

## Appendix 3

# The Sixth Kondratieff Wave and the Cybernetic Revolution

Many economists believe that there exist large-scale cycles with a characteristic period of 40 to 60 years. Joseph Schumpeter (1939) named these long cycles ‘the Kondratieff cycles’ after the famous Russian economist Nikolay Kondratieff who showed in the 1920s that in the long-term dynamics (about half a century) there is a certain cyclical regularity, in the course of which an *upswing* wave of rapid economic indexes' growth is followed by a *downswing* when the indexes drop (Kondratieff 1925, 1935). Those long cycles are also called Kondratieff waves or K-waves for short.

Thus, Kondratieff waves (Kondratieff cycles) are the repeated fluctuations of important economic variables with a characteristic period of about 40–60 years, within which at one (upswing) phase the growth rates of indicators tend to accelerate, and at the other (downswing) phase they tend to slow down. We will refer to the upswing phases as *A-phases* and the downswing ones – as *B-phases*. These long cycles have particular strong connections with innovations (for more details see Korotayev and Grinin 2012; Grinin and Korotayev 2014a; Grinin, Korotayev, and Tausch 2016).

We have established a close correlation between production principle cycles and Kondratieff cycles (for more details see Grinin 2012c, 2013; Grinin L. and Grinin A. 2014; Grinin, Korotayev, and Tausch 2016). Taking into account that K-waves emerge only at a certain level of economic development of societies, we can consider the *K-waves as a specific mechanism connected with the emergence and development of the industrial-trade production principle and the way of expanded reproduction of industrial economy*. Given that each new K-wave does not just repeat the wave motion, but is based on a new technological mode, *K-waves in a certain aspect can be treated as mature phases of the development of the trade-industrial production principle and the*

*first phases of development of the scientific-cybernetic production principle.*

### **1. The Trade-Industrial Production Principle as a Cycle Consisting of K-Waves**

As it has been shown in our above mentioned papers the first three K-waves are connected with the industrial production principle. The special attention is paid to the correlation between the duration of the industrial production principle phases and the duration of K-wave phases. Certainly, there can be no direct duration equivalence of both K-waves and their phases, on the one hand, and the industrial production principle phases, on the other, due to the different duration of the industrial production principle phases (that is within the principle of production's cycle its phases differ in duration, but their duration proportions remain the same in each production principle [see Appendix 2; Grinin 2006a, 2009b]). However, we have succeeded in establishing a more complex ratio according to which *at the average one K-wave correlates with one phase of the industrial production principle*. In general, we found out that three and a half waves coincide with three and a half phases of the industrial principle of production! It is clearly seen in Table 1. Such a correlation is not coincidental, as innovative development of the industrial production principle is realized through long Kondratieff cycles which are largely defined by large-scale innovations.

**Table 1.** Periods of the trade-industrial production principle and Kondratieff waves

Phases of the Trade-Industrial Production Principle	The Third Phase, 1730–1830 ≈ <b>100 years</b>	The Fourth Phase, 1830–1890 ≈ <b>60 years</b>	The Fifth Phase, 1890–1929 ≈ <b>40 years</b>	The Sixth Phase, 1929–1955 ≈ <b>25 years</b>	Total: ≈ 225 years, from 1760 – <b>195 years</b>
1	2	3	4	5	6
The Number of the K-wave	Zero (B-Phase) / The First Wave (A-Phase), 1760–1817 – <b>about 60 years</b>	The End of the First Wave / The Second Wave, 1817–1895 – <b>more than 75 years</b>	The Third Wave, The Upward Phase, 1895–1928 – <b>more than 35 years</b>	Third wave, The Downward Phase, 1929–1947 – <b>about 20 years</b>	About <b>190 years</b>

1	2	3	4	5	6
The Phase of K-wave	B-Phase of the Zero Wave, <sup>1</sup> 1760–1787	The Second half of the Downward Phase, 1817–1849	The Upward Phase, 1895–1928	The Downward Phase, 1929–1947	
The Phase of K-wave	The Upward Phase, 1787–1817	The Upward Phase, 1849–1873			
The Phase of K-wave		The Downward Phase, 1873–1895			

*Note:* For simplicity, we take concrete years for the beginning and the end of the periods, though such a transition obviously lasts for a certain period of time.

## 2. The Cybernetic Revolution, Scientific-Cybernetic Production Principle, and the Fourth, Fifth, and Sixth K-Waves

Table 2 demonstrates the connection between three first phases of the scientific-cybernetic production principle (which coincide with three phases of the Cybernetic Revolution) and three Kondratieff waves (the fourth, fifth and sixth). Correlation is here even stronger than between the first three K-waves and the trade-industrial production principle phases, due to the shorter duration of the scientific-cybernetic production principle phases in comparison with those of the industrial production principle.<sup>2</sup>

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<sup>1</sup> We took as the beginning a zero K-wave which downward phase coincided with the beginning of the Industrial Revolution, *i.e.* the 1760s (as we know, it is downward phases that are especially rich in innovations).

<sup>2</sup> The reason for the shorter duration is the general acceleration of historical development.

**Table 2.** The scientific-cybernetic production principle (initial phases) and Kondratieff waves

Phases of the Scientific-Cybernetic Production Principle	The first phase (initial phase of the Cybernetic Revolution) 1955–1995  <b>≈ 40 years</b>	The second phase (middle phase of the Cybernetic Revolution) 1995 – the 2030s/40s.  <b>≈ 35–50 years</b>	The third phase (final phase of ‘self-regulating systems’ of the Cybernetic Revolution) the 2030s/40s–2055/70s  <b>≈25–40 years</b>	Total: <b>≈ 100–120 years</b>
K-Wave and Their Phases	The Fourth Wave, 1947 – 1982/1991  <b>≈ 35–45 years</b>	The Fifth Wave, 1982/1991 – the 2020s. The beginning of the upward phase of the sixth wave (2020–2050s) <b>≈ 30–40 years</b>	The sixth wave, 2020 – 2060/70s. The end of the upward phase and downward phase (the latter ≈ 2050 – 2060/70s) <b>≈ 40–50 years</b>	About <b>110–120 years</b>
K-Wave and Their Phases	Upward phase, 1947 – 1969/1974s	Downward phase of the fifth wave, 2007–2020s		

K-Wave and Their Phases	Downward phase, 1969/1974 – 1982/1991	Upward phase of the sixth wave, 2020 – 2050s.	
K-Wave and Their Phases	The fifth wave, 1982/1991 – 2020s, upward phase, 1982/1991 – 2007		

### 3. K-waves and Changing Main Technological Sector

It is known that many researchers correlate each Kondratieff wave with a change of the leading technological sector in economy (see Note 3 for the literature sources). Applying the theory of production principles and production revolutions allow us to revise the sequence of the major (leading) production sectors during the change of K-waves (Grinin 2012c).<sup>3</sup>

**Table 3.** K-waves, technological modes and leading macrosectors

Kon-dratieff Wave	Date	A New Mode	Leading Macro-sector	Production Principle and Number of Its Phase
1	2	3	4	5
First	1780–1840s	The textile industry	Factory (consumer) industry	Trade-Industrial, 3
Second	1840–1890s	Railway lines, coal, steel	Mining industry and primary heavy industry and transport	Trade-Industrial, 4
Third	1890–1940s	Electricity, chemical industry and heavy engineering	Secondary heavy industry and mechanic engineering	Trade-Industrial, 5/6
Fourth	1940-e – the early 1980s	Automobile manufacturing, manmade materials, electronics	General services	Trade-Industrial, 6, Scientific-Cybernetic, 1
Fifth	1980s – ~2020	Micro-electronics, personal computers	Highly-qualified services	Scientific-Cybernetic, 1/2

<sup>3</sup> During the table compiling we took into account ideas and works cohering with the theories which explain the nature and pulsation of K-waves by changing of technological ways and/or *techno-economic paradigms*: Mensch 1979; Kleinknecht 1981, 1987; Dickson 1983; Dosi 1984; Freeman 1987; Tylecote 1992; Glazyev 1993; Mayevsky 1997; Modelski and Thompson 1996; Modelski 2001, 2006; Yakovets 2001; Freeman and Louçã 2001; Ayres 2006; Kleinknecht and van der Panne 2006; Dator 2006; Hirooka 2006; Papenhausen 2008; see also Lazurenko 1992; Glazyev 2009; Polterovich 2009; Perez 2002.

1	2	3	4	5
Sixth	2020/30s – 2050/60s	<i>MANBRIC- technologies</i> (medical, addi- tive, bio-nano- robotics, info- and cognitive)	Medical human services	Scientific- Cybernetic, 2/3

#### **4. Peculiarities of the Fourth K-wave with Respect to the Beginning of the Cybernetic Revolution**

The fourth K-wave (from the second half of the 1940s to the 1980s) fell on the initial phase of the Cybernetic Revolution. The beginning of a new production revolution is a special period which is connected with the fast transition to a more advanced technological component of economy. All accumulated innovations and a large number of new innovations generate a new system that has a real synergetic effect. It would appear reasonable that *an upward phase of the K-wave coinciding with the beginning of a production revolution can appear more powerful than A-phases of other K-waves.*<sup>4</sup> That was the feature of the upswing A-phase of the fourth K-wave (1947–1974) which coincided with the scientific-information phase of the Cybernetic Revolution. As a result a denser than usual cluster of innovations (in comparison with the second, third and fifth waves) was formed during that period. All this also explains why in the 1950s and 1960s the economic growth rates of the World System were higher, than in A-phases of the third and fifth K-waves. The downswing phase of the fourth K-wave (the 1970s – 1980s) in its turn also fell on the last period of the initial phase of the Cybernetic Revolution. This explains in many respects why this downswing phase was shorter than those of the other K-waves.

#### **5. The Fifth K-wave and the Delay of the New Wave of Innovations**

It was expected that the 1990s and the 2000s would bring a radically new wave of innovations, comparable in their revolutionary character with the computer technologies, capable to create a new technological mode. Those directions which had already appeared and those ones, which are

<sup>4</sup> Therefore, it appears reasonable that A-phase of the sixth K-wave can also make a great progress, as it will coincide with the beginning of the Cybernetic Revolution final phase. Thus, the sixth wave is to have a stronger manifestation than the fifth one. We will return to this point below.

now supposed to become a basis for the sixth K-wave were considered to be a breakthrough. However, it was the development and diversification of already existing digital electronic technologies and rapid development of financial technologies that became a basis for the fifth K-wave. Those innovations which were really created during the fifth K-wave as, for example, low carbon energy technologies, still have a small share in the general energy, and, above all, they do not grow properly. Some researchers believe that from the 1970s up to the present is the time of the decelerating scientific and technological progress (see discussion about it in Brener 2006; see also Maddison 2007). Polterovich (2009) also suggests a notion of a technological pause. But, in general, the mentioned technological delay is, in our opinion, insufficiently explained. We believe that taking features of the intermediate modernization phase of a production revolution (that is the second phase of the production principle) into account can help explain this. Functionally it is less innovative; rather during this phase earlier innovations are widely spread and improved. As regards the 1990s – 2020s (the intermediate phase of the Cybernetic Revolution) the question is that the launch of a new innovative breakthrough demands that the developing countries reach the level of the developed ones, and the political component of the world catches up with the economic one; all this needs changes of the structure of societies and global relations (see about some aspects Grinin and Korotayev 2010b, 2015). Thus, the delayed *introduction of innovations of the new generation* is explained, first, by the fact that the center cannot endlessly surpass the periphery in development, that is the gap between developed and developing countries could not increase all the time. Secondly, economy cannot constantly surpass the political and other components, as this causes very strong disproportions and deformations. And the appearance of new general-purpose technologies, certainly, would accelerate economic development and increase disparities. Thirdly, introduction and distribution of the new basic technologies do not occur naturally, but only within the appropriate social political environment (see Grinin 2012c, 2013; see also Perez 2002). In order for basic innovations to be suitable for business, structural changes in political and social spheres are necessary, eventually promoting their synergy and wide implementation in the world of business.

Thus, the delay is caused by the difficulties of changing political and social institutions on the regional and even global scale, and also

(and, perhaps, first of all) within the international economic institutions. The latter can change only thanks to the strong political will of the main players, which is difficult to execute in the framework of the modern political institutions. These institutions rather can change under the conditions of depressive development (and probable aggravation of the foreign relations) compelling to reorganization and breakage of the conventional institutions that could hardly be changed due to the lack of courage and opportunities under ordinary conditions.

The above said explains as well the reasons of different rates of development of the center and periphery of the World System during the fifth K-wave (for more details see Grinin 2013; see also Grinin and Korotayev 2010a; 2015; Grinin, Korotayev, and Tausch 2016). The pe-riphery was expected to catch up with the center due to the faster rates of its development and slowdown of the center development. However, one should not expect continuous crisis-free development of the periphery – a crisis will come later and probably in other forms. Without slow-down of the development of the periphery and serious changes full harmonization of the economic and political component will not happen. Consequently, it might be supposed that in the next decade (approximately by 2020–2025) the growth rates of the peripheral economies can also slow down, and internal problems will aggravate that, as said above, can stimulate structural changes in the peripheral countries and strengthen international tension. Thus, we suppose that in the next 10–15 years the world will face serious and painful changes.

## **6. The Phase of Self-Regulating Systems and the Sixth K-Wave**

### **6.1. A-Phase of the sixth K-wave: Acceleration to enter the final phase of the Cybernetic Revolution**

The sixth K-wave will probably begin approximately in the 2020s. Meanwhile the final phase of the Cybernetic Revolution has to begin later, at least, in the 2030–2040s. Thus, we suppose, that a new technological mode will not develop in a necessary form even by the 2020s (thus, the innovative pause will take longer than expected). However, it should be kept in mind that the beginning of the K-wave upswing phase is never directly caused by new technologies. This beginning is synchronized with the start of the medium-term business cycle's upswing.



And the upswing takes place as a result of the levelling of proportions in economy, the accumulation of resources and other impulses that improve demand and conjuncture. One should remember, that the beginning of the second K-wave was connected with the discovery of gold deposits in California and Australia, the third wave with the increase in prices for wheat, the fourth one with the post-war reconstruction, the fifth one with the economic reforms in the UK and the USA. And then, given an upswing, a new technological mode (which could not completely – if at all – realize its potential) facilitates overcoming of cyclic crises and allows further growth.

Consequently, some conjunctural events will also stimulate an upward impulse of the sixth K-wave. And, for example, the rapid growth of the underdeveloped world regions (such as Tropical Africa, the Islamic East, and some Latin American countries) or new financial and organizational technologies can become a primary impulse. Naturally, there will also appear some engineering and technological innovations which, however, will not form a new mode yet. Besides, we suppose that financial technologies have not finished yet its expansion in the world. If we can modify and secure them somehow, they will be able to spread into various regions which underuse them now. One should not forget that large-scale application of such technologies demands essential changes in the legal and other systems, which is absolutely necessary for developmental levelling in the world. Taking into account a delay of the new generation of technologies, the period of the 2020s may resemble the 1980s. In other words, it will be neither a growth recession, nor a rise, but rather an accelerated development (with stronger development in some regions and continuous depression in others).

Then, given the above mentioned favorable conditions, during this wave the final phase of the Cybernetic Revolution will begin. In such a situation it is possible to assume that the sixth K-wave's A-phase (the 2020–2050s) will have much stronger manifestation and last longer than that of the fifth one due to more dense combination of technological generations. And since the Cybernetic Revolution will evolve, the sixth K-wave's downward B-phase (2050 – the 2060/70s), is expected to be not so depressive, as those during the third or fifth waves. In general, during this K-wave (2020 – the 2060/70s) the Scientific and Information Revolution will come to an end, and the scientific-cybernetic production principle will acquire its mature shape.

## 6.2. Another scenario

The final phase of the Cybernetic Revolution can start later – not in the 2030s, but in the 2040s. In this case the A-phase of the sixth wave will terminate before the beginning of the regulating systems revolution; therefore, it will not be based on fundamentally new technologies and will not become as powerful as is supposed in the previous scenario. The final phase of the Cybernetic Revolution in this case will coincide with the B-phase of the sixth wave (as it was the case with the zero wave during the Industrial Revolution, 1760–1787) and at the A-phase of the seventh wave. In this case the emergence of the seventh wave is highly possible. The B-phase of the sixth wave should be rather short due to the emergence of a new generation of technologies, and the A-phase of the seventh wave – rather long and powerful.

## 7. The End of the Cybernetic Revolution and Disappearance of K-waves

The sixth K-wave (from about 2020 till the 2060/70s), similar the first K-wave, will proceed generally during the completing production revolution. However, there is an important difference. During the first K-wave the duration of a phase of the industrial production principle significantly exceeded the duration of the whole K-wave. But now a phase of the K-wave will exceed the duration of a phase of production principle. This alone should essentially alter the unfolding sixth K-wave; the seventh wave will be feebly expressed or will not start at all (on the possibility of the latter see above). This forecast is based also on the fact that the end of the Cybernetic Revolution and distribution of its results will promote the integration of the World System and considerably increase the influence of new universal regulation mechanisms. It is quite reasonable, considering the fact that the coming final phase of the revolution will be the revolution of the self-regulating systems. Thus, the economic management should reach a new level. *So, K-waves appear at a certain stage of social evolution and are likely to disappear at its certain stage.*