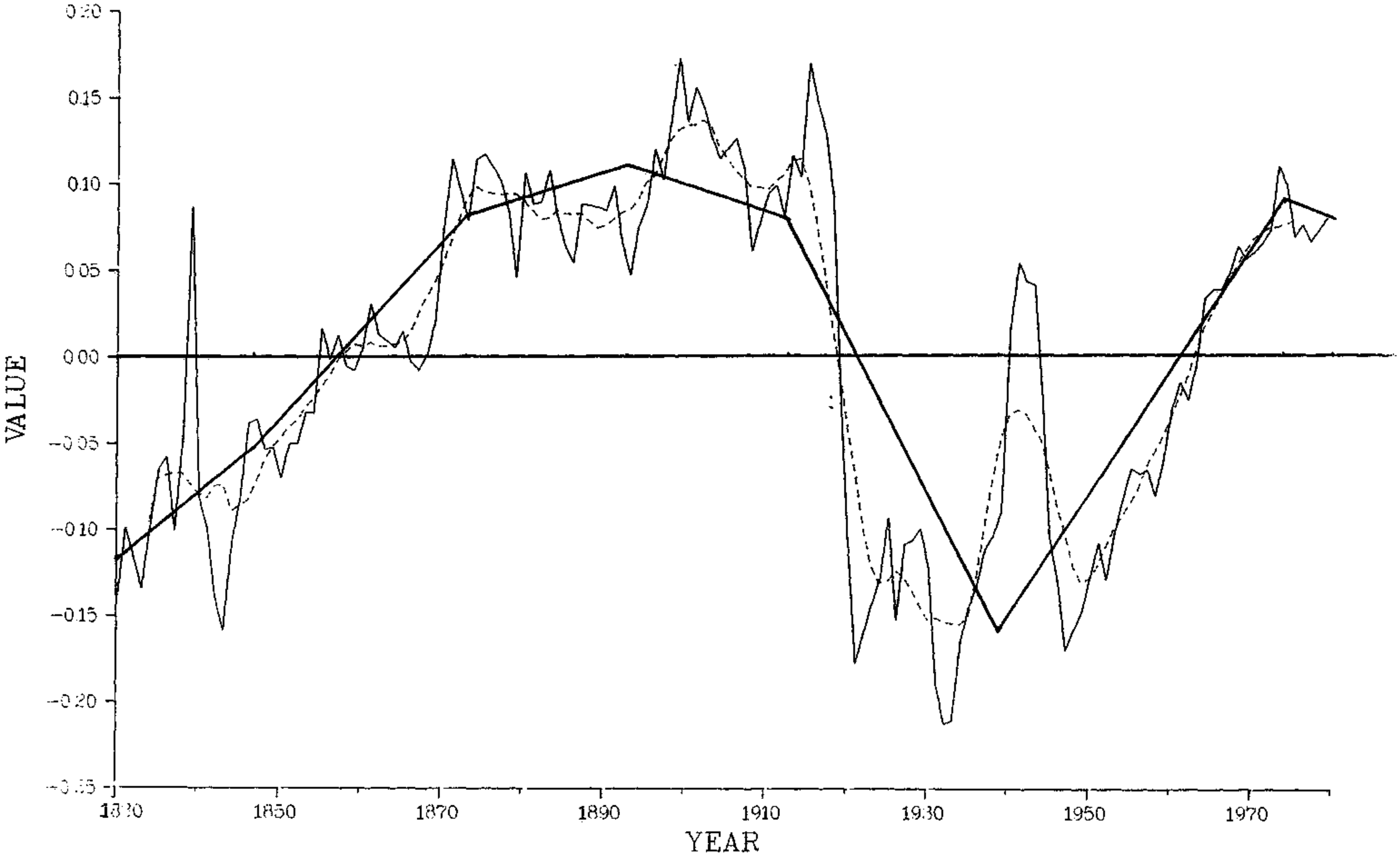
GRAPH A9 : GROSS NATIONAL PRODUCT OF THE U.S.A.

DETRENDED WITH −54.24515 + 0.03106 * YEAR



GRAPH A10 : GROSS DOMESTIC PRODUCT OF THE UNITED KINGDOM

DETRENDED WITH -31.30935 + 0.01785 * YEAR



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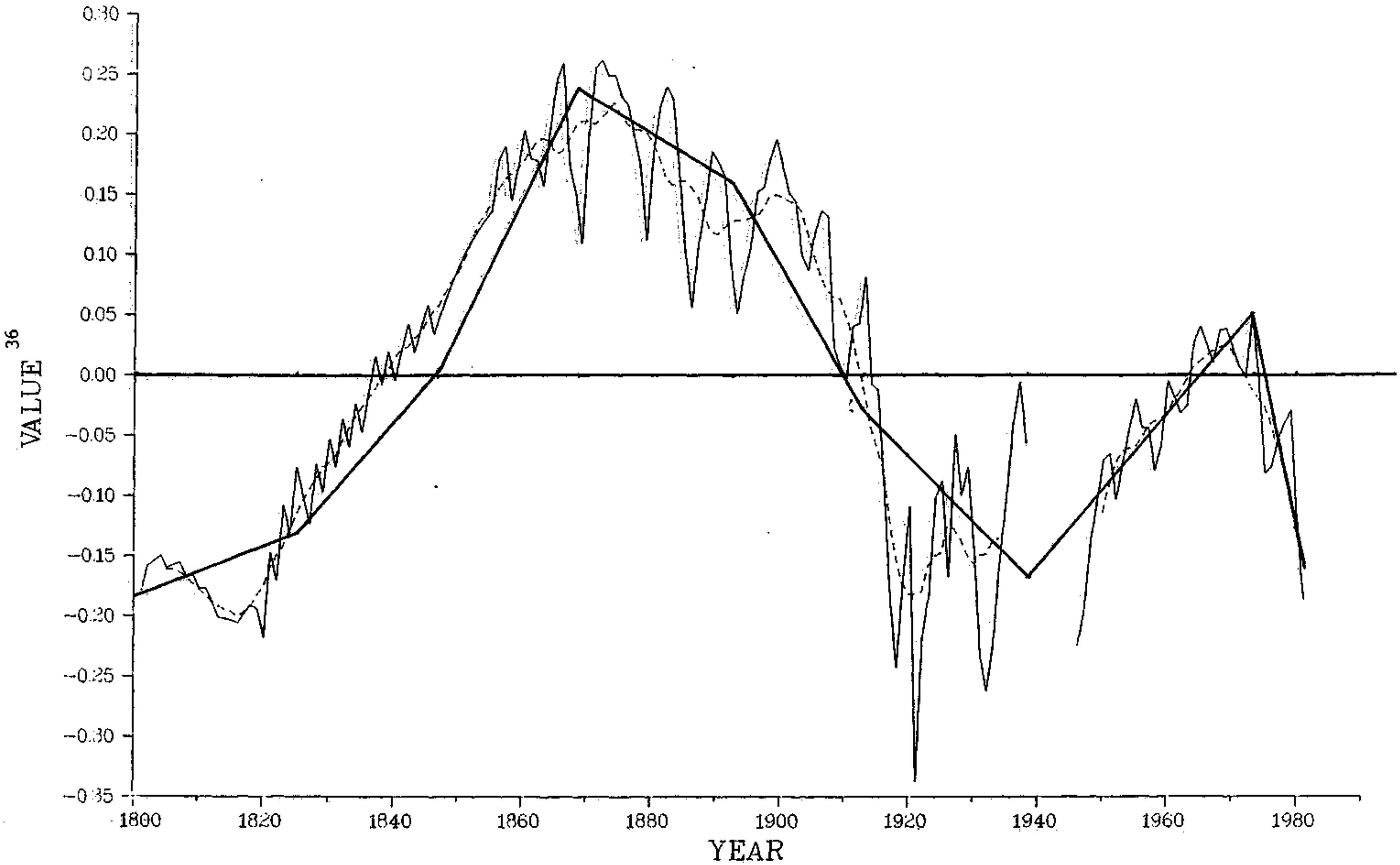
GRAPH A 11 : MANUFACTURING PRODUCTION OF THE UNITED KINGDOM

DETRENDED WITH −41.11218 + 0.02397 * YEAR



Appendix

Implementing the GLS estimate.

Knowing the autocorrelation pattern:

$$\varepsilon_t = \sum_{i=1}^{n} \rho_i \varepsilon_{t-1} + u_t \qquad (u_t \sim IN(0,\sigma^2))$$

it is possible to calculate the covariance matrix Σ and subsequently apply GLS. This is, however a time-consuming and computationally ineffecient method. It is known that there exists a triangular matrix V such that

$$V'V = \Sigma^{-1}$$

Therefore, V discribes a transformation, which, if applied to the residuals, gives us identical normally distributed non-correlated variables. We have now, in fact, shifted the problem of generating Σ to that of generating the triangular matrix V, describing the necessary transformation. The larger part of this transformation, however, follows directly from the rewritten autocorrelation pattern:

$$\varepsilon_t - \sum_{i=1}^{n} \rho_i \varepsilon_{t-i} = u_t$$

the right side of which consists of non-correlated disturbances, while the left side describes a row of the needed matrix V

$$[0,\ldots0,-\rho_n,-\rho_{n-1},\ldots,-\rho_2,-\rho_1,1,0,\ldots,0]$$

It can easily be seen that we always need the n values preceding the values to be transformed; this implies a loss of observations at the beginning of the time series and after possible interruptions (World Wars). It is certainly possible to avoid the loss of observations caused by the interruptions, but this requires a substitution process based on the assumption that the autocorrelation pattern remains unchanged during the interrupted periods. Given the disturbances of the economies by World Wars, this does not appear to be a very realistic assumption. Therefore, we preferred to describe the disturbances before and after the interruptions separately; this implies that we treat the time series as if, after the interruptions, the stochastic process had started anew. Therefore, in some cases, we would lose three times the n starting observations.

To avoid this loss we also need to find the n rows describing the transformation for the first n observations.
Clearly, this has to be done in a different manner. From the knowledge of the autocorrelation pattern we can conclude that the autocorrelation matrix Σ is symmetrical in both its diagonals. Therefore, its inverse Σ^{-1} must be symmetrical in both its diagonals as well. From the part of V we already know, and the fact that V is triangular, we conclude that V is a band matrix. But if V is a band matrix so is Σ^{-1}. With the part of V we already know we can calculate a part of Σ^{-1}. The other parts of Σ^{-1} are easily constructed using the symmetry and its band form. Once we have found Σ^{-1} we can easily complete V using the method of Choleski. After using V to transform the observations we can apply OLS on the transformed variables.