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SCIENTOMETRIC EVIDENCE FOR THE EXISTENCE OF LONG ECONOMIC GROWTH CYCLES IN EUROPE 1500–1900

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(Received August 30, 1997)

In times of economic stagnation, the debate about "long waves" of economic growth typically refreshes. This has also been the case in the period of the world-wide economic stagnation since 1970. But the results concerning the existence of long-term cycles of economic activity are still controversial. In this contribution, the "ups and downs in the pulse of science and technology" (*Price*) are related to economic growth cycles. It turns out that Schumpeter's contention of an inverse relationship between the level of scientific and technological activity on the one side and economic growth on the other side is correct for 1500 to 1900. Thereby also an indirect proof is furnished for the existence of long economic growth cycles in the last centuries.

The debate about long economic waves

Rhythms of economic activity were already a subject of some 19th-century writers, some of it with Hegelian, some of it with mystical backgrounds. But it was Soviet Russia's *Kondratieff* who – in the first third of our century – made substantial empirical analyses of economic growth cycles named after him now. (With such empirical-grounded work he quickly fell into the despotic political system's disgrace.) *Kondratieff* showed the existence of two and a half "Kondratieffs" in price movements of different countries - with about fifty years length of each cycle.[1] The debate itself about "Kondratieffs" seemed to swing inversely with the rhythm of economic cycles. That is, in times of economic depression the debate revitalized, and in times of prosperity the participants lost interest. One may prove this by scientometric means, but I intend to focus on another subject of scientometrics, namley the quantitative development of science and technology. The relationship of their development to economic growth cycles can be seen quite analogous, as will be shown.

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The debate about long economic waves

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Before I go into *medias res* I would like to outline the main topics of my speech. First I would like to work out some of the main quarrels of the debate about long economic growth cycles. Of course, this is a subjective and external assessment made by a non-economist. Then that crucial contention of Schumpeter in connection with "long waves" is explained, which is able to evoke very scientometric interest. Schumpeter postulated an inverse relationship between long economic growth cycles and growth of important ideas in science and technology. Having pointed out some methodological difficulties of measuring the relationship, I shall present some empirical evidence for the correctness of Schumpeter's view. It is finally argued that the empirical results presented here are an indirect proof for the existence of long economic growth cycles.

Let us come back now to the economic debate. I am aware that I am moving on slippery ice when I try to make pronounced conclusions, because economists themselves have extremely contrary standpoints. For some economists it is a matter of sure that "long waves" of economic activity indeed exist, and they speak without scientific scruples of the coming 6th Kondratieff, for example. Other economists deny rigorously the existence of long waves. For myself, I see three most important points of the discussion.

The first point is that nobody denies that there are indeed ups and downs in the level of economic activity. Most observers meanwhile agree that these ups and downs are to be found not only by means of indirect indicators as price movements, but that they can be found in figures of real production as well.

The second point concerns the methodological difficulties to describe possible periodicities of such long-term economic ups and downs. Again and again, empirical doubts and counter-examples are put forward against periodicity, and again and again, evidence in favour of regularity is presented. Only chaos theory may resolve the riddle of those contradictions. The phenomenological descriptions of economic ups and downs have little to do with long waves, but rather with historical periods or phases of economic activity of different lengths. But it is the periodicities that are able to attract further scientific attention. Only periodicities, be they more or less fuzzy, may signalize a common causal basis of economic fluctuations. The methodological difficulties to reliably exhibit possible periodicities are tremendous, and often enough they are underestimated. Some improvements have been made, however, and in this respect the discussion has become clearer (cf. for example Ref. 2).

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My third point questions whether it makes sense at all to seek common causal traits of economic fluctuations which could be the result of most different circumstances. Can such a complex process as economic activity have causes which all flow into one common temporal structure? This is not the only view which seems not to be very plausible. The critiques of long wave adepts put their fingers, however, on the sore spot of their opponents: the total lack of a reasonable causal picture of long waves. I want to stress here the term long wave; it is unquestioned that reasonable causal pictures of certain economic phases and periods exist. What counts, are common causal traits of long waves. Steps are made in the direction of causal reasoning by *Berry*,[3] for example. Before I proceed to the core of my concern let me explain what science and technology might have to do with long economic waves.

Science and technology in the context of long waves

I spoke of a lack of a causal understanding of long economic waves. It might be not adequate to call Schumpeter's studies of long economic growth cycles in industrialized societies a causal picture. However, he at least drew some main lines of such a picture. It is well-known that he stressed the role of pioneer entrepreneurs for economic growth. Also, he spoke of different levels of innovative activity in societies: in an economic upswing the innovative activity is fading out; in an economic downswing, innovative activity is stimulated. The Schumpeterian observations laid down the foundation for Neo-Schumpeterian theories, which put exactly this mechanism in the core of thinking about economic ups and downs since industrialization. The theories attracted major interest because of their attempt to offer some causal understanding of economic growth cycles. The central issue of Neo-Schumpeterians is the role of science and technology in growth cycles. They believe in an interaction of scientific-technological developments on the one side and of economic growth on the other side. In their view, neither of both develops continuously. *Mensch*,[4] for example, pointed out that important industrial innovations – the so-called basis innovations – are coming in clusters. Correlating those clusters with the long waves of economic activity since 1750, he found that basis innovations are inversely related to growth cycles, which is totally in accordance with Schumpeter's thesis. There are some differences among Neo-Schumpeterians. Mensch explicitly denies that science and technology itself develops discontinuously; C. Freeman, however, found cluster-like developments also in the very technological development as reflected, for example, in patents. In what follows I shall restrict myself exclusively to the development of science and technology and their

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Two central measuring problems

The first central measuring problem is the assessment of the development of economic activity for some centuries. Here I came to a quite simple, but risky solution as well: I rely on a recent sound review of *Goldstein* in his book *Long cycles*.[5] *Goldstein* has put together plenty of data and assessments to be found in literature about economic history – not only the literature of adepts of long waves, but assessments of those authors who are sceptics or ignorants as well. By means of such comparisons of different sources he came to a fairly consistent conspectus of cycles of economic activity in Europe from the end of the Middle Ages on. This periodization did not lead to a quantitative picture of the level of economic activity, but only to a qualitative picture. For the time being it is illusory to expect something else.

The second central problem is to measure the number of basis inventions, ordinary inventions, and scientific ideas.

Innovations are understood as economic activities based on new technologies or new scientific developments. Basis innovations have a major influence on economic development; typically they call into life completely new branches of industry. The problem occurs when one has to select the few basis innovations out of thousands of less prominent innovations. Another problem is the dating problem: How can a single year of a basis innovation be selected which is legitimated as the year in which the innovation emerged for the first time? I cannot discuss these thorny problems here *en detail*. For the sake of shortness, I simply refer here to *van Duijn*[6] who presented a diligent compilation which was less criticized than Mensch's list.

Each basis innovation is linked to a corresponding basis invention by *van Duijn*. I am interested here in these inventions in a statistical manner only. Of course, for the identification of such a basis invention the same methodological difficulties exist as for basis innovations.

In a similar superficial manner I shall not discuss problems of how to measure "ordinary" technology, i.e. inventions, by means of patent data that I intend to use below. In the course of the last years, scientometricians came to a fairly well-balanced picture of advantages and of drawbacks of patent data.[7] I can only refer to this discussion when I am ready here to use them as indicators for the growth of technology.

Measuring the growth of scientific ideas might be a task still far more difficult than to measure basis innovations or technology. I shall rely on statistics of *Sorokin*[8] which relationship to economic growth; innovations, i.e. economically virulent science and technology, are left out.

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Ups and downs in economic growth and in the growth of basis inventions, basis discoveries, and ordinary inventions

First, I consider the relationship between economic ups and downs on the one side, and basis inventions on the other side. In Table 1 I present economic ups and downs according to the above mentioned economic growth schema of *Goldstein*. In the columns the change of the number of basis inventions for exactly the Goldstein periods of economic ups and downs are recorded. An economic up means that the economy of a period flourishes; an economic down means that the economy shrinks - compared to the period before. In the next column I compare the economic periods on the one side and the situation for basis inventions for the same time interval on the other side.

Table 1
Most important inventions (moving 10-year-averages, i.e., sums for the years (x-4, ... x, x+1, ... x+5)/10; average of the annual growth rates in per cent. Relationship to the economic cycles. Economic cycles according to *Goldstein* (Ref. 5). + means upswing; - means downswing. The source of inventions are the inventions of the *van Duijn* list (Ref. 6)

Economic cycle	Characteristic	Basis inventions according van Duijn's record Moving 10-year-averages; then average of annual growth rates in per cent. Relationship to the growth cycle
1763-1790	–	12.63
1791-1814	+	2.22 inverse
1815-1848	–	3.75 inverse
1849-1872	+	–0.26 inverse
1873-1893	–	3.95 inverse
1894-1917	+	–2.66 inverse
1918-1940	–	7.76 inverse
1941-1968	+	–1.51 inverse*

* 1941-1967 (last interval computed: 1950-1959).

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1918-1940 — 7.76 inverse

1941-1968 + inverse*

* 1941-1967 (last interval computed: 1950-1959).

If there is an economic upswing and, at the same time, a downswing in basis inventions, I call this an "inverse" relationship. If both point into the same direction (i.e., if both together show an "up" or a "down") I call this a "direct" relationship. From Table 1 one can see that an inverse relationship between economy and basic technological ideas existed for the three "long waves" of economic development 1791 to 1940 and for the upswing of the fourth wave. The development of basic technological ideas is expressed in growth rates of moving 10-year-averages of the annual number of basis inventions.

Now I proceed to the calculations extracted from the Darmstädter chronology. Here I had to reduce the depth of focus to 10-year-intervals, because the Darmstädter counting of Sorokin is based on summations of 10-year-intervals. The Goldstein periods of economic ups and downs were rounded to 10-year-intervals by myself. Because the periods of economic ups and downs have different lengths, I had to compute the average growth rates of technological inventions of each corresponding period (in the scale of 10-year-intervals). The growth rates of (mostly two or three) upswing 10-year-intervals and of (mostly two or three) downswing 10-year intervals are now compared with the period before; finally, the result is compared with the economic tendency, everything analogous to the procedure of the first table. One can see from Table 2, that in 12 out of 15 cases the relationship is inverse. This would be significant on a 0.05 level of the Runs test if there were 13 or more such cases.[10]

The same procedure was performed with scientific discoveries. Now in all 15 cases an inverse relationship is exhibited (what is now statistically significant, of course).

It would be necessary to validate these results with the help of other science and technology time tables and other sources. This is carried through in the monograph I mentioned above.

What is the result if one does not take outstanding discoveries or basis inventions, but rather ordinary discoveries or inventions? I concentrate myself on inventions, namely patents. It is not the place here to discuss the relationship between ordinary and most important inventions; I am only interested in the inverse/direct relationship here. I compiled patent statistics from the beginning of the 19th century on for the USA, Great Britain, France and Germany. The result is illuminating: For the European countries, the inverse Schumpeter relationship prevails; for the USA, however, a direct relationship. This confirms some observations scattered in the literature on the US and the European patent systems. I cannot go into detail here.

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Table 2
Economic phases according to *Goldstein* (Ref. 5, p. 67; rounded to 10-year-intervals by myself). + means upswing; – means downswing. Discoveries and inventions according to the Darmstädter countings of *Sorokin* (Ref. 8), 10-year-intervals; average growth rates of an economic upswing or downswing in per cent

Economic cycle	Characteristic	Basis discoveries (average growth rates of 10-year intervals; per cent)	Characteristic	Basis inventions (average growth rates of 10-year intervals; per cent)	Characteristic (average growth with respect to the period before; relationship to the economic cycle)
1510–1530	+	68.33		–25.87	
1531–1540	–	100.00	+ inverse	57.14	+ inverse
1541–1560	+	8.17	– inverse	9.09	– inverse
1561–1580	–	11.05	+ inverse	15.03	+ inverse
1581–1600	+	6.98	– inverse	11.25	– inverse
1601–1620	–	19.89	+ inverse	–19.96	– direct
1621–1650	+	13.86	– inverse	10.02	+ direct
1651–1690	–	22.03	+ inverse	29.57	+ inverse
1691–1720	+	–5.64	– inverse	–3.88	– inverse
1721–1750	–	37.70	+ inverse	42.90	+ inverse
1751–1760	+	–10.74	– inverse	–36.54	– inverse
1761–1790	–	37.98	+ inverse	49.18	+ inverse
1791–1810	+	17.22	– inverse	8.47	– inverse
1811–1850	–	23.96	+ inverse	29.72	+ inverse
1851–1870	+	2.03	– inverse	9.53	– inverse
1871–1890	–	9.62	+ inverse	6.46	– direct

Concluding remark

The results do not only confirm the Schumpeter view described above. They also indirectly confirm the existence of long economic growth cycles, the length of which has to be discussed *en detail*. I do not want to speculate about causes of such economic cycles. Rather I would like to speculate about the causes of waves of scientific and of technological successes. In my view, scientific and technological success is based on the system of higher education and learning of a country in the very end. The systems of higher education of the USA (and of Japan) on the one side and of Great Britain, France and Germany on the other side are different. One of the most important differences is the system of financing. I am convinced that the functioning of this system has to be studied intensely to come closer to the causes of the empirical results reported above. Most experienced scientists told me that presenting a paper should promote forthcoming books; and therefore, I should take the last chance to refer you to some further results and speculations contained in my forthcoming monograph.

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Economic phases according to Goldstein (Ref. 5, p. 67; rounded to lO-year-intervals by myself). means upswing; — means downswing Discoveries and inventions according to the Darmstfidter countings of Sorokz'n (Ref. 8), IO-year-intervals; average growth rates of an economic upswing or downswing in per cent

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1531—1540 — 100.00 inverse 57.14 inverse

1541—1560 8.17 — inverse 9.09 — inverse

1561—1580 — 11.05 + inverse 15.03 inverse

1581—1600 + 6.98 — inverse 11.25 inverse

1601—1620 - 19.89 inverse —l9.96 — direct 1621-1650 + 13.86 — inverse 10.02 direct

1651—1690 - 22.03 inverse 29.57 inverse

1691—1720 + — inverse —3.88 — inverse 1721—1750 — 37.70 inverse 42.90 inverse

1751—1760 + —10.74 — inverse —36.54 — inverse 1761~1790 — 37.98 inverse 49.18 inverse

1791—1810 + 17.22 — inverse 8.47 — inverse

1811—1850 — 23.96 inverse 29172 inverse

1851—1870 2.03 - inverse 9.53 — inverse

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