

"Long Waves" in English and German economies historical series from the middle of the sixteenth to the middle of the twentieth century

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“Long Waves” in English and German Economic Historical Series from the Middle of the Sixteenth to the Middle of the Twentieth Century*.

I. State of research and scientific interest

Upswings and downswings taking irregular courses, exhibiting both different rates of variation and changing directions, and which moreover manifest themselves in economic time-series, and thus indicate phases of prosperity and depression of capitalist economies, at least for the last 150–200 years, constitute the empirical background on which the current discussion about the phenomenon of “long waves” is taking place.¹ It is chiefly in recent discussions that the attempt has been made to integrate these long wave cyclical fluctuations into an approach which starts from the study of all relevant economic and social factors. This approach tries to find out, to what extent economic, political, and social events are dependent on such fluctuations.²

Although such an approach implies the conviction that it is worth while dealing with “long waves”, it should not be overlooked, however, that this conception has departed a long way from a view which regards ups and downs as the regular course of all economic and historical events.³ The hypothesis of a fundamentally cyclical course inherent in the system, which is basic to the classic theory,⁴ seems to be of mi-

* I owe much gratitude to my esteemed teacher Prof. Dr. Franz Irsigler for his engaged help and useful contributions to the discussion while I was composing this paper.

1. For the current discussion see *Petzina, D.; van Roon, G.*: *Konjunktur, Krise, Gesellschaft. Wirtschaftliche Wechsellagen und soziale Entwicklung im 19. und 20. Jahrhundert.* (Geschichte und Gesellschaft. Bochumer Historische Studien, Bd. 25) Stuttgart 1981; and *Schröder, W. H.; Spree, R.*: *Historische Konjunkturforschung.* Stuttgart 1980.
2. See Petzina's comments on this approach: “Lange Wellen” und “Wechsellagen”: Die derzeitige Diskussion. In: *Petzina/Roon*: *Konjunktur, Krise, Gesellschaft* (supra, n. 1), p. 17; as to the problems attached to such a view see *Schröder/Spree*: *Historische Konjunkturforschung* (supra, n. 1). Important impulses were given by *Hans Rosenberg's* book: *Große Depression und Bismarckzeit.* Berlin 1967, who attributed a twofold function to the long oscillations of the economic development. One of these functions was to be “reales Erkenntnisobjekt, ..., ebenso Ergebnis wie Anlaß von spezifischen Wirkungszusammenhängen; loc. cit., p. 19.
3. The evident trend phases constitute the actual object of investigation; the question whether they necessarily recur as cyclical fluctuations, or not, is of secondary importance.
4. This paper cannot claim to analyze the history of scientific dogmas; it must be pointed out, however, that *Kondratieff, van Gelderen* and others were of the opinion that the reasons for

nor importance in such an approach. Therefore the question whether there is a possibility of identifying long-term cycles with the aid of a statistical procedure independent of the object that is to be analyzed, appears to have become less significant.⁵

It is not very surprising in this context that the serious problems of an empirical test and conceptualization of "long waves", which have not yet been solved, have nearly always been ignored.⁶ Two important points should, however, not be left out of account:

- "Long waves" as they are discussed nowadays are regarded as a cyclical phenomenon and as actual indicators of the course of economic processes.⁷
- Serious methodical objections have been made against all attempts of finding empirical proofs of long-term cycles; for this reason, the empirical evidence of "long waves" is still regarded as an unsolved problem.⁸

This paper is conceived as a contribution to the discussion about the problems of a methodical-statistical proof of the existence of "long waves", and it introduces methods which to some extent have been completely newly developed to solve this problem.⁹ Whereas the exact determination of the trend has been the main problem of the treatises which have hitherto dealt with this topic, because only trend-free time series can be tested with regard to their cyclical structure, a method for the elimination of

the existence of "long waves" are necessarily inherent in the capitalist way of production and that there is no capitalist production which does not exhibit such a wavy course. See e.g. the very instructive comments by *Ekland, Klas*: Long Waves in the Development of Capitalism. In: *Kyklos* 33 (1980), pp. 383-419; or *Duijn, J. J. van*: De lange golf in de economie. Kan innovatie ons uit het dal helpen? Assen 1979, pp. 27-38.

5. *Stier*, however, holds the opinion that "die Frage nach geeigneten statistischen Verfahren eigentlich am Anfang aller Untersuchungen stehen muß", see *Stier, W.*: Zur Rolle und Funktion statistischer Verfahren in der empirischen Wirtschaftsforschung und der Wirtschaftsgeschichte. In: *Petzina/Roon*: Konjunktur, Krise, Gesellschaft (supra, n. 1) p. 297.
6. This is true of all treatises which take the existence of "long waves" for granted, but do not analyze empirical series statistically. See e.g. *Spree, R.*: Was kommt nach den langen Wellen? In: *Schröder/Spree*: Historische Konjunkturforschung (supra, n. 1), p. 305.
7. This fact is illustrated in *Petzina's* survey of research, *Petzina, D.*: "Lange Wellen" und "Wechselagen" (supra, n. 2). The approaches which put the trend periods at the centre of interest differ very much from this one. *W. W. Rostow* is probably the most exposed representative of this view, see his survey: *Kondratieff, Schumpeter and Kuznets: Trend Periods Revisited*. In: *Journal of Economic History* 35 (1975), cf. *Spree's* comments: Wachstumstrend und Konjunkturzyklen in der deutschen Wirtschaft von 1820-1913. Göttingen 1978, esp. pp. 32-97.
8. See the fundamental comments by *Stier, W.*: Zur Rolle und Funktion (supra, n. 5); and *Stier*: Die "langen Wellen" in der Konjunktur. Einige statistische Bemerkungen. In: *Wirtschaftsdienst* 1976 XII, p. 637 ff.; *Nullau's* article is also very instructive; *Nullau, B.*: Die Kondratieff-Wellen—Ein Slutsky Effekt? In: *Wirtschaftsdienst* 1976/IV. p. 177 ff.; cf. the methodical literature in n. 42.
9. The filter-methods developed by *Prof. Stier* and his team collaborators are mainly dealt with in this paper. The development of these methods is described in: *Stier, W.*: Konstruktion und Einsatz von Digitalfiltern zur Analyse und Prognose ökonomischer Zeitreihen. Opladen 1978; *Stier, W.*: Über eine Klasse von einfachen FIR-Tiefpass-Selektionsfiltern. In: *Allg. Stat. Archiv*, Heft 3, 1978. I would like to express my gratitude to Prof. *Stier* and Dr. *Schulte* for their useful help and support.

the trend is introduced in this paper which achieves the necessary exact determination of the trend.¹⁰ Clear hints as to the existence of "long waves" can only be gained with the aid of spectral analysis which is based on trend-free series.¹¹

The more important question concerning the shape and position of these long-term cycles within their historical dimension of time can only be solved if these clear hints are available. To represent the problem of proving the existence of "long waves" in such a way, is the only possibility of making a critical analysis of the postulated cyclical phenomena. The results of the analysis will show to what extent traditional conceptions which have sought to explain the phenomenon of "long waves" ought to be put in a new light and also, how the present state of research ought to be revised, or at least partly revised. The statistical methods introduced in this paper cannot, however, claim to be conclusive and, therefore, we hope that from the statistical standpoint the last word has not yet been spoken on this problem.¹²

The current discussion¹³ about long-term cycles is marked by extremely controversial views.¹⁴ In addition to the older treatises¹⁵ on "long waves", which in most cases made use of the historical-descriptive method, in subsequent years, diverse models

10. The fundamental work is *Schulte, H.*: Statistisch-methodische Untersuchungen zum Problem langer Wellen. = Schriften zur wirtschaftswissenschaftlichen Forschung, Bd. 135, Meisenheim 1981, and *Schulte*: Ein neuer statistischer Ansatz zur Identifizierung von Wellenbewegungen in der langfristigen Wirtschaftsentwicklung. In: *Petzina/Roon*: Konjunktur, Krise ... (supra, n. 1), pp. 300-322.
11. As far as I know, an analysis which makes use of modern filter methods has only been made once in: *Metz, R.; Spree, R.*: Kuznets-Zyklen im Wachstum der deutschen Wirtschaft während des 19. und frühen 20. Jahrhunderts. In: *Petzina/Roon*: Konjunktur, Krise ... (supra, n. 1) p. 343 ff. The recently published treatises which have been concerned with this problem are in most cases confined to a spectral analytical proof of "long waves". See e.g. *Bossier, F.; Hüge, P.*: An Empirical Examination of Long Cycles from Belgian Data. In: *Petzina/Roon*: Konjunktur, Krise... (supra, n. 1), pp. 331-342.
12. The empirical results will show that quite a lot of filter types are still needed to provide operable procedures for important scientific concepts.
13. Important aspects of this discussion can be found in the omnibus volumes publ. by *Petzina/Roon*: Konjunktur, Krise... (supra, n. 1) and *Schröder/Spree*: Historische Konjunkturforschung; also in *Delbeke's* short but instructive article *Delbeke, Jos.*: Recent Long-Wave Theories. A critical survey. In: *Futures*, Aug. 81, p. 246 ff.
14. On the one hand there is the opinion that it would be better "die 'langen Wellen' des Wirtschaftswachstums und der Konjunktur endlich zu begraben", see *Spree, R.*: Was kommt nach den "langen Wellen" (supra, n. 6), p. 314; on the other hand it is argued that "there certainly exists a prima facie case for the existence of Kondratieff cycles worthy of further investigation", Research Working Group upon Cyclical Rhythms and Secular Trends: Cyclical Rhythms and Secular Trends of the Capitalist World-Economy: Some premises, hypotheses and questions. In: *Review*, II (4), p. 487; cit. according to *Gordon, D. D.*: Stages of Accumulation and Long Economic Cycles. In: *Hopkins, T. K.; Wallerstein, I.*: Processes in the World-System. Beverly Hills, Calif. forthcoming.
15. See e.g. *Parvus, H. A.*: Die Handelskrise und die Gewerkschaften. München 1901; *van Geldern, I.; Fedder, I.*: 'Springvloed, Beschwingen over industriële ontwikkeling en prijsbeweging. In: *Die Nieuwe Tijd* 18 (1913); *Wolff, S. de*: Prosperitäts- u. Depressionsperioden. In: *Festschrift K. Kautsky*. Jena 1924, but also *Spiethoff, Schumpeter* and *Kuznets*.

have been designed which have regarded long-waved fluctuations as the essential and intrinsic course of capitalist economies.¹⁶

All these authors have aimed at proving those factors within the socio-economic process that cause the regular change from prosperity into stagnation, and vice versa. It is typical of all these models that they try to explain this phenomenon with the aid of a very small number of variables, which in turn are either defined as economic endogenous or exogenous factors.¹⁷ The essential point is, however, that both the empirical evidence of "long waves" and their specific length are assumed as a matter of fact, and as being determinable through experience. This circumstance is rather astonishing, considering the great number of serious objections to the procedures which have hitherto been used.

The main reasons why it is so difficult to give empirically exact proofs of "long waves" are the following: In order to prove "long waves" as a cyclical phenomenon it is absolutely necessary to dispose of very long series which ought to be several times as long as the postulated length of the cycles. In reality, it is, however, hardly possible to compile numerical expressions of identical phenomena over such long periods of time. That is either because the necessary sources are not available, or the economic variables have changed so much in meaning that the identity of the phenomena measured cannot be secured, regardless of the fact that methods of measuring and of collecting data permanently change.¹⁸

Even if one does not take these data-problems into consideration, and surmises, for example, that time series meet these requirements to a certain extent,¹⁹ the statistical proof presupposes an appropriate transformation of the scientific concept into a workable statistical proposition.²⁰ All attempts which have hitherto been made have

16. See *Delbeke's* survey: *Recent Long-Wave Theories* (supra, n. 13) and the article written by *H. van der Wee* and *J. Delbeke* in this book.

17. In this context, the meaning of basic innovations, capital-accumulation, over-investment, technological development, industrial concentration are discussed, although there is no common agreement on the decisive interrelationship between the variables.

18. These data problems especially arise, when the 20th century is the object of analysis, cf. the fundamental remarks on this problem by *Borchardt, K.*: *Wandlungen des Konjunkturphänomens in den letzten hundert Jahren.* = *Bayerische Akademie der Wissenschaften, Sitzungsberichte* Jhg. 1976, Heft 1. All relevant books point to the difficulties which arise, if one tries to compile statistical long-term series, cf. *Mitchell, B. R.*: *Statistischer Anhang 1700-1914.* In: *C. M. Cipolla; K. Borchardt* (Hrsg.): *Europäische Wirtschaftsgeschichte*, Bd. 4, Stuttgart/New York 1977; also see *van der Wee, H.*: *European Historical Statistics and Economic Growth.* In: *Explorations in Economic History* 13 (1976), pp. 347-351.

19. Especially with regard to grain prices of the pre industrial period, these requirements are in most cases fulfilled. If, however, series of price indices are used, considerable problems arise. See e.g. *van der Wee, H.*: *Prices and Wages as Development Variables: A Comparison between England and the Southern Netherlands 1400-1700.* In: *Acta Historiae Neerlandicae* 10 (1978), pp. 58-78.

20. The problems attached to such a transformation are discussed in statistics as so-called "adequacy problems"; see *Menges, G.*: *Ätialität und Adäquation. Dem Andenken an Heinrich Hartwig (1907-1981).* In: *Statistische Hefte* 22 (1981) Heft 2, pp. 144-149; *Bott, D.*: *Adäquationsprozeß und Entscheidungsproblem.* In: *Statistische Hefte* 22 (1981) Heft 1, pp. 2-24, general statements on these problems also in *Metz, R.*: *Theoretische Aspekte der stati-*

failed in achieving this adequate transformation, and as has been pointed out already, it should have been a matter of the statistician's scientific honesty to declare that the hypothesis formulated cannot, or cannot yet be proved for purely statistical reasons,²¹ for if one considers "long waves" as a cyclical phenomenon, as most of the older treatises do, to eliminate the trend as a non-cyclical course from the series, beforehand, cannot be avoided.²² Even a spectral-analytical proof of cycles of the "Konratieff-type" can only be achieved, if the series which is to be analyzed has a completely stationary, i.e. trend-free course. The procedures which have hitherto been used to eliminate the trend from the series were either only capable of determining the trend in such a way that if there existed any "long waves" they were eliminated, or as it happened with polynomial approximation, their way of operation could not be numerically tested.²³

In this context the following aspects are of great importance:

1. There is no generally accepted model to give a sufficient description of a cyclical course of this length, which may be caused either by endogenous, or exogenous factors. In consequence, the respective length of a cycle cannot be theoretically deduced.
2. The reduction of a model to a very small number of explanatory variables is unsatisfactory, both from a theoretical point of view, and within the historical context. Concerning the models to which these objections do not apply, or only partly apply, the fluctuations of the trend are at the centre of interest. This is for example true of Rostow's model, which exceeds all other models in its historical complexity;²⁴ Rostow has made the attempt to explain the historical trend-periods as the result of different combinations of variable factors.

It is commonly agreed that it is formally impossible to test, with the aid of empirical methods, whether the trend-periods have a cyclical course. Such a view of the problem consequently excludes the question of cyclicity of trend-periods because it cannot be checked.²⁵

stischen Analyse langfristiger Konjunkturschwankungen. In: *Petzina/Roon: Konjunktur, Krise ...* (supra, n. 1) and the literature given there.

21. This opinion is held by *Stier, W.*: Die "langen Wellen" in der Konjunktur (supra, n. 8), p. 637.
22. This adequate trend-elimination is the necessary prerequisite of any proof of "long waves"; apart from the above mentioned methodical literature, see *König, H.*; *Wolters, J.*: Zum Problem langfristiger Wachstumszyklen: Eine Spektralanalyse der englischen Entwicklung von 1700-1913. In: *Zeitschrift f.d.ges. Staatswissenschaft* 128 (1972), pp. 72-96.
23. This principally applies to all procedures which are neither linear, nor time-invariant. Although these procedures achieve an elimination of the trend, their effect both on the different oscillations (frequencies) and thus also on the "long waves" cannot be tested. See e.g. *Schulte, H.*: Ein neuer statistischer Ansatz (supra, n. 10) p. 303, and *König/Wolters: Eine Spektralanalyse* (supra, n. 22), p. 94.
24. Rostow gives a comprehensive description of this approach, *Rostow, W. W.*: *The World Economy. History & Prospect*. Austin, London 1978. Comments on this approach are given by *Holtfreich, C.-L.*: Wachstum I: Wachstum der Volkswirtschaften, in: *Handwörterbuch der Wirtschaftswissenschaften*, 17./18. Lfg. Stuttgart 1979, p. 413 ff., and *Spree, R.*: Was kommt nach den "langen Wellen" (supra, n. 6) p. 308 f.
25. A lowpass filter which achieves a clear separation between the low frequency bands would be the appropriate method to analyze trend-periods. As to the construction of such filters

3. An adequate statistical apparatus, which is a necessary prerequisite of such an empirical proof, was not available. As far as the methods which have hitherto been used are concerned, they have all failed in achieving a clear separation between the trend and the "long waves" and, therefore, no definite clues to the existence of "long waves" could be derived by means of spectral analysis.
4. In most cases, the material available does not meet the requirement of being uniform. The few long-term series available are highly disaggregated product and price series, which have only limited value as indicators of the relevant processes. Moreover, they necessarily span several phases of the structural change of the whole society, and thus simulate a structural uniformity, which in itself constitutes a historical problem.²⁶

The pessimistic tenor of these remarks is still enforced by the fact that all models of "long waves" cannot be sufficiently verified with the aid of statistical methods.²⁷ There are, however, several reasons why it is worth while making a new attempt to prove the existence of "long waves".

1. As long as a more or less great heuristic value is attributed²⁸ to long-term cycles of the "Kondratieff-type" both in history and in the analysis of the current economic development, an empirical test is absolutely necessary.
2. The filter-method above mentioned renders it possible to test the existence of "long waves" empirically, in a completely new way. The problem of eliminating the trend can be solved by means of this method.
3. The fact that we use highly disaggregated series guarantees that approximately identical phenomena are measured.
4. It is commonly agreed that long-term analyses are necessary and practicable. Although in most cases no continuous long-term series are used to this purpose, the intention is yet nearly the same; the derivation of informations about tendencies with special regard to structural peculiarities.²⁹

see *Stier, W.*: Verfahren zur Analyse saisonaler Schwankungen in ökonomischen Zeitreihen. Berlin/Heidelberg/New York 1980, p. 127f.

26. This opinion is held by *Knut Borchardt*: Wirtschaftliches Wachstum und Wechsellagen 1800–1914. In: Handbuch der deutschen Wirtschafts- und Sozialgeschichte, Bd. 2, hrsg. v. H. Aubin und W. Zorn, Stuttgart 1976, p. 200.
27. *Spreer, R.*: Was kommt nach den "langen Wellen" (supra, n. 2) p. 305.
28. This function seems to be increasingly attributed to long-term cycles, not only in treatises dealing with economic-historical topics, but also in the current economic-political discussion. Only a few examples can be mentioned here: *Fischer, W.*: Die Weltwirtschaft im 20. Jahrhundert, Göttingen 1979, p. 43; *Fels, G.*: Erklärungshypothesen zur internationalen Rezession. In: Die Rezession 1974/75—ein Wendepunkt der längerfristigen Wirtschaftsentwicklung? Symposium zum 50jährigen Bestand des Österreichischen Institut für Wirtschaftsforschung, hrsg. v. H. Seidel, F. Butschek, Stuttgart 1977, pp. 19–31; cf. the discussion on the approach of the Kieler working-group which is based on the "distribution-theory", *Glismann, H. H.*; *Rodemer, H.*; *Wolter, F.*: Lange Wellen wirtschaftlichen Wachstums (Replik und Weiterführung). In: *Petzina/Roon*: Konjunktur, Krise... (supra, n. 1), p. 66ff., as to the criticism of this concept, see the literature given there. Concerning the pre-industrial period see *Haan, H.*: Prosperität und Dreißigjähriger Krieg. In: Strukturprobleme der Frühen Neuzeit. = Geschichte und Gesellschaft, 7. Jhg. Heft 1, Göttingen 1981, pp. 91–118.
29. From the great number of books and articles dealing with this problem the following ones shall be mentioned: *Bairoch, P.*: Niveau de développement économique de 1810 à 1910. In:

The methods and results described in this paper can be regarded as the first attempts to prove oscillations of the "Kondratieff-type" within some selected long-term series. The intention of this paper exceeds all other research work which has hitherto been concerned with this problem in so far, as it intends to determine the shape and position of these long-term cycles. They will only be accepted as patterns of interpretation of economic and social developments if there is a possibility of characterizing them by their upswings and downswings, and their specific length within their historical dimension of time.

The analysis is confined to 9 time-series, which cover the space of time from 1531 to 1979.³⁰ 6 out of the 9 series are price series, which have only limited value as being representative of economic processes. This paper does not aim to test theoretical models of economic development but, on the contrary, tries to find clear clues as to the empirical evidence of "long waves" within economic time-series. As the empirical material on which the analysis is based also covers the pre-industrial period, it can be expected that the results achieved will give us some hints towards the model of "säkulare Wechsellen",³¹ which has been developed by agrarian history. Although the contents of the model of "Wechsellen", developed in reference to the pre-industrial period, fundamentally differs from the concept of "long waves", a descriptive comparison between the pre-industrial and the industrial period seems to be very promising, above all, as grain prices to which such a comparison should be confined represent an economic factor of the first rank for the pre-industrial period.³²

Pragmatic aspects were decisive for the choice of the time-series.³³ In particular, we have analyzed the following series:³⁴ Wheat and rye prices from 1531-1959 as indicators of the development of grain prices in the "Deutsches Reich", wheat prices from Exeter/GB (1531-1938), and a price index of English vegetable agrarian products (1661-1938) as indicators of the movement of prices of agrarian products in Great Britain; one indicator for both, the English coal and cotton-yarn production

Annales E.S.C. 15 (1965); *Bairoch, P.*: Europe's Gross National Product: 1800-1975. In: The Journal of European Economic History 5 (1976), pp. 273-340; *Maddison, A.*: Long Run Dynamics of Productivity Growth. In: Banca Nazionale de Lavoro Quarterly Review 32 (1979).

30. As to the description of the empirical material see the comments in the appendix.

31. This kind of model which was mainly developed by W. Abel has recently been discussed in connection with the dynamics of the feudal production, see e.g. *Kriedte, P.*: Spätfeudalismus und Handelskapital. Göttingen 1980; *Kriedte, P.*: Spätmittelalterliche Agrarkrise oder Krise des Feudalismus. In: Strukturprobleme der Frühen Neuzeit. = Geschichte und Gesellschaft 7. Jhg. Heft 1, 1981, pp. 42-68. Without further discussing the problems attached to this model, it must be pointed out that in this model a central importance is attributed to long-term fluctuations of grain prices both as conditioning, and as conditioned elements.

32. It has been pointed out already that such a comparison would be very important for a great deal of research work into business-cycles, see e.g. *Ebeling, D.*; *Irsigler, F.*: Zur Entwicklung von Agrar- und Lebensmittelpreisen in der vorindustriellen und der industriellen Zeit. Beobachtungen am rheinischen Beispiel. In: Archiv f. Sozialgeschichte 19 (1979), pp. 299-329, who followed a suggestion of Knut Borchardt.

33. Such a kind of procedure can easily be reproached with "Measurement without Theory". The statements given above ought to have shown why I thought it unnecessary to take recourse to a theory.

34. The exact description of the material will be found in the appendix.

from 1700–1950, and one index respectively, of real wages as indicator of the long-term movement of real wages in England and Germany from 1809–1970, and finally the real gross domestic investments of the United Kingdom from 1830 to 1979.

II. Methodical problems and statistical procedures

In spite of long-lasting and intensive discussions, there is no common consent over what is to be regarded as “long wave”. Terms like trend-fluctuations, trend-cycles, “säkulare Wechsellagen”, “Wechselspannen”, “Kondratieff-cycles”, etc., partly designate different and partly identical phenomena.³⁵ The cyclical character of the phenomenon, which is the basic requirement of the whole concept, suggests the following definition as a working hypothesis:

“Long waves” are cycles within trend-free series with an average duration ranging from about 30 to 60 years; the specific length of the cycle may very well vary within certain limits.³⁶

The following comments shall explain the difficulties that arise if one tries to prove the existence of long-term cycles:

If one regards a concrete time-series as the result of a great number of oscillations of different frequencies and different strength of amplitude, spectral analysis gives informations both about the oscillations existing in a concrete time-series³⁷ and about the relative importance of different oscillations for the total fluctuation which determines them. Oscillations spanning long periods of time generate spectral mass at the zero point, or within a small space around it within the spectral density function. The more distinct these oscillations prove to be within the concrete time-series, the higher is the spectral value within the density function. The fact that the spectral value is as high as that, restricts the importance of spectral analysis as a method of splitting up frequencies to such an extent that actually existing oscillations of higher frequency cannot be proved. Consequently, the spectral density function exhibits a monotonous downward course from the left upper side to the right lower side of the graph.³⁸ This course is typical of economic time-series.

35. Rosenberg has already pointed to this semantic confusion. *Rosenberg, H.*: Große Depression (supra, n. 2), p. 8.

36. The essential point is that this definition does not anticipate any decision about the use of certain procedures. The procedures were designed in such a way that cycles which are shorter than 20 years cannot be represented in the dimension of time.

37. Several treatises clearly show the conditions under which spectral analysis constitutes a useful analytical instrument in economic historical research. See e.g. *Granger, C. W. J.*; *Hatanaka, M.*: Spectral Analysis of Economic Time Series, Princeton 1964; *König, H.*; *Wolters, J.*: Einführung in die Spektralanalyse ökonomischer Zeitreihen. Meisenheim am Glan 1975; *Koopmans, L. H.*: Spectral Analysis of Economic Time Series. New York 1974; *Fishman, G. S.*: Spectral Methods in Econometrics. Cambridge Mass. 1969, and the literature mentioned in *Metz, R.*: Agrarpreiszyklen und Wirtschaftskonjunktur. Spektralanalytische Untersuchungen zu Kölner Agrarpreisreihen des 19. Jahrhunderts. In: *Schröder/Spre* (Hrsg.): Historische Konjunkturforschung (supra, n. 1), p. 255 ff.

38. Granger already described this shape as typical spectral shape of economic variables, see *Granger, C. W. J.*: The Typical Spectral Shape of an Economic Variable. In: *Econometrica* 34 (1966), pp. 150–161.

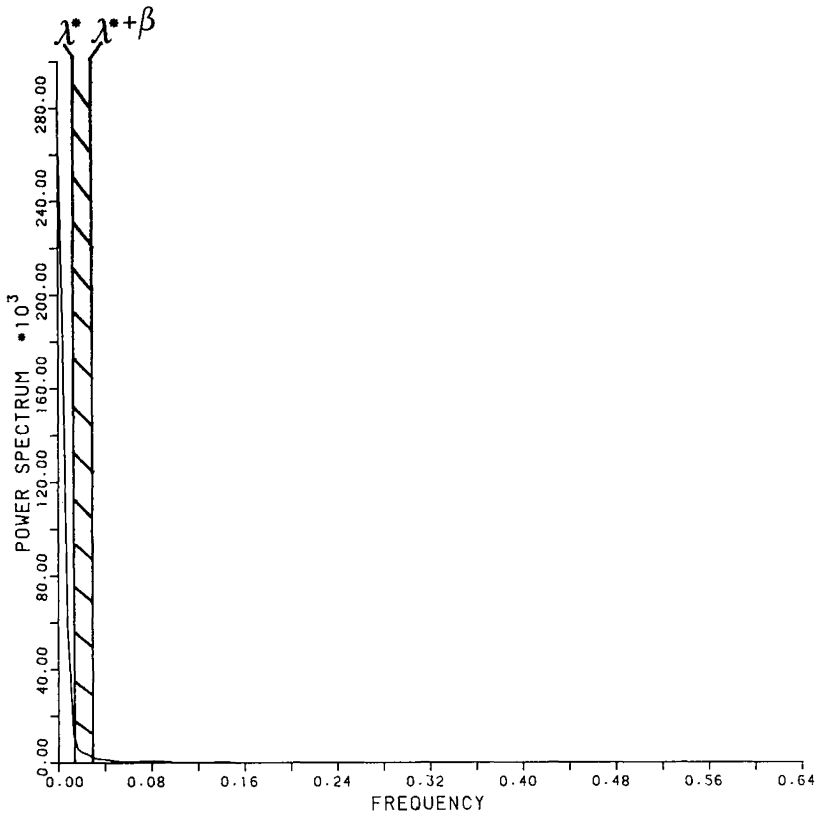


Fig. 1: Spectrum of wheat prices before trend removal

Figure 1 shows a spectral density function for the series of wheat prices (1531–1959). The space within which presumably existing “long waves” ought to exhibit peaks within this spectrum is limited by λ^* and $\lambda^{*+\beta}$. An informative spectral analysis presupposes the elimination of the trend from the series beforehand. The effect of such a trend elimination on the different frequency bands of a time-series can be illustrated with the aid of the transfer function, provided that the elimination procedure is linear and time-invariant: Figure 1 shows that the transfer function³⁹ is only

39. The opportunity of analyzing the effect of different methods constitutes a great progress in the field of the analysis of time-series; cf. the report on S. Heiler’s lecture given in presence of the committee of “Deutsche Statistische Gesellschaft für Neuere Statistische Methoden” on: *Zeitreihenanalyse heute—Ein Überblick—*. In: *Allg. Stat. Archiv* 65 (1981) 1. Heft, p. 99ff. Newbold’s article shows that a great deal of current research in this field is of little relevance for economic historical research. *Newbold, P.*: Some Recent Developments in Time Series Analysis. In: *International Statistical Review* 49 (1981), pp. 53–66.

allowed to have the zero value at the zero point, or within a small space around it, and ought to have reached the value 1 not later than at the point λ^* to make sure that “long waves” are not unintentionally eliminated by the trend elimination.⁴⁰ Filters which approximate such a course are called highpass filters because they only transmit high frequency oscillations into the filter-output series. Figure 2 shows the transfer function of a highpass filter, which has hitherto met these requirements better than all the other ones. The positions of λ^* and $\lambda^{*+\beta}$ show, however, that this filter is of no use for our statement of the problem because the frequency components in which we are interested, are out-filtered with the trend.⁴¹

This fact, which is true of all highpass filters which have hitherto been used means that a spectral analysis based on series that are filtered in such a way cannot give any clues to the existence of “long waves” because they ought to have been al-

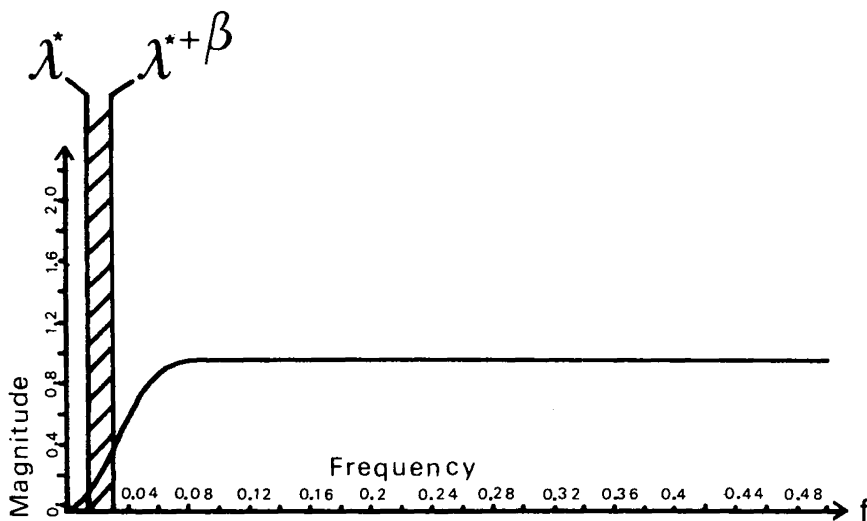


Fig. 2: Transfer function of a highpass filter

40. The transfer function indicates the value with which the input frequency is multiplied before being transferred into the output series. The value, zero, indicates that the frequency is totally eliminated, the value, one, that the frequency is transferred unchanged; all other values indicate that an intensification or decrease, repeated ever so often, is taking place. The difficulties attached to the search of filters with an “optimal transfer function” are described by *Wäsch, P.*: Zur Berechnung von Filtern im Frequenzbereich, In: Vierteljahreshefte zur Wirtschaftsforschung, Heft 4, 1971, pp. 320–329, see *Stier, W.*: Über eine Klasse von einfachen FIR-Tiefpass-Selektionsfiltern. In: Allg. Statist. Archiv (1978), p. 161 ff.
41. The graph has been taken from *Schulte, H.*: Statistisch-methodische Untersuchungen (supra, n. 10), p. 138. Apart from the fact that this kind of filter does not possess ideal transfer-characteristics, it is almost impervious in the domain of the “long waves”; this feature is clearly shown by the course of the function within the hatched plane.

ready out-filtered with the trend.⁴² Filters that prove to have intensifying effects on the frequency domain cannot be used, either; because if one makes use of these filters, cycles can be ascertained by means of spectral analysis, even if they do not exist within the original series.⁴³ There are also serious methodical objections to the attempt to determine the course of the trend with the aid of polynomials. Apart from the fact that it is very difficult to determine the polynomial degree scientifically, it is impossible to determine the transfer function of polynomials and, therefore, the effects of the trend elimination cannot be numerically determined.⁴⁴ To regard the analysis of time-series as a "Filter-Design-Problem",⁴⁵ is a methodically completely new approach. This concept consists of two main steps: Firstly, a transfer function adequate to the scientific concept is given, and then an optimal filter is constructed accordingly.⁴⁶ This procedure constitutes from the methodical view a complete break with the classic component model and that means that considerations formulated with the aid of the estimate theory are no longer decisive for the evaluation of the trend elimination.⁴⁷

The necessity of determining an optimal transfer function beforehand presupposes a clearer definition of scientific terms within the frequency domain. Therefore, the researcher has to determine clearly, in advance, what is to be defined as trend. The course of the transfer function realized changes along with the factors that have been determined beforehand. This comparatively strong link between economic-historical concepts and formal-statistical criteria can only be of advantage if scientific interpretations and analyses orientate themselves by the numerical results of statistical methods, as is clearly exemplified by research into business-cycles and economic growth. In accordance with these considerations, in the following pages, we define trend as those oscillation components of a time-series which generate spectral mass within the frequency bands between zero and λ^* .⁴⁸

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42. This problem has not yet been adequately solved in all the analyses of "long swings". See e.g. the spectral analytical investigations of the "Kuznets-cycles" by *Adelmann, I.*: Long Cycles-Fact or Artifact? In: *American Economic Review* 60 (1965) p. 444 ff.; *Harkness, J. P.*: A Spectral Analytic Test of the Long-Swing Hypothesis in Canada. In: *The Review of Economics and Statistics* 50 (1968), p. 429 ff.; *Howrey, Ph. E.*: A Spectrum Analysis of the Long-Swing Hypothesis. In: *International Economic Review* 9 (1968) pp. 228; *Klotz, B. P.*; *Neal, L.*: Spectral and Cross-Spectral Analysis of the Long-Swing Hypothesis. In: *Review of Economic Statistics* 15 (1973).
43. This fact is exemplified by *König/Wolters*: Eine Spektralanalyse (supra, n. 22) with the aid of the analyses made by *Hoffmann* and *Kuznets*.
44. See *Schulte's* remarks; *Schulte, H.*: Statistisch-methodische Untersuchungen (supra, n. 10), p. 112 ff.
45. The theory of linear, discrete, time-invariant systems which are of great importance particularly in natural sciences, constitutes the theoretical foundation for it. As fundamental literature dealing with this topic see *Cadzow, James, A.*: Discrete Time Systems. An Introduction with Interdisciplinary Applications. Englewood Cliffs 1973; *Rabiner, L. R.*; *Gold, B.*: Theory and Application of Digital Signal Processing. Englewood Cliffs 1975.
46. An attempt to outline the theoretical problems attached to such a kind of procedure is described in *Metz, R.*: Theoretische Aspekte (supra, n. 20).
47. See *Stier's* remarks: Verfahren zur Analyse (supra, n. 25), p. 112 ff.
48. As to the operation and justification of such a definition; see *Schulte's* comments: Statistisch-methodische Untersuchungen (supra, n. 10), p. 140 ff.

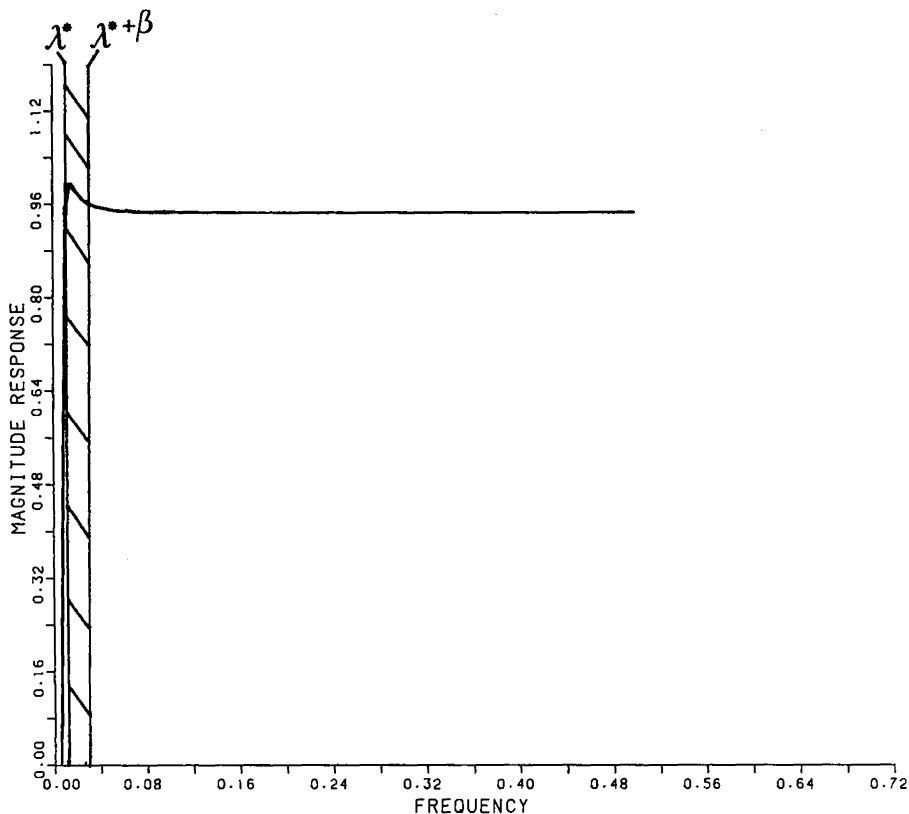


Fig. 3: Transfer function of a notch-filter

In empirical research only time-series of a definite length are available. Therefore it is useful to confine the analysis to those oscillations the periodical duration of which is not longer than the number of values of the time-series. The λ^* mentioned above is consequently the inverse-value of the length of the time-series.⁴⁹ By means of a special combination of parameters, a so-called notch-filter is designed which exactly achieves this separation.⁵⁰ Figure 3 shows the transfer function of such a kind

49. On principle, the maximal length of a provable periodical oscillation is identical with the length of the time-series. Because of practical reasons it is useful, however, to analyze only those oscillations the maximal length of which is equivalent to half of the length of the time-series. See *Schulte, H.:* Statistisch-methodische Untersuchungen (supra, n. 10), p. 157 ff.

50. As to the determination of these parameters by means of which the zero points of the notches, the opening of the notches and the normating frequency are determined, see *Schulte, H.:* Statistisch-methodische Untersuchungen (supra, n. 10) and *Stier, W.:* Verfahren zur Analyse (supra, n. 25), in particular, the band-width calculated by means of the

of filter.⁵¹ In this connection the essential point is that a trend formulated, in advance, is transformed with the aid of the filter theory, and that this trend is not influenced by the statistical procedure, but is, on the contrary, defined by the scientist, beforehand, or rather results from the specific formulation of the question. This kind of filter-construction, as well as the transformation of scientific concepts into statistically operable procedures, leave a subjective margin of decision because what is to be defined as trend can only be determined within certain limits.⁵² Spectral analysis can, however, supply us with useful criteria of decision for this delimitation. As the

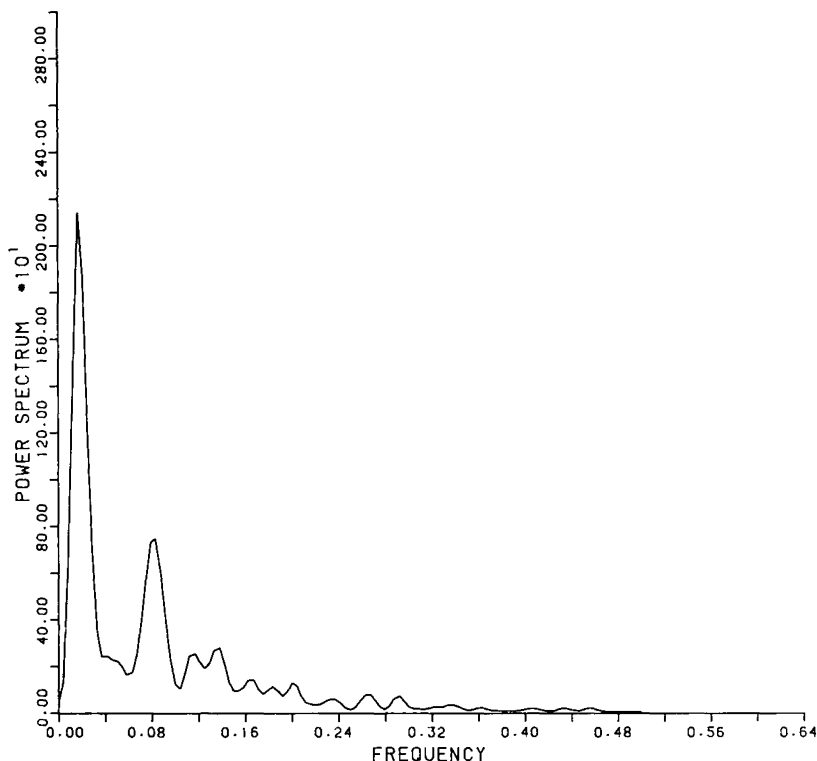


Fig. 4: Spectrum of wheat prices after trend removal

opening of the notches—in time units—, p. 74ff., concerning the effect of the variations of the zero points and notches on the spectrum of the series, see *Metz/Spreer*: Kuznets-Zyklen (supra, n. 11), pp. 346–354.

51. The course of the function within the hatched field shows that possibly existing “long waves” are transferred unchanged into the initial series.
52. *Stier, W.*: Verfahren zur Analyse (supra, n. 25), p. 79ff., discusses these problems with regard to methods of seasonal adjustment.

trend manifests itself as spectral mass within the space around the zero-frequency, spectral analysis will be used in the following as a method of testing the effects of the notch-filter on the low-frequency oscillations of the different series.⁵³

Figure 4 shows the spectrum of the series underlying Figure 1 after the trend has been determined by means of the notch-filter.⁵⁴ The function has now nearly reached the value zero at the frequency band zero and exhibits a clear peak above the frequency band $1/60$; a “long wave” with an approximate length of 60 years is implied therein. Figure 5 shows the course of both the trend-free series and the original series.

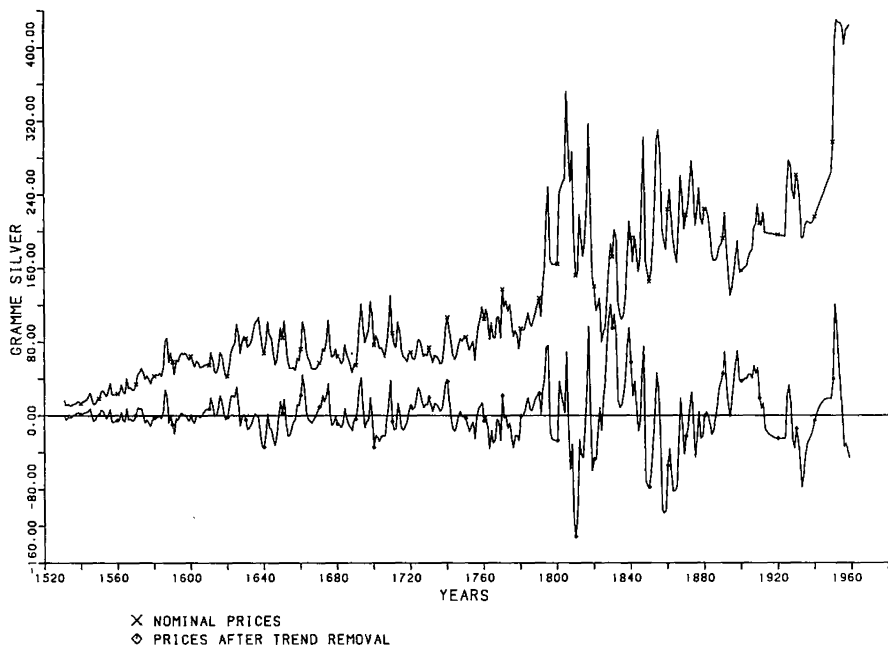


Fig. 5: Wheat prices in Germany 1531–1959

53. Spectral analysis is very often used to analyze the effect of filters in the frequency domain, particularly with regard to methods of seasonal adjustment see *Stier, W.*: Verfahren zur Analyse (supra, n. 25), p. 106ff; additional literature is given in: *König/Wolters*: Einführung (supra, n. 37), p. 106ff. Analyses comparable with Stier's (cf. supra) for the high-frequency domain are not known to me concerning the low-frequency domain.

54. The respective filter parameters: Two zero points at the frequencies 0 and 0.00233; Delta of the first notch 0.05, Delta of the second notch 0.025, normating frequency 0.015922; concerning the determination of the Deltas see *Schulte, H.*: Statistisch-methodische Untersuchungen (supra, n. 10) p. 157ff.

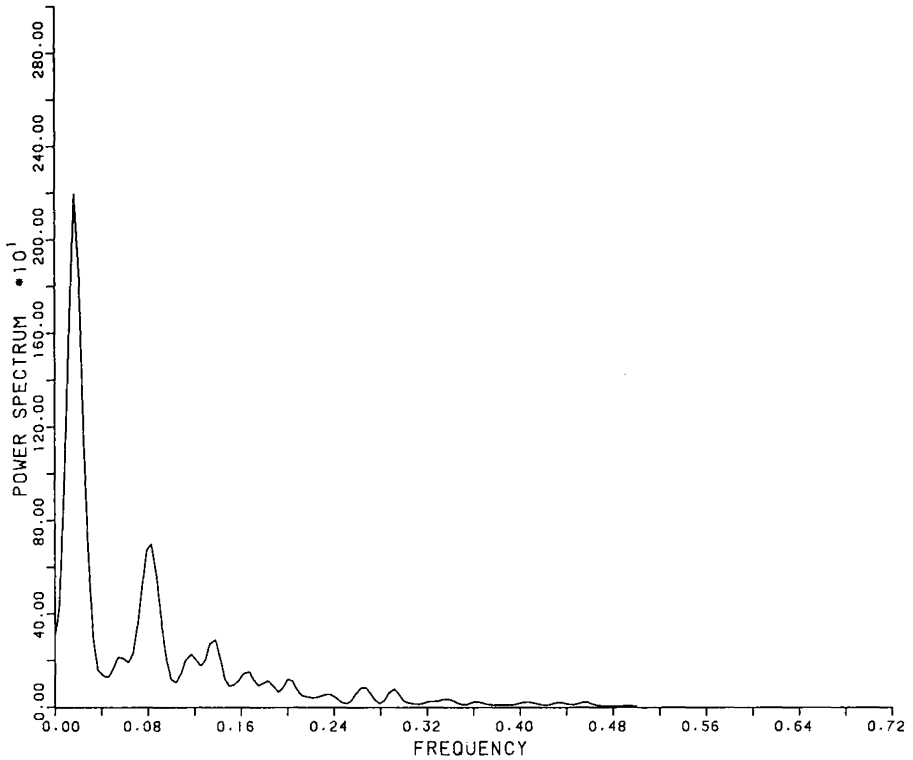


Fig. 6: Spectrum after modified trend removal (Delta = 0.025/0.0125)

The above mentioned margin of decision which is involved in the definition of the trend concerns the determination of the stop-band through the choice of the parameters Δ .

Figure 6 shows the spectrum of grain prices after the passband of the filter has been enlarged by means of a reduction of Δ_1 and Δ_2 . As has been expected, the spectral mass of the zero-frequency band is larger than before and, therefore, the question arises which kind of spectral density function indicates the optimal adequation between the filter and the scientific concept. This problem cannot, however, be solved with the aid of the filter theory because no adequate statistical test criteria are available.⁵⁵

The following points should, however, be kept in mind: The notch-filter designed by Schulte/Stier achieves an exact separation between the trend and the long-term cycles, which has been thought impossible up to now.

55. After the use of both filters time-series are stationary; this is necessary for spectral analysis. In the subsequent remarks these problems will be taken up again.

The filtered series are completely stationary time-series. They can be exactly proved with the aid of the filter theory and, therefore, guarantee that the cyclical components analyzed in these series are not artifacts, which might be conditioned by the different filters. The series filtered are fundamental for the spectral analytical proof of cycles of different length within the frequency domain.

Whereas most of the recently published, methodically orientated treatises on this problem have confined themselves to such a spectral analytical proof, in the following, further steps of analysis will be made to determine the position and shape of these long-term cycles within their course of time.⁵⁶ Because of the fact that within the spectrum of the trend-free series a considerable number of high-frequency oscillations can still be discerned, it is necessary to try to eliminate these short-term cycles in order to isolate the long-term cycle. To this purpose, as a rule, one makes use of a lowpass filter which only transmits low-frequency oscillations into the initial filter series and, consequently, any existing trend. If one, however, filters a series from which

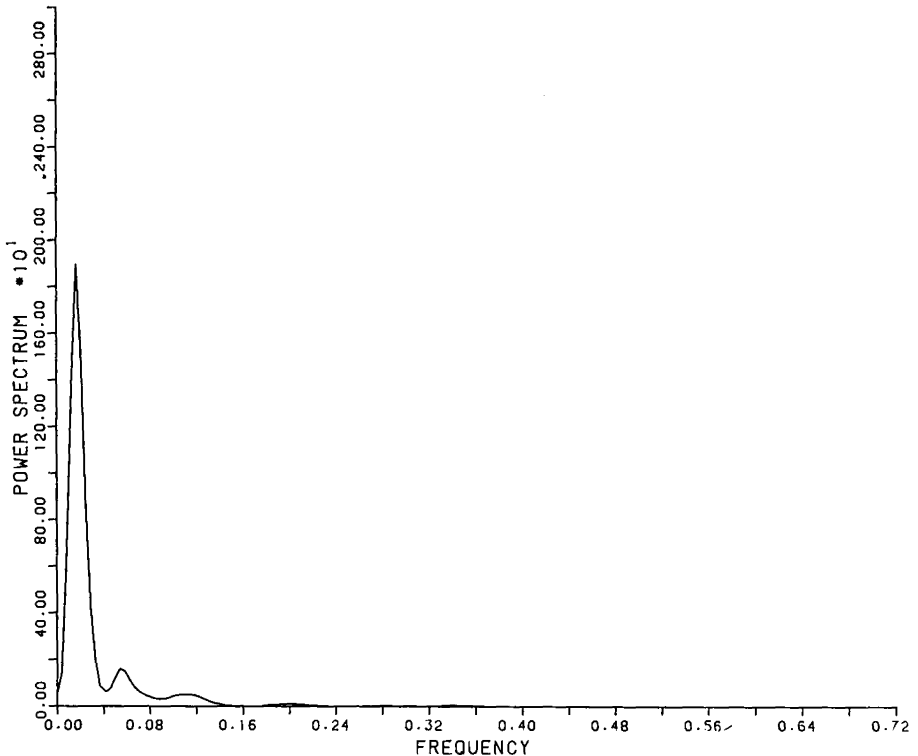


Fig. 7: Spectrum after trend- and high frequency removal

56. Cf. also the methodical remarks in Metz/Spree: Kuznets-Zyklen (supra, n. 11), p. 346 ff.

the trend has already been eliminated, the desired effect of a bandpass filter is achieved. The series filtered does not contain any other components of oscillation than those that vary between the "Normierungsfrequenz" of the notch-filter and the cut-off frequency of the lowpass filter,⁵⁷ and at best contain exactly the "long wave" with a possible length between 20 and 60 years within the dimension of time.

In Figure 7 spectral analysis shows the effect of such a lowpass filter method on the grain price series after trend- and high frequency removal.

III. Main characteristics of "long waves"

In Table 1 (see appendix), the results achieved from the different series by means of spectral analysis after the trend elimination with the notch-filter have been compiled. In each of the series long-term cycles can be ascertained. In all the series of agrarian prices that precisely fix the index of the value aspect of agrarian cycles, at least till 1850,⁵⁸ cycles of the "Kondratieff-type" with an average length of about 60 years become visible. An alternative estimate made for the pre-industrial period from 1531–1796 did not bring about any other results concerning the length of the different cycles. In this context it is remarkable, however, that in the pre-industrial period the short-term harvest-cycle seems to be of the same importance for the total variability of the series as the "long-wave"; if the estimate however concerns the whole period of time, the cyclical variation of the series turns out to be clearly dominated by the "long waves". This fact clarifies from a comparison between the two different spectral density functions. They clearly illustrate a decrease in the vulnerability of the agrarian production to crises. By means of a rise in productivity, the extreme price-fluctuations of the classic harvest-cycles could be removed to a high degree.⁵⁹

Concerning the English coal and cotton-yarn production and the investment series, shorter cycles seem to prevail. The proved length of the different cycles fluctuate between 40, 32, and 19 years. The validity of these results is limited, however,

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57. A Kaiser-filter was used for the high-frequency elimination of the filtered series with $N=23$, cut-off-frequency 0.05. It is not necessary to take account of the phase as this filter-type is symmetrically implemented; as to the calculation of such filters see *Stier, W.*: Konstruktion und Einsatz (supra, n. 9), p. 14ff; *Rabiner/Gold*: Theory and Application (supra, n. 45), p. 93 ff.
58. Analyses have shown that value and quantity indicators of the agrarian cycle differ, both regarding their cyclical structure, and their dependency on other indicators of cyclical development; see *Metz, R.*: Agrarpreiszyklen und Wirtschaftskonjunktur (supra, n. 37), p. 273 ff., as to the problem of agrarian cycles within the process of industrialization, see *Spree, R.*: Wachstumstrends (supra, n. 7), p. 125 ff.
59. This development was very much influenced, of course, by the expansion of traffic, and the resulting growing market-integration, and also by the increase in the supply with substitutional goods, see *Teuteberg, H.-J.*: Die deutsche Landwirtschaft beim Eintritt in die Hochindustrialisierung (= Kölner Vorträge und Abhandlungen zur Sozial- und Wirtschaftsgeschichte) Köln 1977; *Abel, W.*: Geschichte der deutschen Landwirtschaft—vom frühen Mittelalter bis zum 19. Jahrhundert. = Deutsche Agrargeschichte, Bd. 2, hrsg. v. G. Franz, 3. Aufl. Stuttgart 1978; *Boserup, M.*: Agrarstruktur und take-off. In: *Rudolf, Braun* u. a. (Hrsg.): Industrielle Revolution. Wirtschaftliche Aspekte. Köln/Berlin 1972, pp. 309–330.

by the fact that in some of the series trend can be proved with the aid of spectral analysis even after the trend elimination has been carried out.⁶⁰ This peculiarity, as a rule, occurs if the original series exhibits a clear exponential growth. The trend-free values of such time-series are marked by extreme fluctuations at the end of the series. These series are no longer stationary covariant, and because of this reason, the requirements attached to the use of spectral analysis are only partly met.⁶¹ Additionally, series of that kind had to be made trend-free with a modified notch-filter in order to check undesirable effects of distortion.⁶² The cycles evidenced remain unchanged even after the modified trend elimination has been carried out. This fact can be taken as a clear hint on the existence of cycles of this very length. It must be confessed, however, that the lengths of the different cycles, which have been evidenced, are of historical value, only for the period since 1840/50, as the majority of the total variance of the series refers to this period. This fact is, for example, clearly to be seen in Figures 17, 18, and 21 (see appendix).

Concerning the series of agrarian prices, a significant change in the length of the cycles, which might be caused by the beginning of the industrialization, can hardly be discerned.⁶³ The lengths of the cycles of the production series, however, seem to have reduced since the middle of the 19th century. Besides, the numerical course of the trend-free production series exhibits strong dynamics in the cyclical behaviour during this period. Although the material compiled by Hoffmann cannot be used for any far-reaching interpretation because of its heterogeneous character, clear differences become visible if one compares the period before the middle of the 19th century with the one afterwards, and the curves of production series with the cyclical course of the series of agrarian prices. The rapid growth which is of fundamental importance for the process of industrialization⁶⁴ is primarily expressed in the cyclical course of the production indicators, without at the same time determining the fluctuations of prices in the one, or the other way.

Long-term cycles can thus be sufficiently described in their historical course by means of their formal characteristics. These are the following: The position and

60. Similar results were achieved when the attempt was made to isolate "Kuznets-cycles" see, *Metz/Spree: Kuznets-Zyklen* (supra, n. 11), p. 353 ff.

61. Stationary processes are the necessary prerequisite of spectral analysis. In practice, a constant mean value ($E(u) = 0$ is generally assumed) and a time-invariant covariance are required. The second requirement does not seem to be met in these series and consequently trend can be ascertained within the spectrum see e.g. *Granger/Hatanaka: Spectral Analysis* (supra, n. 37), p. 190 ff; *König/Wolters: Einführung* (supra, n. 37), p. 150 ff. As far as I know, reliable estimate procedures for series with a non-stationary covariance are not available, cf., however, *Priestley's treatises*, e.g. *Priestley, M. B.: Evolutionary Spectra and Non Stationary Processes*. In: *Journal of the Royal Statistical Society, Ser. B 27* (1965), pp. 204-237.

62. With the aid of such a filter, additional low-frequency oscillations are outfiltered through a third zero point; in this way we succeed in confining the leakage problem.

63. That means that the differences between the respective lengths of the cycles are as great with regard to the 19th and 20th centuries as they are with regard to the preceding period. See Tables 13a and b.

64. This course which is typical only of production series, is surely one of the reasons, why it is so difficult to achieve clear hints as to concrete cycle lengths by means of spectral analysis.

Table 1

Output of the Prussian coal-mining industry		English coal production	
peaks	troughs	peaks	troughs
1839	1846	1828	
1867	1876	(1863)	(1854)
1885	1890		1876
1902		1901	1917

yarn production of the cotton spinning industry		English cotton-yarn production	
peaks	troughs	peaks	troughs
1839	1847	1826	(1847)
1855	1864	(1853)	1861
1871	1880	1872	1895
1892			

the length of the upswings and downswings, the turning points, and the position and length of the amplitude.⁶⁵ The question whether the cycle of the production series, which was at first designated as "long wave", is according to its formal characteristics rather to be numbered among the "Kuznets-type" after the year 1850 can only be discussed in this paper by means of one example.⁶⁶

The following table lists the troughs and the peaks of the English coal- and cotton-yarn production in the 19th and in the beginning of the 20th century⁶⁷ and, moreover, contrasts them with the turning points of the Kuznets-cycles ascertained for the

65. In Table 3 (appendix) the troughs and peaks and in Table 4 (appendix) the resulting upswings and downswings were compiled. Figures 13a and 13b are graphical transformations of Table 4 and show the temporal course of these cycles. The short intermediate cycles which can be ascertained in Figs. 10, 14, 15-21 (appendix) were not taken into consideration because they are only the results of an insufficient lowpass filtering.

66. Regarding the results achieved, a further analysis of this question appears to be of advantage, above all, because the empirical and theoretical fundament of the "Kuznets-cycles" appears in a more positive light, see e.g. *Aldcroft, D. H.; Fearon, P.*: British Economic Fluctuations 1790-1939. London 1972; *Easterlin, R. A.*: Population, Labor Force and Long Swings in Economic Growth. New York 1978; see e.g. *Metz/Spree*: Kuznets-Zyklen (supra, n. 11). This, however, requires an analysis of standardized material by means of identical methods.

67. As to the English series, the years which are put in brackets are intermediate cycles which were not taken into consideration when dating the "long waves", but which mark, however, a relative trough, or peak, in the numerical course of the series.

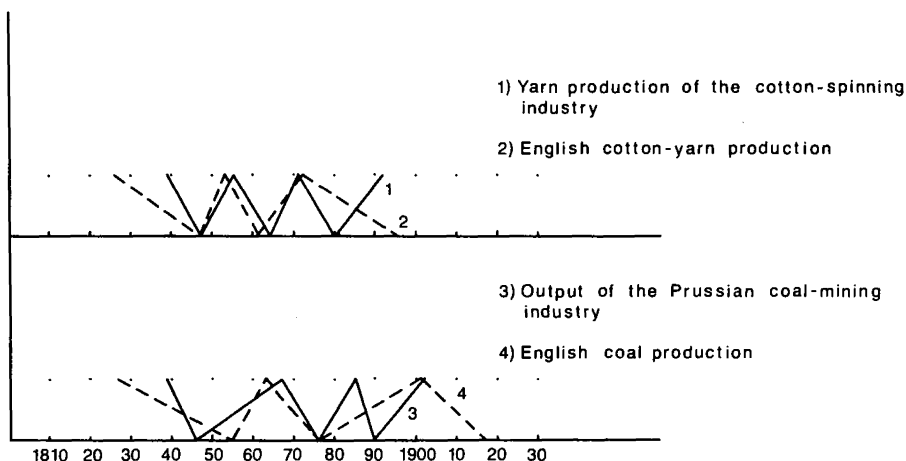


Fig. 8: Schematic course of the long term cycles of table 1

German series.⁶⁸ In Figure 8 the resulting upswings and downswings are graphically represented.⁶⁹

In spite of the fact that the trend has been eliminated from series of different length, with the aid of different notch-filters, we nevertheless get some useful hints for the solution of the question mentioned above. Notwithstanding the fact that the series are based on very heterogeneous material, they exhibit homogeneous turning-points; concerning the coal production: 1863/67, 1876, 1901/02; concerning the yarn production: 1847, 1853/55, 1861/64, 1871/72.

The degree of conformity is very astonishing. More detailed analyses into the problem should be made, above all, as the historical value and the empirical plausibility of the "Kondratieff-hypothesis" largely depend on the solution of this problem, at least as far as the period of high-industrialization is concerned.⁷⁰

In all the series that have been analyzed, a high degree of variation can be discerned within the specific lengths of the different cycles.⁷¹ Concerning grain prices, the shortest cycle measures at about 40, and the longest one at about 70 years. The lengths of the upswings and downswings vary to the same extent. Both the English and the German grain prices pass through a complete cycle from the beginning of the 18th century until 1775. The English upswing phase is, however, twice as long as the German one, concerning the downswing phase, just the opposite is true.

68. Without considering the shorter intermediate cycles, the corresponding years can be easily derived from the graphs printed in *Metz/Spree: Kuznets-Zyklen* (supra, n. 11).

69. Cf. the course of the series in Fig. 17 and 18 in the appendix.

70. A similar view is supported by *Metz/Spree: Kuznets-Zyklen* (supra, n. 11), p. 365.

71. The following comments refer to the results which emerge from Figures 13a and 13b.

It is very astonishing that the different upswings and downswings of the series of agrarian prices nearly synchronize, except for the series of the English wheat prices, which take a different course during the period from 1580 to 1650. This exception is not very important, however, considering the high degree of synchrony of the series. Both the English and the German development of agrarian prices seems to be marked by much shorter upswings and downswings from the end of the 18th until the middle of the 19th century, compared with the period before and afterwards.

Whereas the lengths of the cycles referring to the pre-industrial and industrial period prove to be fairly stable, important changes in the dimensions of the amplitudes of the different cycles become visible at the beginning of the 19th century.

Until about 1780, there is a possibility of linking the upper and the lower turning-points of the "long waves" of grain prices (see Figure 14) by a horizontal straight line. If these "long waves" of grain prices are interpreted within a cycle-model which aims at describing the dynamics of the "feudal production",⁷² the turning-points mark the temporal change of the secular development.⁷³ The strength of the amplitude, which proves to remain unchanged during a space of time of 250 years, characterizes the narrow corridor in the limits of which the agricultural productivity fluctuated.⁷⁴ In consequence, the turning-points clearly reflect the so-called "plafond pluri-séculaire"⁷⁵ of the pre-industrial production, which has been a very important topic in French agrarian historical research.

72. *G. Bois*: *Crise du féodalisme. Économie rurale et démographie en Normandie orientale du début du 14e siècle au milieu du 16e siècle*, Paris 1976, has developed this model, which constitutes an attempt to combine the main ideas of the theory of agrarian crisis with the theory of feudal production. See e.g. *Kriedte, P.*: *Spätmittelalterliche Agrarkrise oder Krise des Feudalismus*. In: *Geschichte und Gesellschaft* 6 (1980).

73. It should not be left out of account, however, that the way in which secular trends of grain price series of the pre-industrial period are dated, as a rule, is incompatible with the "long waves" which are analyzed in this paper. As to such a dating see *Imbert, G.*: *Des mouvements de Longue Durée Kondratieff*. Aix en Provence 1959, p. 18; a dating which obviously goes back to this treatise: *Le mouvement Kondratieff*. In: *Bulletin hebdomadaire* 35 (1978). See also *K. Borchardt's* "Überblick über die säkulären Bewegungen der Wirtschaft". In: *Borchardt, K.*: *Grundriß der deutschen Wirtschaftsgeschichte*, Göttingen 1978, p. 11.

74. This margin of productivity becomes evident in the ratio between seed and harvest. The fundamental treatises dealing with this topic are: *Slicher van Bath, B. H.*: *Yield ratios, 810-1820*, In: *A. A. G. Bijdragen* 10 (1963); *Jansen* has recently published a very informative analysis of these problems: *Jansen, J. C. G. M.*: *Landbouw en Economische Golfbeweging in Zuid-Limburg 1250-1800*. Van Gorcum/Assen 1979. See, as well, the omnibus volume which is representative of French research in the agrarian cycles, *Goy, J.*: *Le Roy Ladurie, E.*: *Les fluctuations du produit de la dîme. Conjoncture décimale et domaniale de la fin du Moyen Age au XVIIIe siècle*. (Cahiers des études rurales) Paris-The Hague 1972.

75. This thesis of a "plafond pluri-séculaire", which has been developed by *le Roy Ladurie*, is very much at the centre of interest of French research, see *Neveux, H.*: *Die langfristigen Bewegungen der französischen Getreideproduktion vom 14. bis zum 18. Jahrhundert*. In: *Scripta Mercaturae* 13 (1979), pp. 75-88. For an excellent short characteristic of French research dealing with these problems see *Irsigler, F.*: *Möglichkeiten und Grenzen quantifizierender Forschung in der Wirtschafts- und Sozialgeschichte des Spätmittelalters und der frühen Neuzeit*. In: *Rhein. Vjbl.* 43 (1979), pp. 236-259.

It has not yet been tested, however, whether the phenomena described are conditioned on monetary factors. If this proved to be true, they would only be expressions of a long-term fluctuating currency stability⁷⁶, but could not contribute to the explanation of real economic phenomena. In order to get some hints for the solution of this question, the Cologne wheat prices⁷⁷, which were passed to us in money of account, that means as nominal prices,⁷⁸ had to be deflated.⁷⁹ By means of this procedure, only those price-variations that arise from a change in the silver equivalent of the money of account are eliminated from the series. Other monetary influences, which might have resulted from an absolute increase in the total amount of money, or from an increasing circulation rate of the total amount of money, could not be taken into consideration.

Figure 9 representing the "long waves" of the trend-free and deflated prices shows that the process of deflating prices neither influences the shape, nor the position of the long-term cycles. The trend of these deflated prices appears to take an approximately stationary course since the beginning of the 17th century, whereas concerning the 16th century, an increasing trend can be ascertained within the series, now as before. Because of this fact, there is no doubt that the price-revolution which occurred in this century was not due to a debasement of the circulating silver mon-

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76. Long-term cycles were very early explained by changes of monetary variables see e.g. *Kondratieff*: Die langen Wellen (supra, n. 15), p. 595 ff., this question is still under discussion, cf. e.g. *Rostow, W. W.*: Why the Poor get Richer and the Richer Slow Down, Austin 1980, esp., Money and Prices, p. 189 ff., concerning the pre-industrial period see *Braudel, F. P.; Spooner, F.*: Prices in Europe from 1450 to 1750. In: The Economy of Expanding Europe in the 16th and 17th Centuries. = The Cambridge Economic History of Europe, vol. IV, publ. by E. E. Rich and C. H. Wilson, Cambridge 1967, and also Abel's remarks, *Abel, W.*: Agrarkrisen und Agrarkonjunktur. Hamburg/Berlin 1978, p. 13 ff.; p. 188 f.
77. See the detailed criticism of the historical sources in *Ebeling/Irsigler*: Getreideumsatz, Getreide- und Brotpreise in Köln, 1368–1797, 1. Teil, Mitt. aus dem Stadtarchiv von Köln, Köln/Wien 1976, p. 11 ff. As the prices are handed down in money of account, they are very much influenced by inflationary movements. The actual value of the money of account can be determined with the aid of the silver contents of the coins which were actually minted. In order to exclude the changes in prices which were due to the demonetization of the money of account, all prices were multiplied with the silver weight of the albus of account.
78. All pre-industrial grain price series are nominal price series, see *Sprenger, B.*: Preisindizes unter besonderer Berücksichtigung verschiedener Münzsorten als Bezugsgrößen für das 16. und 17. Jahrhundert — dargestellt anhand von Getreidepreisen in Frankfurt/Main. In: *Scripta Mercaturae* 1 (1977), pp. 57–72; concerning the situation in Cologne see *Ebeling/Irsigler*: Getreideumsatz (supra, n. 77) p. 32 ff.
79. In order to deflate these prices we have made use of the tables published in *Ebeling/Irsigler*: Getreideumsatz (supra, n. 77) p. 38 ff. Within a project which is concerned with the "Geld- und Währungsgeschichte Mitteleuropas von 1300–1800", and is promoted by the "Stiftung Volkswagenwerk", a group of scientists under the leadership of Prof. F. Irsigler at the University of Trier is attempting to compile such long-term tables for other towns, too. See *Irsigler, F.*: Das Projekt: Geld- und Währungsgeschichte Mitteleuropas im Spätmittelalter und der Frühen Neuzeit. In: *Quantitative Methoden in der Wirtschafts- und Sozialgeschichte der Vorneuzeit*, hrsg. v. F. Irsigler. Stuttgart 1978 (= *Historisch Sozialwissenschaftl. Forschungen* Bd. 4).

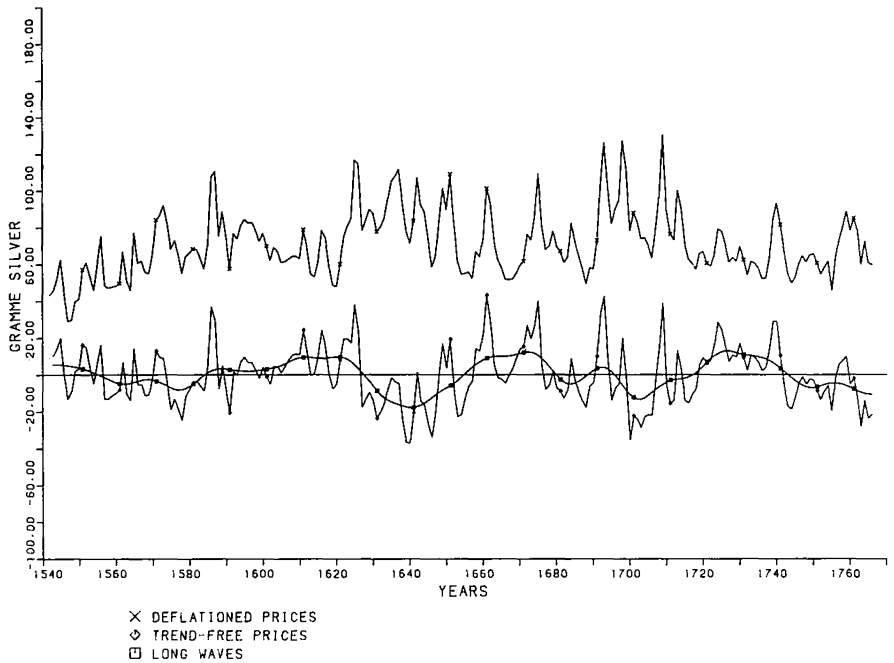


Fig. 9: Long waves of deflated wheat prices

ey.⁸⁰ The presumption that long-term cycles are only expressions of the fluctuating currency stability⁸¹ cannot be supported by these few results, on the contrary: the system of small change, which proves to have been extremely unstable in the pre-in-

80. The term "price-revolution" is used in literature to describe the process of rise in prices. There is not yet a common agreement on the causes of this phenomenon. See *Abel, W.: Agrarkrisen* (supra, n. 76), p. 122 ff., see as well *Irsigler, F.: Getreidepreise, Getreidehandel und städtische Versorgungspolitik in Köln vornehmlich im 15. und 16. Jahrhundert*. In: *Die Stadt in der Europäischen Geschichte*. Festschrift Edith Ennen, hrsg. v. W. Besch, K. Fehn u. a. Bonn 1972, who excellently discusses the fundamental problems and functions of grain prices in pre-modern times with the aid of the Cologne example.

81. The term "currency stability" designates the contents of precious metal of the coins which were minted over a long period of time. The other monetary factors of a possible destabilization of the economic system were not taken into consideration; as to these factors see *Schüttenhelm, J.: Der Geldumlauf im südwestdeutschen Raum vom Rüdlinger Münzvertrag 1423 bis zur ersten Kipperzeit 1618. Eine statistische Münzfundanalyse unter Anwendung der elektronischen Datenverarbeitung*, 2 Bde. (under preparation) and Spooner's treatise which is of general importance, *Spooner, F. C.: The International Economy and Monetary Movements in France, 1493-1725*, Cambridge Mass. 1972.

dustrial period, seems to have effected only the trend, but not the long-term cyclical variations of the price series.

If, however, the long-term movement of the English and German real wage index is included in the comparison,⁸² a striking uniformity of both series, the courses of which are quite the reverse of the long-term movement of grain prices, can be discerned till the 70s/80s of the 19th century. This result emphasizes the importance of the development of agrarian, especially of grain prices for the change of the level of real wages until the beginning of the industrial "take-off". In the following period more complex factors seem to have operated, therefore, a model which is based on such a small number of factors does not suffice any longer to explain the economic development. In this context, it is very remarkable that the German development is marked by much shorter cycles since the 70s/80s of the 19th century, whereas the English index passes through one more complete "long wave" since 1890.⁸³ These results can only be interpreted, however, with serious provisos because the deteriorations caused by the two World Wars can hardly be measured.

IV. Comments on the problem of interpreting "long waves" within their historical dimension of time

In the following paragraph the importance of the "long waves" deduced with the aid of a small number of indicators and their classification in the present state of historical growth and business-cycle research shall be described in rough outlines. The authors who have been concerned with the problem of dating trend-periods and "long waves" of the pre-industrial period have, as a rule, based their analyses on series of grain prices. These series have been analyzed with the aid of rather different methods.⁸⁴ Irrespective of this fact, a comparison between the results achieved seems to be

82. This analysis of the real wage indices does not intend to contribute to the discussion about the development of real wages and of the living standard. The only aim is, to test whether long-term cyclical oscillations of the Kondratieff-type emerge from these series, or not. The economic and social relevance of such a pattern of oscillations for the question of the living standard is quite a different problem. Apart from the literature mentioned in n. 122 see *Desai, V.*: Real Wages in Germany 1871-1913, Oxford 1968; *Bry, G.*: Wages in Germany 1871-1945. Princeton 1960; *Weigand, E.*: Zur historischen Entwicklung der Löhne und Lebenshaltungskosten in Deutschland. In: Historische Sozialforschung 19 (1981), July; for England e.g. *Hobsbawm, E. J.*: The Standard of Living during the Industrial Revolution. A Discussion. In: Economic History Review 16 (1963); *Flinn, M. W.*: Trends in Real Wages 1750-1850. In: The Economic History Review 27 (1974), pp. 395-413; *Tunzelmann, G. N. von*: Trends in Real Wages, 1750-1850, Revisited. In: The Economic History Review 32 (1979), pp. 33-49.

83. See the comments made by *Gömmel* which concern this period: Realeinkommen in Deutschland. Ein internationaler Vergleich. Nürnberg 1979 (= Vorträge zur Wirtschaftsgeschichte, hrsg. v. H. Kellenbenz; J. Schneider, Heft 4).

84. Apart from *Abel's and Neveux's* treatises, which have already been mentioned, see *Rostow, W. W.*: The World Economy (supra, n. 24), pp. 81-90; *van der Wee, H.*: Prices and Wages as Development Variables (supra, n. 19); *Freiburg, H.*: Agrarkonjunktur und Agrarstruktur in vorindustrieller Zeit. In: Vierteljahrsschrift für Sozial- und Wirtschaftsgeschichte 64 (1977), pp. 289-327.

of advantage because of the uniformity of the material that has been used. For instance, the “long waves” of grain prices were determined by Ebeling/Irsigler by means of the Cologne grain prices.⁸⁵ The dating of these series was based on material that had been smoothed by means of a binomial filter. The trend periods were consequently at the centre of interest. This procedure differs from the method I have introduced in this paper, both from the methodical point of view and in the way it conceptualizes the object which is analyzed. Nevertheless, fairly astonishing results were achieved: showing identical turning-points, the upswings from 1620–42, 1668–98 and 1736–70, to which Ebeling/Irsigler refer, are all characterized in our representation by cyclical downswings. As this kind of dating of the upswings largely corresponds to the results achieved by other scientists,⁸⁶ a more precise analysis of the state of affairs proves to be necessary.

To this end, the trend eliminated with the aid of the notch-filter was calculated and represented in a graph: The trend determined with the aid of the filter theory reveals a mounting course with wavy tendency (see Fig. 10). The upswings and downswings

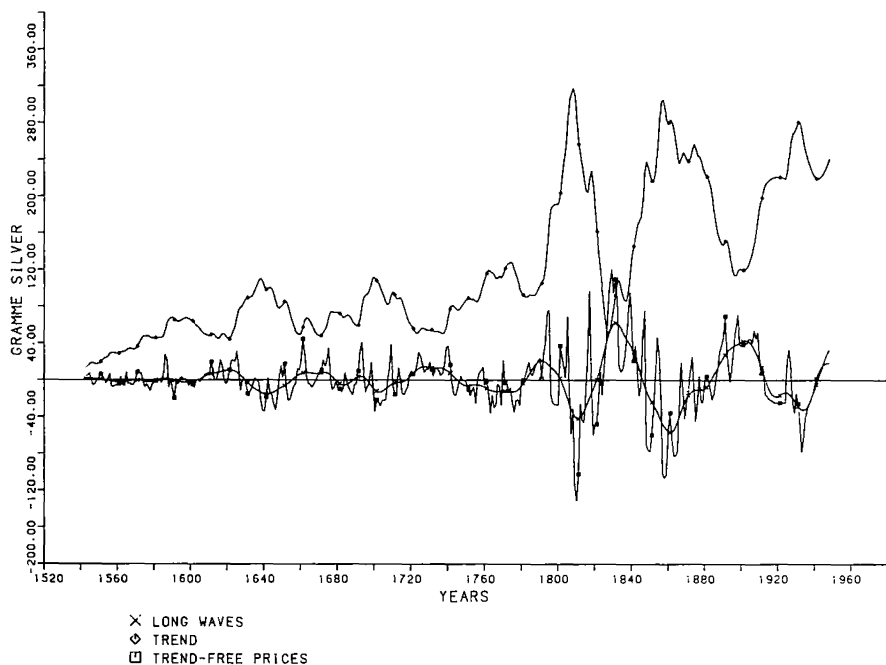


Fig. 10: Trend and long waves of wheat prices

85. *Ebeling/Irsigler: Getreidepreise* (supra, n. 77), p. 47.

86. As to such datings, the corresponding periods are in most cases interpreted as phases of enforced economic growth. See e.g. *Braudel/Spooner: Prices in Europe* (supra, n. 76), p. 436, whose comments mainly refer to Baehrel's treatises.

of the trend take a course that is quite the reverse of the “long waves” of the trend-free series.

The supposition that this result is due to the method that has been used requires a careful analysis of this phenomenon. To this end, the attempt has been made of eliminating the trend from the series with the aid of modified filter parameters in a way that any wavy movement ought to be eliminated from the trend.⁸⁷ Figures 11 and 12 indicate that this aim cannot be achieved without abandoning the previous definition of trend that underlies this procedure.⁸⁸

Although the frequency domain within which the notch-filter is meant to out-filter frequencies can be reduced in size, as much as you like, non periodical oscillations are simultaneously transferred into the filter-output in increasing numbers. This kind of procedure soon collides with the trend-definition given beforehand.⁸⁹ The effect is

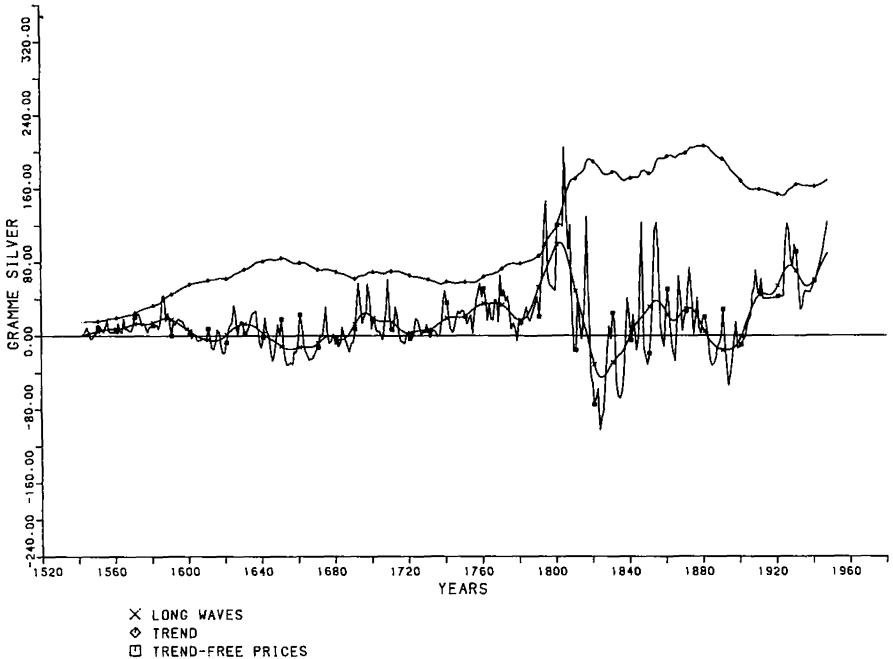


Fig. 11: Trend and long waves of wheat prices ** Delta = 0.01 **

87. The ulterior motif was to transfer more low-frequencies into the filter-output by means of a diminution of the Delta, in order to smooth the trend.

88. In this series, the spectrum clearly exhibits a “trend” in the trend-free series.

89. As to these problem see, *Schulte, H.*: Statistisch-methodische Untersuchungen (supra, n. 10), p. 157 ff.

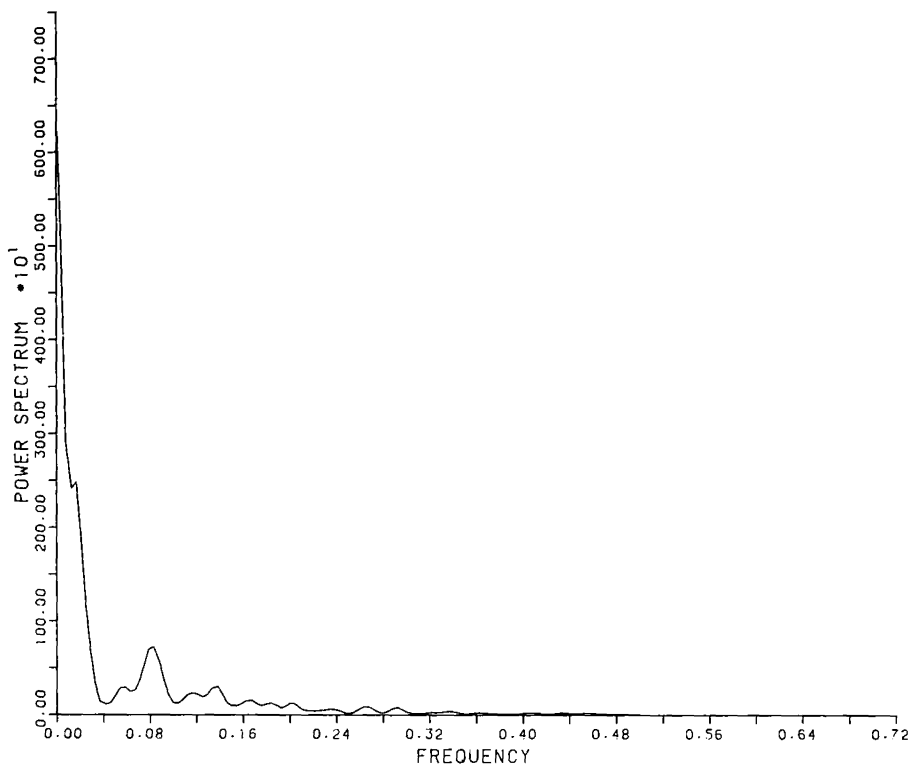


Fig. 12: Spectrum of trend-free wheat prices in Fig. 11

that the spectral density function exhibits an increasing quantity of spectral mass within the zero frequency band. As has been expected, the numerical course of the filtered series changes along with the change of the trend-definition, and from this results a shifting of the turning-points of the "long waves". That is due to the fact that with the reduction of the notch such a great number of low-frequency oscillation components are transferred into the filter-output that the initial series and the filtered series are in extreme cases nearly identical.⁹⁰ Consequently, both series achieve an identical dating of the "long waves". The questions whether this procedure leads to a collision between the purposes, or whether the results achieved have only been conditioned by peculiarities of the trend elimination, which in turn might depend on the procedure itself, shall be left undecided.

90. With regard to "seasonal adjustment" *Stier, W.*: Verfahren zur Analyse (supra, n. 25), p. 89 describes this effect.

In this context, it must be pointed out that the trend eliminated from the series which show exponential growth does not take a wavy course, which might be the reverse of the trend-free series, on the contrary, the trend proves to take an exponentially increasing course.

If, however, this phenomenon does not result from a methodically exact separation of oscillations in the low-frequency domain, it ought to lead to a revision of handed-down conceptions in economic history. The problems attached to these questions are evident: A methodically exact trend removal, which can be tested by means of the filter-theory, eliminates a kind of trend that has hitherto been identified and interpreted as "long waves". By means of the trend removal, the existence of "long waves" can be proved within the trend-free series, which in turn take a course that is inverse to the wavy course of the trend. The connection between both movements has, however, not yet been explained.

Some theoretical considerations shall be added which are meant to make the preliminary result of the inverse course appear more plausible, at least for the pre-industrial period. In times of economic growth, which manifests itself in the secular movement of prices, an increase in productivity in its first phase can be ascertained. This results in the long term, in an improvement in the supply of grain. Owing to this, the cycles of the price curve, which indicate short-term tendencies of shortage and surplus within this process of improvement in supply, move erratically down; in consequence, the short-term cyclical variation becomes less erratic. This development abruptly changes at the upper turning-point of the trend-period. The short-term cycle is enforced, in that, an increased strain on the level of demand and production is evident, which in turn leads to a rise of the long-term cycle. These considerations appear to be fairly plausible to explain the movement of grain prices in the pre-industrial period. Production series, however, only partly exhibit the same phenomenon: The trend course is quite the reverse of the "long wave"; that is true as long as the course of the values of the different series does not show any exponential growth, that means, before the period of high-industrialization. Because of the fact that such an inverse-development which can be discerned in production series cannot be plausibly interpreted, the presumption suggests itself that these results concerning the dating of the turning-points are conditioned by the method itself. Further analyses ought to show whether this supposition is really founded on facts and what kinds of methodical peculiarities achieve such a result.⁹¹

By means of one more example, the results achieved concerning the cycle-length shall be critically compared with other analyses which have relied on different methods. Glismann/Rodemer/Wolter⁹² made the attempt of achieving an international comparative dating of "long waves" by means of several series for the period from 1800-1979. The methodical procedure can be regarded as representative of a great number of treatises that have been concerned with this problem. The trend is esti-

91. Because of this reason, the data given in Tables 3 and 4 can only be used with the proviso of further analyses. It must, however, be mentioned once again that the determination of the cycle-length and of the lengths of the upswings and downswings does not depend on this problem.

92. *Glismann, H. H.; Rodemer, H.; Wolter, F.: Lange Wellen wirtschaftlichen Wachstums (supra, n. 28).*

mated as exponential trend according to the least squares method.⁹³ This estimate cannot, however, be numerically determined within the frequency domain.⁹⁴ The series of investments in the United Kingdom from 1830 to 1975, for instance, exhibits several cycles, at least till about 1890, whereas its course escapes a clear interpretation for the period from 1914 till 1940.⁹⁵ The authors deduce from this and other similar courses of different series that the economic development in the United Kingdom may be fitted very well into the pattern of "Kondratieff-cycles".⁹⁶ This result is very surprising in connection with the statement of these authors⁹⁷ that there is a possibility of deriving long-term oscillations with a duration of 30 or more years from some of the German index numbers, i.e., long-term cycles which are shorter than "Kondratieff-cycles". This hypothesis can be supported by comparative analyses which I have recently made. The spectral analysis of series from which the trend has been eliminated by means of the notch-filter reveals the existence of a cycle with an average length of nearly 36 years.⁹⁸ Leaving aside the problem of how to date the turning-points, the course of the series shows much shorter cycles than is typical of the "Kondratieff-cycles". The course of the series, which has been made trend-free by means of the exponential function,⁹⁹ clearly shows that the exponential trend underestimates the cyclical development till 1880; consequently, nearly all values are marked by a positive amplitude till that date. If the trend is, however, calculated by means of the procedure discussed in this paper, the effects which it has on the frequency domain are already known, much shorter cycles are indicated within the course of the trend-free series. If the attempt is made to transform the trend by means of the filter-theory, the great cycle, which Glismann/Rodemer/Wolter deduced as "bürgerlicher Kondratieff" proves to be a sequence of much shorter-term cycles in which trend is still discernable. Without discussing the serious problems attached to such an approach any further, it should be noted that a proof of really existing cycles presupposes an exact determination of non-periodical oscillations within the time-series, with the aid of the filter-theory. That is the only possibility of preventing oscillation components, which must be taken into consideration as part of the trend because they do not prove to have a periodical course, from influencing the dating of cyclical phenomena. Combined with spectral analysis this procedure offers the only opportunity of distinguishing between the different types of cyclical fluctuations which are of historical relevance, in an analytically exact way. In view of the importance attached to empirical results in economic-historical models, the discussion

93. This procedure is justified as follows: "Der gewählte Funktionstyp muß die *"tatsächliche Entwicklung"* (stressed by R. M.) möglichst genau beschreiben". Glismann et. al. p. 77. This, however, presupposes that this development is known beforehand.

94. See the critical comments on an exponential trend course, *Schulte, H.:* Statistisch-methodische Untersuchungen (supra, n. 10), p. 115.

95. This emerges from Figure 4 published by the authors, p. 105.

96. Glismann et.al., p. 80. In spite of these 'international parallelen Entwicklungen' deviations can be ascertained, of course.

97. Glismann et.al., p. 77 "Aus einigen Kennziffern konnte gefolgert werden, daß möglicherweise eine längerfristige Schwingung mit einer Phase von 30 oder mehr Jahren besteht".

98. See the values in Table 2 and Figure 21 concerning the course of the trend-free series.

99. See Figure A 4, Glismann et.al., p. 105.

about the peculiarities which are conditioned by the procedure ought to be intensified in a way that has hitherto been thought unnecessary.

V. Summary and prospects

The results of spectral analysis indicate the existence of long-term cycles in all the series that have been analyzed. Such a proof presupposes an exact transformation of those components of oscillation of a series which cannot be proved any longer as periodical oscillations within the respective length of the series, and which are as a rule subsumed under the term "trend". It is, however, only in agrarian price series that those cycle-lengths which are regarded as typical of the "Kondratieff-type" can be proved by means of spectral analysis.¹⁰⁰ The other series that have been analyzed appear to exhibit much shorter cycles, at least during the period of evident growth.¹⁰¹ After the series have been filtered with the aid of several other filters, the courses of the long-term cycles reveal clear differences in respect to their formal characteristics. These extreme differences in the lengths of the different cycles and in the duration of the upswings and downswings are of great importance for a further evaluation and interpretation of this pattern of oscillations. There is, however, much reason to doubt whether such a sequence of cycles can still be interpreted theoretically or whether it must be regarded as the result of specific historical events and detached from a concept of relations between variables.¹⁰² On the other hand, the representation of these long-term cycles within their dimension of time clearly shows the heuristic value of models which starting from a hypothetical cycle-length try to define those complexes of variables that generate cycles of this very length, or at least try to make them plausible.¹⁰³ The scientist must, however, be always aware of the danger of constructing approaches of explanation of phenomena which in reality do not exist, or which exist in a completely different form.

As the course of the "long waves" represented here appears to result from a wavy variation of the level of shorter-term cycles, it is worth while questioning to what extent "long waves" are only formal expressions of specific characteristics of successive shorter-term cycles.¹⁰⁴ It depends on the answer to this question whether "long waves" can be of use as autonomous explanatory elements.

100. An average length of about 50 years is generally assumed, see e.g. *Rostow, W. W.*: The Long Cycle: An Integrated View. In: *Rostow: Why the Poor get Richer* (supra, n. 76), p. 4.

101. Both, the results of the spectral analysis, and the historical course of these cycles confirm this fact.

102. An approval of this view would limit the explanatory value of such a model very much; *Spree, R.*: Was kommt nach den "langen Wellen" (supra, n. 2), p. 311.

103. See *Wagner, A.*: Demographische Ursachen langfristiger Wachstumszyklen? Fragen zur Konzeption ökonomischer Zyklentheorien. In: *Schröder/Spree: Historische Konjunkturforschung* (supra, n. 1), p. 339 ff. Although Wagner argues that this hypothetical cycle-length is problematic, he tries to overcome this difficulty by taking recourse to the demographic development, but without determining the uncertain cycle-length empirically, beforehand. Wagner is not the only one who tries to solve this problem in such a way.

104. As to the relevance of such an idea for the Kuznets-cycles, see *Metz/Spree: Kuznets-Zyklen* (supra, n. 11), p. 365.

Irrespective of these problems, the fact that short-term cycles exhibit a specific course requires an explanation of those factors of macro-economic dynamics which cause the turn of the course of the different cycles with an appreciable regularity. Even if the scientist regards "long waves" as a sequence of phases of the structural change of the whole society, he has to explain those factors beforehand.¹⁰⁵ The interpretation of empirical evidences is rendered more difficult by the fact that if one tries to date the turning-points, it cannot be estimated how far the results that have been achieved, especially the inverse course of the upswings and downswings in the trend and in the "long wave," are conditioned by the statistical procedures. This re-

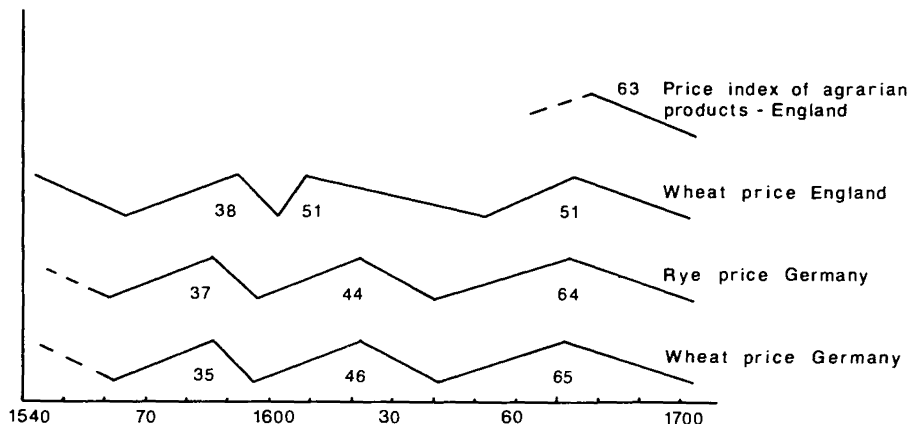


Fig. 13a: Schematic course of the "long waves" in the individual series 1531-1700

sult ought to be carefully analyzed with the aid of the filter-theory, in particular the special characteristics of the phase of the filter within the low-frequency domain.¹⁰⁶ Filters which dispose of a plain zero-phase, and which moreover achieve an exact separation between the trend and the "long wave" are being developed and, therefore, relevant results might be achieved by future research work.¹⁰⁷

Notwithstanding the fact that these methodical difficulties have not yet been solved, the use of formally exact methods already indicates the necessity of revising

105. See Spree, R.: Was kommt nach den "langen Wellen" (supra, n. 2), p. 311.

106. On principle, the phase of these recursive filters can only be analyzed with certain provisos, see Stier, W.: Verfahren zur Analyse (supra, n. 25), p. 67 ff. The results which have been achieved, however, imply that the filter causes a phase shift near by the zero point.

107. These filters work according to a principle that differs very much from the one of the recursive filters. See the report on Stier's lecture before the committee of the "Deutsche Statistische Gesellschaft für Neuere Statistische Methoden" on: Konstruktionsprinzipien digitaler Filter. In: Allg. Stat. Archiv 65 (1981), 1. Heft, p. 101.

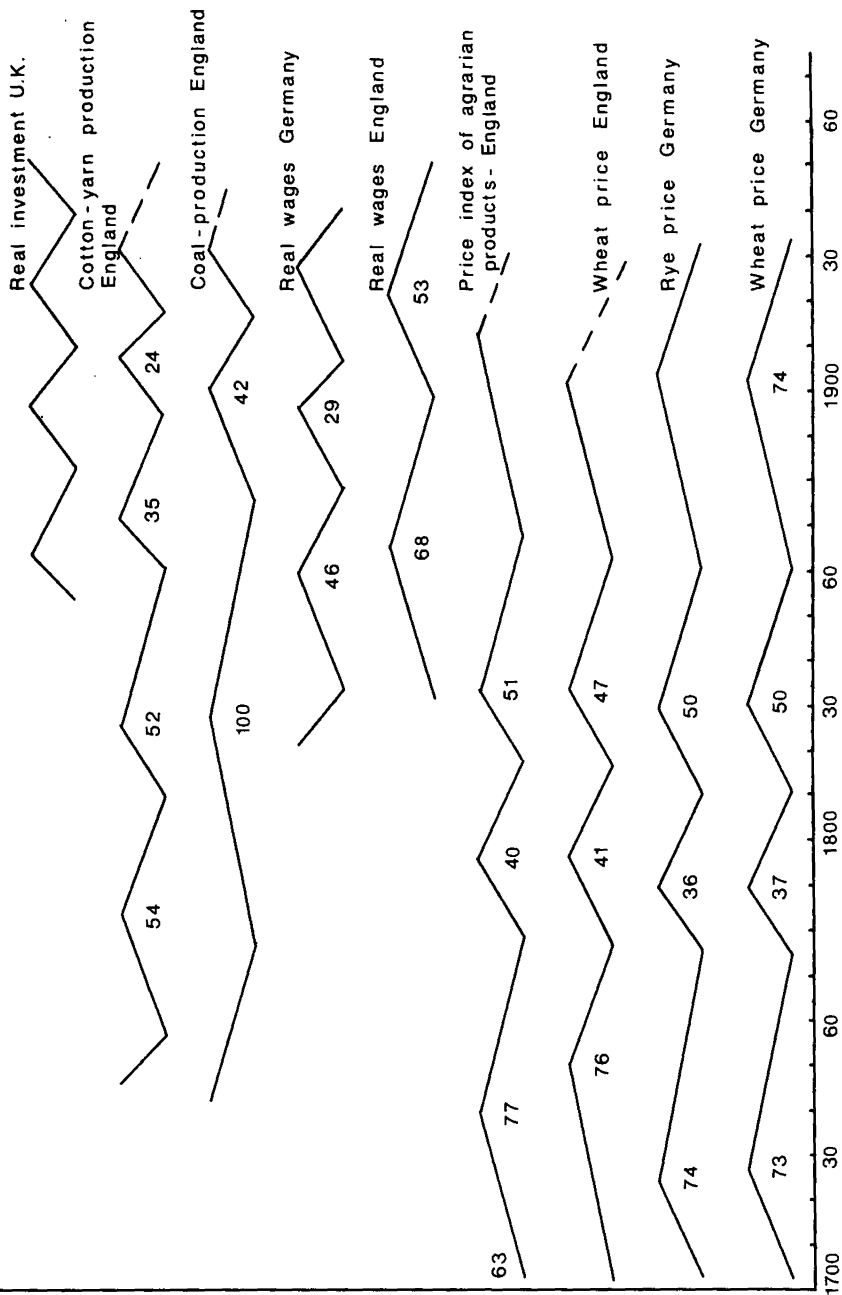


Fig. 13b: Schematic course of the "long waves" in the individual series 1700-1968

traditional conceptions about the shape and the contents of economic terms. Contents that are constituent of economic terms have nearly always been derived from an inadequate use of the results of simple statistical procedures, as for example from the calculation of polynomials of low degree. The analytical tools which are roughly described in this paper achieve an exact transformation of scientific terms into adequate formal-statistical concepts, i. e., into different types of filters. The fact that a clear separation between the trend and the “long wave” can be achieved by means of these filters indicates the necessity of defining scientific terms more precisely and with more attention to the methods than has hitherto been done. An empirical-statistical analysis ought to be preceded by a new attempt to define the main terms of eco-

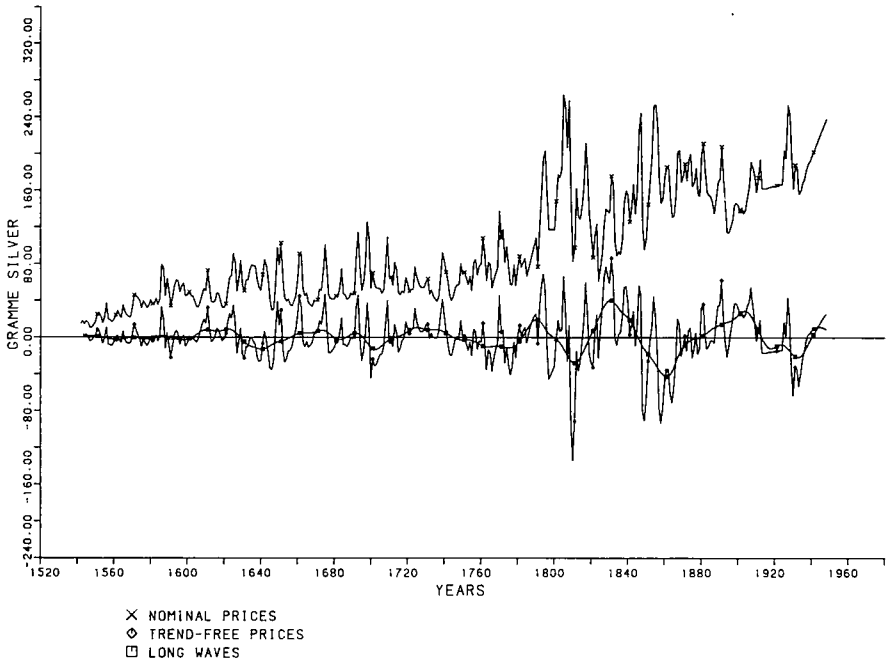


Fig. 14: “Long waves” of the German rye prices 1542–1948

nomical and historical research in a way that shall be appropriate to the new methods of analysis of time-series, if an empirical proof cannot be achieved otherwise. This kind of empirical research also points to the difficulties which arise if ambiguous economic terms are transformed into formal-statistical terms without being scientifically conceptualized beforehand. This, for example, applies to the decision about what is to be defined as trend, in terms of the filter-theory. The empirical results prove that by means of spectral analysis only the limits within which a sound defini-

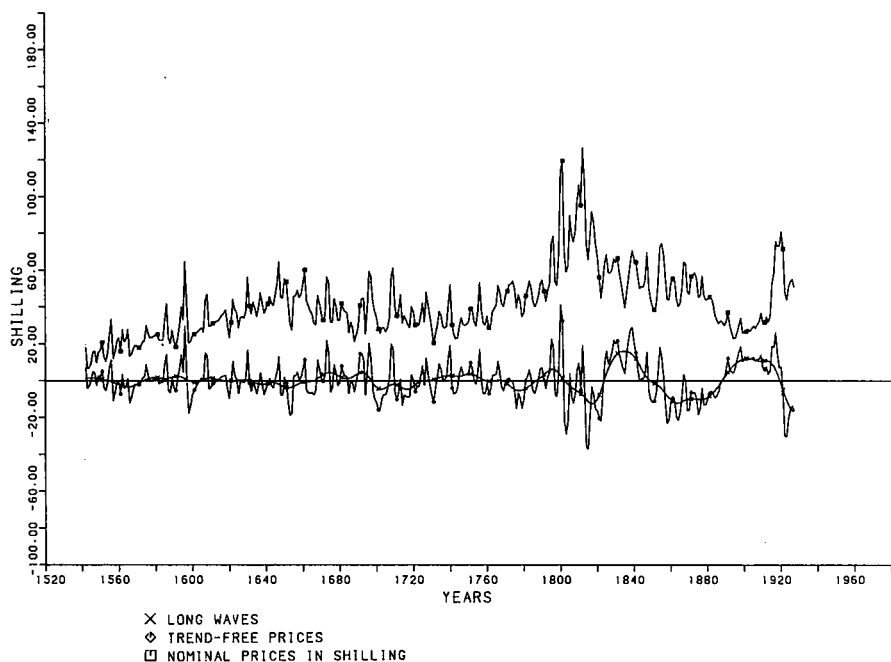


Fig. 15: "Long waves" of the English wheat prices 1542-1927

tion is to be found can be determined. This fact clearly shows that statistical-mathematical procedures cannot claim to offer an opportunity of determining the meaning and dimension of economic terms. On the contrary, the important function of such methods for economic history is to confront economic and historical terms, models or theoretical systems with empirical evidences, in order to deduce clear statements about the explanatory value of such theoretical constructions. Statistics can play an important role in this research-process only if the empirical evidences which contradict these models induce the scientist to revise his theoretical concepts.

Appendix

Description of the empirical data.

The Cologne wheat and rye prices were drawn from the edition published by Ebeling/Irsigler.¹⁰⁸ As regards the quotations of prices, they are unweighted nominal av-

108. See the exact description of the source in *Ebeling/Irsigler: Getreideumsatz* (supra, n. 77).

erage annual prices of the Cologne weekly market from 1531 to 1796. In order to compare them with quotations of prices of later periods, the Cologne prices had to be uniformly converted into Reichsmark per ton; to this end, all quotations of prices had to be multiplied with the silver equivalent of the albus of account¹⁰⁹ of 1777 and the results had to be divided through the fictive silver content of the 'Reichsmark', which was measured at 5.56 gramme.¹¹⁰ In addition, the weight per malter, which was

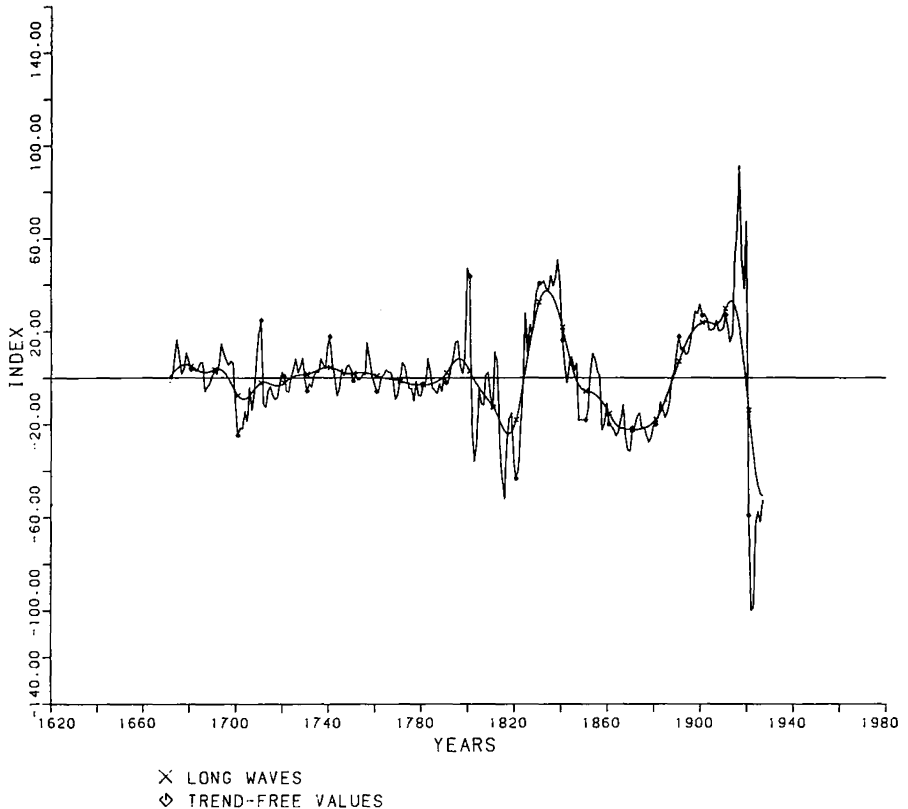


Fig. 16: "Long waves" of the English agrarian price index 1672-1927

109. Because of reasons of compatibility all the prices had to be reduced to gramme silver; the use of the last given value of silver of the "Albus of account" guarantees that there is no shift of level within the series. The silver value is 0.157 g; see *Ebeling/Irsigler: Getreideumsatz* (supra, n. 77), p. 42.
110. See *Abel, W.: Agrarkonjunktur* (supra, n. 76), p. 290ff. concerning the problems of reduction of coins and measures esp. p. 293.

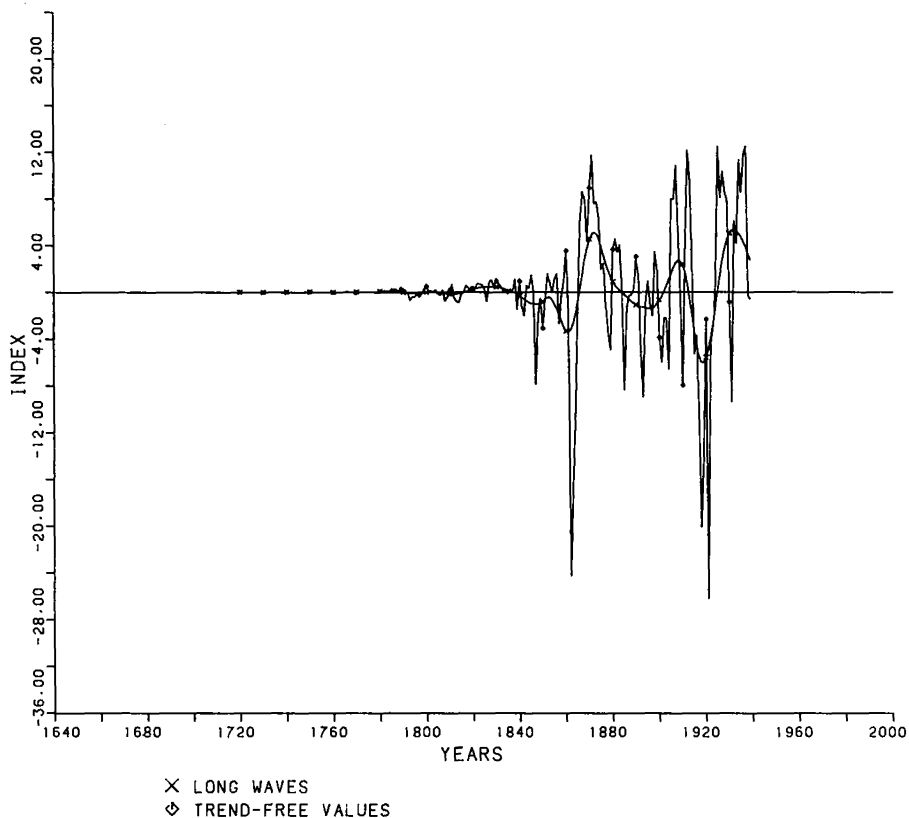


Fig. 17: "Long waves" of the English cotton yarn production 1711-1939

measured at 117 kg for wheat, and at 108 kg for rye,¹¹¹ had to be converted into units of 1,000 kg. The analyses referring to the period from 1797 to 1817 were based on the Berlin wheat prices, which have been published in Wilhelm Abel's book. In order to avoid a shift of the price level of these series, they had to be chained statistically.¹¹² The quotations from 1818 to 1850 and from 1876 to 1913 refer to the Cologne wheat prices, as well; those concerning the period from 1851 to 1875 had to be completed with quotations drawn from the "Vierteljahresheft zur Statistik des Deutschen

111. There are different data in literature concerning dry measure reductions. The data published here are based on the malter weights given by *Ebeling/Irsigler*. Abel's data are slightly different: *Agrarkrisen* (supra, n. 76), p. 294.

112. As to the statistical problems see *Anderson, O.*: *Indexzahlen*. In: *Handwörterbuch der Wirtschaftswissenschaften*, 4. Bd., Stuttgart/New York 1978, pp. 98-108.

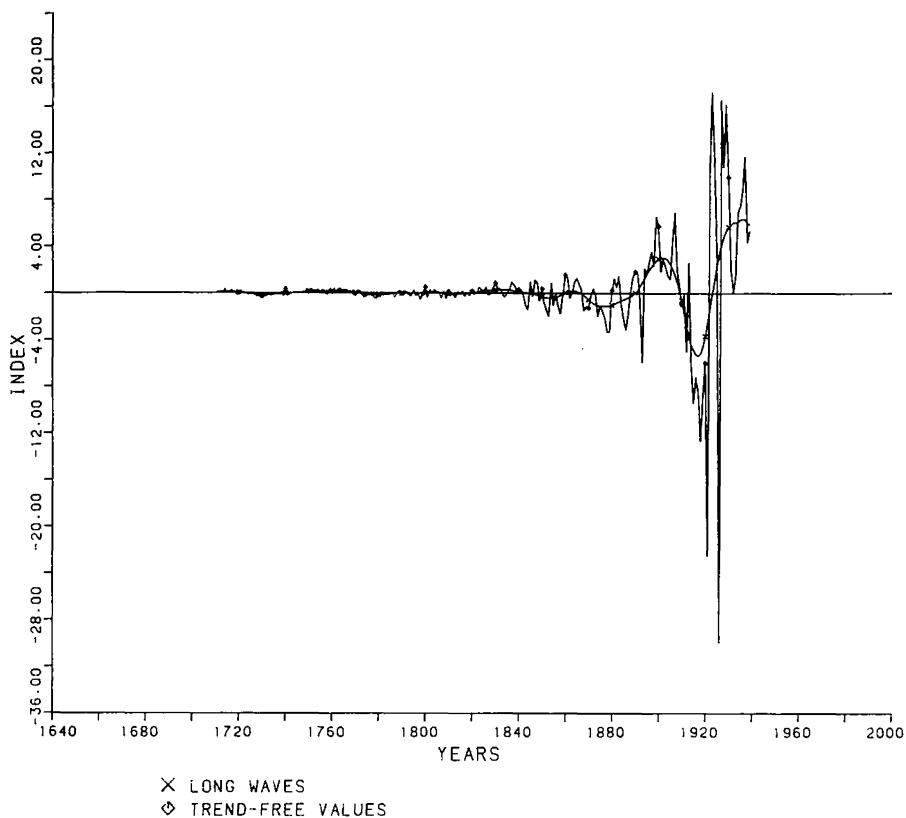


Fig. 18: "Long waves" of the English coal production 1711-1939

Reiches".¹¹³ The quotations of prices concerning the period from 1914 to 1959 were drawn from the series of producers' prices of agricultural products published by Hoffmann.¹¹⁴ All these quotations of prices are nominal prices,¹¹⁵ the same is true of the rye prices.

The series of the English wheat prices referring to the period from 1531 to 1770 were taken from the Exeter wheat prices published by Beveridge, and those concern-

113. Concerning the description of the material see *Ebeling/Irsigler*: Zur Entwicklung (supra, n. 32), p. 301 ff.

114. *Hoffmann, W. G.; Grumbach, F.; Hesse, H.*: Das Wachstum der deutschen Wirtschaft seit der Mitte des 19. Jahrhunderts. Berlin 1965.

115. This is not even altered by a multiplication with a constant silver weight.

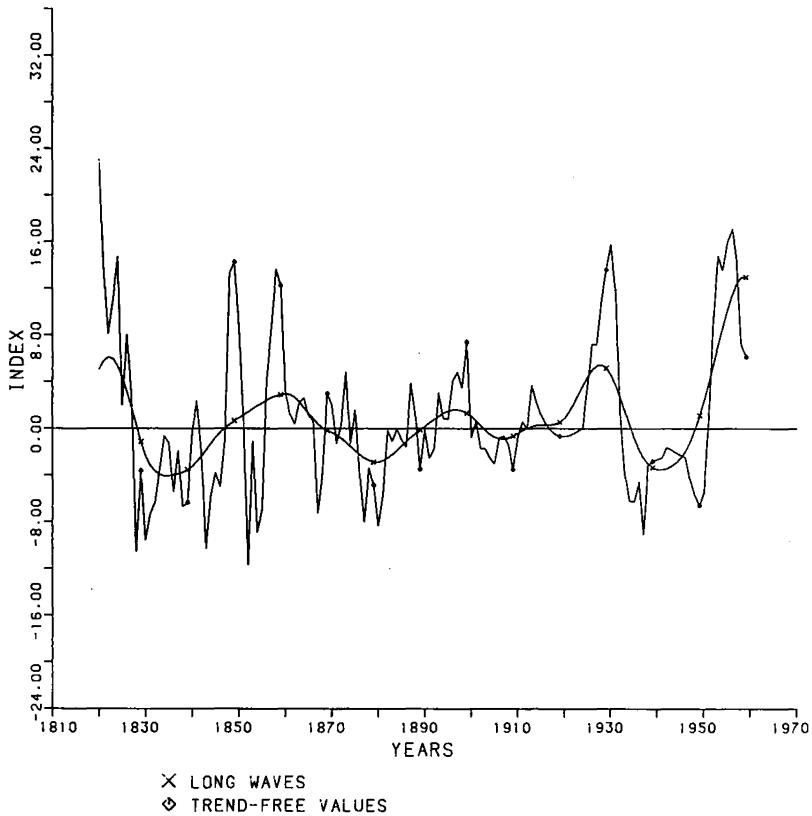


Fig. 19: "Long waves" of the real wage index in Germany 1820-1959

ing the time from 1771 to 1938 were drawn from the "London Gazette"¹¹⁶, which published the official prices for England, Wales and Scotland.¹¹⁷ All the prices had to be converted into shilling per Imperial Quarter (Winchester Quarter = 281,9 liters, Imperial Quarter = 290,8 liters).¹¹⁸ The series concerning the English vegetable agrarian products contains three different series of indices. These series were in turn selected with regard to the highest degree of uniformity of the data inquiry and of the contents of the shopping-basket, moreover, the material had to be comparable with

116. Price indices were taken from *Mitchell, B. R.; Deane, Ph.: Abstract of British Historical Statistics.* Cambridge 1971, p. 484 ff.

117. As to this material, cf. also *Abel, W.: Agrarkrisen* (supra, n. 76), p. 295 ff.

118. According to *Abel, a. a. O.*, p. 296 f. the Winchester Quarter comprised 281,9 and the Imperial Quarter 290,8 liters.

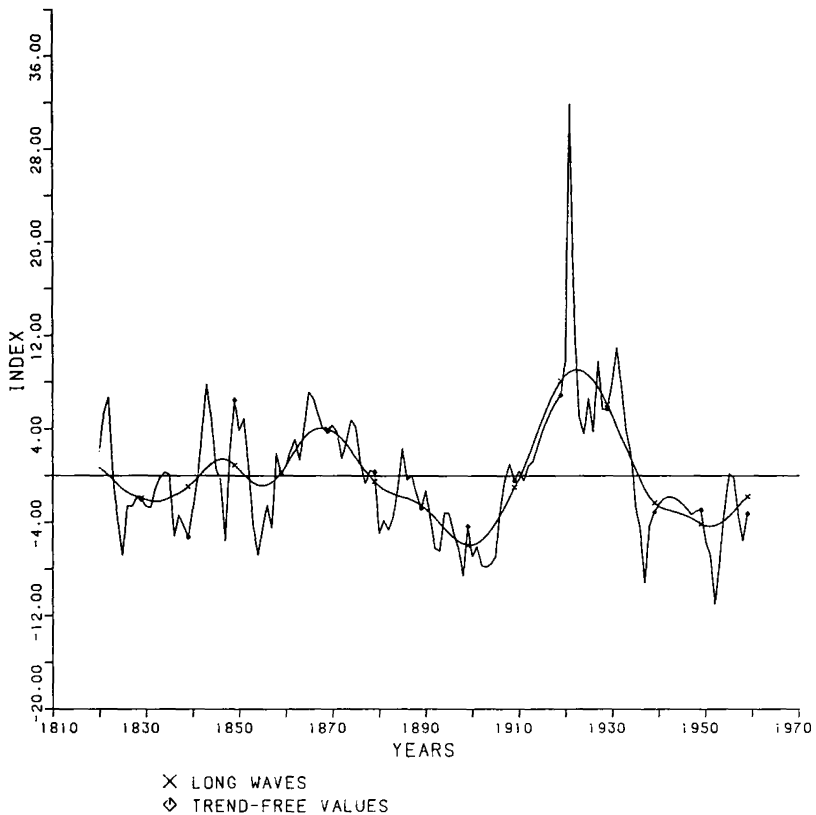


Fig. 20: "Long waves" of the real wage index in England 1820-1959

the German series. In detail, the following indices were chained statistically: Schumpeter's index to "Consumers' goods (a)" from 1661 to 1822; from 1822 to 1913 Rouseaux's index to "Vegetable Products (a)"; from 1914 to 1938 Sauerbeck's index to "Vegetable (a)".¹¹⁹ In contrast to the index determined by Gayer, Rostow, Schwartz, which can be regarded as the best of all price indices for the period from 1790 to 1850, all the indices mentioned above were calculated without being weighted before.

The quotations concerning the English cotton-yarn production were drawn from Hoffmann's book.¹²⁰ Hoffmann compiled this index series with the aid of different

119. Regarding the index series see *Mitchell/Deane*: Abstract (supra, n. 116), p. 468 ff., the letters put in brackets refer to the respective footnotes of the series in *Mitchell/Deane*.

120. As to the following remarks see *Hoffmann, W. G.*: *British Industry 1700-1950*. Oxford 1965, p. 228-230, 254f.

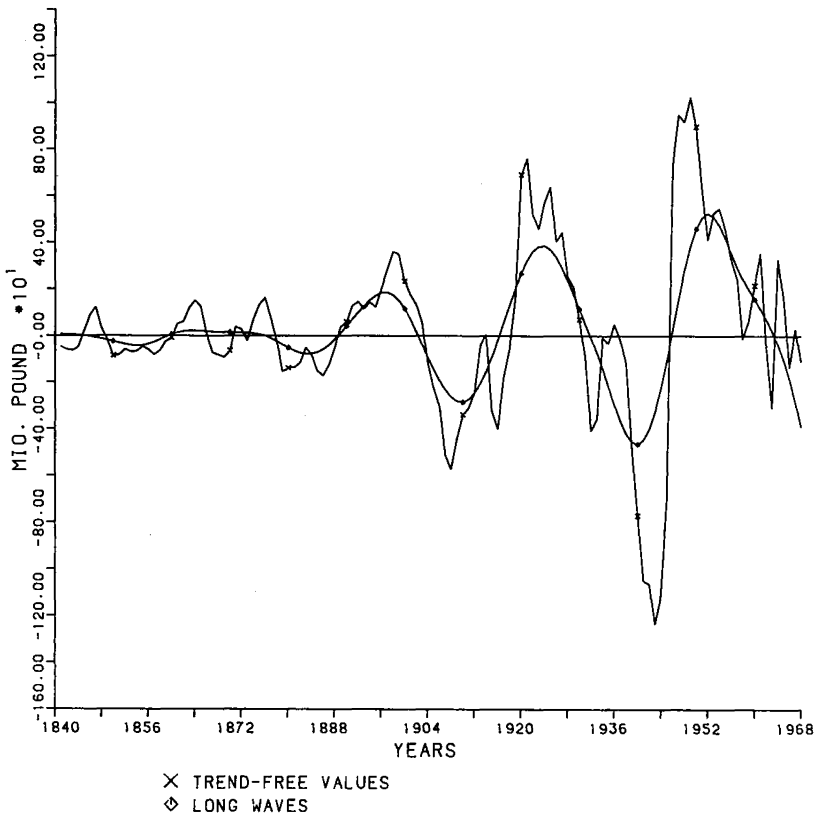


Fig. 21: "Long waves" of the real gross domestic investments in the United Kingdom 1841-1968

series; their representative value consequently varies from series to series. For instance, the cotton stored in England until 1800 was completely left out of consideration. It is due to the fact that the contents of the different series of indices are subject to permanent changes that the results achieved can only be interpreted with great provisos. Moreover, it must be taken into account that the series concerning the period from 1700 to 1800 differs very much in its indicatory function from the series which refers to the subsequent period. The same applies to the series of the English coal production. From 1700 to 1853 the content of this series differ very much from that which refer to the subsequent period.

The compilation of the English series of real wages required some additional steps.

Table 2: Results of the spectral analysis referring to the "long waves" in the individual series

(Cycle-length in years, short-term cycles were not listed)

	TRE1*	TRE1 a.K.**	TRE1 (3 notches)
Wheat prices Germany	60	60	-
Rye prices Germany	60	60	-
Wheat prices Cologne (1531-1796)	60	60	-
Wheat prices England	60	60	-
Agrarian price index England	55	55	-
Coal production England	40	40	40
Cotton yarn production England	30	30	30, 19
Real wage index England	50	50	-
Real wage index Germany	NF, 40	32	32
Real gross domestic investments U. K. 1830-1979	33	33	-

* after trend elimination with a notch-filter

** after trend elimination with a notch-filter and subsequent lowpass filter (Kaiser-filter)

This was due to the fact that the real wage index determined by Phelps Brown¹²¹ does not start before 1860. To this end, the nominal wages paid for both industrial¹²² and agricultural labour¹²³ had to be summed up to one total index according to the percentage of persons employed in the different sectors of production. In order to achieve an appropriate weighting for each year, the estimates made by Deane/Cole about the percentage of persons employed in the lines of production: agriculture, forestry, fishing, manufacture, mining, and industry had to be lineary interpolated.¹²⁴ The total wage index resulting from this procedure was thereupon deflated until

121. *Phelps Brown, E. H.*: Levels and Movements of Industrial Productivity and Real Wages Internationally Compared, 1860-1970. In: *The Economic Journal* 83 (1973), pp. 58-71.

122. As to the period from 1809-1850, the index series of average wages of different professions publ. by *Mitchell, B. R.*: *European Historical Statistics, 1750-1970*. London 1975, p. 184 and p. 190 is concerned. As to the period from 1850-59, the series is based on Wood's treatise. *G. H. Wood*: *Real Wages and the Standard Comfort since 1850*. In: *Journal of the Royal Statistical Society* (1909).

123. The data concerning wages in agriculture in England and Wales were taken from *Mitchell/Deane*: Abstract (supra, n. 116), p. 348 ff.

124. The relative importance of the wages of the different lines of production for the whole wage level can be estimated to some extent by means of the proportion of persons employed in the different branches of production. Although the data published by *Deane/Cole*: *British Economic Growth 1688-1959*. Cambridge ²1969, p. 142, may be faulty, they were nevertheless used to determine the index of real wages as they appeared to reflect the general tendency rather correctly.

Table 3: Turning-points of the "long waves" in England and Germany

Series	Peaks	Troughs
Wheat prices Germany	1586, 1622, 1672, 1727, 1790, 1831, 1903	1562, 1596, 1641, 1703, 1775, 1811, 1861, 1934
Rye prices Germany	1586, 1622, 1673, 1725, 1790, 1830, 1904	1561, 1597, 1640, 1703, 1776, 1811, 1861, 1933
Wheat prices England	(1543), 1592, 1609, 1674, 1751, 1797, 1834, 1902	1565, 1602, 1652, 1702, 1777, 1817, 1863
Agrarian price index England	1678, 1740, 1796, 1834, 1913	1703, 1779, 1818, 1868
Coal production England	1742, 1828, 1901, (1932)	1777, 1876, 1917
Cotton yarn prod. England	1746, 1784, 1826, 1872, 1908, (1932)	1757, 1810, 1861, 1895, 1918
Real wage index England	1868, 1922	1832, 1899, 1951
Real wage index Germany	1822, 1860, 1897, 1928	1834, 1879, 1907, (1941)
Real groß domestic investments U. K.	1864, 1897, 1924, 1952	1854, 1883, 1910, 1940

Table 4: Upswings and downswings of the "long waves"

	Upswings	Downswings
Wheat prices	1562/86, 1596/22, 41/72, 1703/27, 75/90,	1586/96, 1622/41, 72/1703, 1727/75, 90/
Germany	1811/31, 1861/1903	1811, 1831/61, 1903/34
Rye prices	1561/86, 97/1622, 40/73, 1703/25, 76/90,	1586/97, 1622/40, 73/1703, 25/76, 90/1811,
Germany	1811/30, 61/1904	30/61, 1904/33
Wheat prices	1565/92, 1602/09, 52/74, 1702/51, 77/97,	1543/65, 1592/1602, 09/52, 74/1702, 51/77,
England	1817/34, 1863/1902	97/1817, 1834/63, 1902-?
Agrarian price	1703/40, 79/96, 1818/34, 68/1913	1678/1703, 40/79, 1796/1818, 1834/68
index England		
Coal prod.	1777/1828, 76/1901, 1917/(32)	1742/77, 1828/76, 1901/17
Cotton prod.	1757/84, 1810/26, 61/72, 95/1908, 18/(32)	1742/77, 84/1810, 26/61, 72/95, 1908/18
England		
Real wage	1832/68, 1899/1922, 1951/(?)	1868/99, 1922/51
England		
Real wage	1834/60, 79/97, 1907/28	1822/34, 1860/79, 97/1907, (1928/41)
Germany		
Real gross domestic	1854/64, 1883/97, 1910/24, 1940/52	?/1854, 1864/83, 1897/1910, 1924/40, 1952/
investments U. K.		?

1850 with the general price index determined by Gayer/Rostow/Schwartz¹²⁵ and for the period from 1851 to 1859 with Rousseaux's price index,¹²⁶ which to this end had to be chained, before, with the index determined by Gayer/Rostow/Schwartz. The real wage index that resulted from this procedure until 1859 was finally statistically chained with Phelps Brown's index (1860-1970).

In order to calculate the German real wage index, only two series of indices had to be chained. For the period from 1809 to 1859 the index compiled by R. Gömmel,¹²⁷ which seemed to be the most appropriate one to be compared with the English index, was involved; for the period from 1860 to 1970 Phelps Brown's index was used once more.

Zusammenfassung:

“Lange Wellen” in wirtschaftshistorischen Reihen Englands und Deutschlands von der Mitte des 16. bis zur Mitte des 20. Jh.

Angesichts der gegenwärtigen weltweiten Rezession ist das Interesse am Phänomen der Kondratieff-Zyklen wieder stark belebt worden. Trotz einer intensiven wissenschaftlichen Diskussion und zahlreicher empirischer Analysen besteht bis heute kein Konsens in der Frage der Realität solcher Zyklen. Zwar zeigen sich in vielen ökonomischen Indikatorenreihen Trendschwankungen, doch es ist sowohl in der theoretischen wie der statistischen Forschung ungeklärt, ob sich diese Schwankungen mit einer angebbaren Regelmäßigkeit wiederholen.

Die Nichtlösbarkeit des Problems in der bisherigen Forschung ist einmal auf das Fehlen geeigneter Datenreihen zurückzuführen, zum anderen auf den Umstand, daß kein brauchbares statistisches Verfahren für eine gegenstandsneutrale Untersuchung zur Verfügung stand. Die zunächst mit hohen Erwartungen eingesetzte Spektralanalyse wird neuerdings mit Recht starker methodischer Kritik unterzogen; denn der in allen ökonomischen Zeitreihen vorhandene Trend macht eine informative Spektralanalyse unmöglich, da diese immer ein Ergebnis liefert, dessen Form bereits *Granger* als “typical spectral shape of an economic variable” bezeichnet hat. Ein spektralanalytischer Nachweis langer Wellen erfordert daher immer die vorherige Trendbereinigung der Zeitreihe.

Diese exakte Trendbereinigung gelang bislang nicht. Entweder wurden die langen Wellen mit dem Trend ausgefiltert oder es waren die Auswirkungen der Trendbereinigung im Frequenzbereich nicht überprüfbar, so daß immer offen blieb, ob eventuell ausgewiesene lange Schwingungen erst durch das Verfahren erzeugt wurden (Slutzky-Effekt). Die Nichtüberprüfbarkeit der Hypothese von der Existenz langer Wellen war insgesamt ein sehr unbefriedigender Zustand.

125. *Gayer, A. D.; Rostow, W. W.; Schwartz, A. J.*: The Growth and Fluctuation of the British Economy 1790-1850, 2 vols., Oxford 1953, vol. 1, p. 468-470.

126. The index can be found in *Mitchell/Deane*: Abstract (supra, n. 116), p. 471.

127. *Gömmel, R.*: Realeinkommen in Deutschland. Ein internationaler Vergleich 1810-1914 (supra, n. 83).

Ein völlig neuer Weg zur Lösung dieser Frage besteht darin, Zeitreihenanalyse als Filter-Design-Problem zu begreifen und sich methodisch ganz vom klassischen Komponentenmodell zu lösen. Einer Arbeitsgruppe um Prof. Stier in Bochum ist es gelungen, Filter zu konstruieren, die jene scharfen Trenneigenschaften aufweisen, mit denen das Problem der langen Wellen optimal angegangen werden kann. Der Schlüssel liegt in der Kombination dieser neuen rekursiven Filter mit der Spektralanalyse. Damit lassen sich, über die Intention bisheriger Arbeiten hinausgehend, Form und Lage von Langfristzyklen in der historischen Zeitdimension erstmals darstellen.

Das Verfahren wurde auf verschiedene Zeitreihen (Preisserien, Produktions- und Lohndaten) angewandt. Von den z. T. überraschenden Ergebnissen seien nur einige kurz skizziert: Langfristzyklen sind in allen untersuchten Reihen nachweisbar. Allerdings zeigt sich der typische Kondratieff-Zyklus nur in Preisreihen. Produktionsreihen weisen eindeutig kürzerfristige Zyklen auf, die vielleicht dem Typ der Kuznets-Zyklen zuzuordnen sind, wahrscheinlich aber einen neuen Typus langer Wellen darstellen. Die mit Hilfe der Spektralanalyse diagnostizierten Zyklen-Typen erfahren allerdings bei der Darstellung in der historischen Zeit wesentliche Modifikationen. Von Zyklus zu Zyklus ändert sich nicht nur die jeweilige Zyklenlänge, sondern auch die Dauer der Auf- und Abschwungsphasen. Hinzu kommt, daß die Amplitudenschläge deutliche Unterschiede zwischen vorindustrieller und industrieller Zeit aufzeigen.

Vergleichsuntersuchungen mit deflationierten Preisreihen haben gezeigt, daß eine schwankende Geldwertstabilität nicht Ursache dieser Zyklen sein kann, sondern nur den Trend beeinflusste.

Die als Trend ausgefilterten nicht-periodischen Schwingungen zeigen keinen gleichmäßig linearen, sondern einen wellenförmigen Verlauf. Ob es sich bei diesem Phänomen um ein methodenbedingtes Ergebnis handelt muß vorerst offen bleiben.

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