Kondratieff Waves in the Global Studies Perspective

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Kondratieff Waves in the Global Studies Perspective*

Andrey V. Korotayev and Leonid E. Grinin

The analysis of long economic cycles allows us to understand long-term world-system dynamics, to develop forecasts, to explain crises of the past, as well as the current global economic crisis. The article offers a historical sketch of research on K-waves; it analyzes the nature of Kondratieff waves that are considered as a special form of cyclical dynamics that emerged in the industrial period of the World System history. It offers a historical and theoretical analysis of K-wave dynamics in the World System framework; in particular, it studies the influence of the long wave dynamics on the changes of the world GDP growth rates during the last two centuries. Special attention is paid to the interaction between Kondratieff waves and Juglar cycles. The article is based on substantial statistical data, it extensively employs quantitative analysis, contains numerous tables and diagrams. On the basis of the proposed analysis it offers some forecasts of the world economic development in the next two decades.

The article concludes with a section that presents a hypothesis that the change of K-wave upswing and downswing phases correlates significantly with the phases of fluctuations in the relationships between the World-System Core and Periphery, as well as with the World System Core changes.

Keywords: *cyclical dynamics, Juglar cycles, Kondratieff waves, K-waves, World System, long waves, phases of long waves, world economy, Nikolay Kondratieff, world GDP, technological innovation, core and periphery, leading sector, technological system, technological style.*

Qualitative movement toward new unknown forms and levels cannot proceed infinitely, linearly and unhindered. There are always certain limitations; such movement is accompanied by the emergence of disproportions, growth of competition for resources, and so on. On the other hand, continuous human effort to overcome environmental resistance to such movement has created conditions for the continuous emergence of more and more complex and effective structures at the level of both individual societies and the World System as a whole. However, relatively short periods of fast development alternated with periods of stagnation, crisis, and sometimes even collapse. This was one of the main causes that led to the formation of cyclical components of social macrodynamics that in pre-industrial epoch could include cycles with many different periods, including secular and even millennial ones (*e.g.*, Korotayev, Malkov, and Khaltourina 2006; Korotayev and Khaltourina 2006; Turchin 2003, 2005a, 2005b; Nefedov 2004; Turchin and

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Nefedov 2009; Turchin and Korotayev 2006; Korotayev *et al.* 2010; Grinin and Korotayev 2012).

In the industrial period we see the emergence of new cyclical components including Juglar cycles[1] with a characteristic period between 7 and 11 years that manifest themselves in energetic booms and crises that suddenly engulf social systems. Note that those cycles are intrinsic components of the developmental dynamics of such societies. However, they are not the only cycles that are characteristic for the industrial and postindustrial systems, whereas one of the most interesting aspects of their cyclical dynamics is represented by cycles with a characteristic period of 40 to 60 years known as Kondratieff waves (or just K-waves).

The analysis of long economic cycles allows analysts to comprehend the long-term dynamics of the World System development, and helps to develop forecasts; it also facilitates our understanding of the crises of the past, as well as the current global economic crisis. In the present article we will analyze the emergence of K-waves in the World System economic dynamics in the nineteenth century and the changes that can be traced in K-wave patterns in the twentieth century, but especially after the Second World War. We will also analyze the peculiarities of the study of K-waves within the World System scale and will demonstrate that an adequate understanding of the nature of the modern K-wave dynamics can only be achieved if this phenomenon is studied precisely within this framework.

Long Waves in the World Economic Dynamics

In the 1920s, the Russian economist Nikolay Kondratieff observed that the historical record of some economic indicators then available to him appeared to indicate a cyclic regularity of phases of gradual increases in values of respective indicators followed by phases of decline (Kondratieff 1922: ch. 5; 1925, 1926, 1935, 2002); the period of these apparent oscillations seemed to him to be around 50 years. He found this pattern with respect to such indicators as prices, interest rates, foreign trade, coal and pig iron production (as well as some other production indicators) for some major Western economies (first of all England, France, and the United States), whereas the long waves in pig iron and coal production were claimed to be detected since the 1870s for the world level as well (note that as regards the production indices during decline/downswing phases we deal with the slowdown of production growth rather than with actual production decline that rarely lasts longer than a year or two, whereas during the upswing phase we deal with a general acceleration of the production growth in comparison with the preceding downswing/slowdown period [see, *e.g.*, Modelski 2001, 2006 who prefers quite logically to designate 'decline/downswing' phases as 'phases of take-off', whereas he designates the upswing phases as 'high growth phases']).

Among important Kondratieff predecessors one should mention J. van Gelderen (1913), M. A. Bunyatyan (1915), and S. de Wolff (1924). One can also mention William Henry Beveridge (better known, perhaps, as Lord Beveridge, the author of the so-called *Beveridge Report on Social Insurance and Allied Services* (1942) that served as the basis for the British Welfare State, especially the National Health Service, after the Second World War), who discovered a number of cycles in the long-term dynamics of wheat prices, whereas one of those cycles turned to have an average periodicity of 54 years (Beve-

[1] In addition to short-term Kitchin cycles and medium-term Kuznets swings (see, *e.g.*, Kitchin 1923; Kuznets 1930, 1958; Abramovitz 1961; Korotayev and Tsirel 2010c).

ridge 1921, 1922). Note that Kondratieff at the time of his discovery of long waves was unaware of the results of the above mentioned scientists (see, *e.g.*, Kondratieff 1935: 115, note 1).

Kondratieff himself identified the following long waves and their phases (see Table 1).

Table 1. Long waves and their phases as identified by Kondratieff

Long wave number	*Long wave phase*	*Dates of the beginning*	*Dates of the end*
First	A: upswing	The end of the 1780s or beginning of the 1790s	1810–1817
	B: downswing	1810–1817	1844–1851
Second	A: upswing	1844–1851	1870–1875
	B: downswing	1870–1875	1890–1896
Third	A: upswing	1890–1896	1914–1920
	B: downswing	1914–1920	

The subsequent students of Kondratieff cycles identified additionally the following long-waves in the post-World War 1 period (see Table 2).

Table 2. 'Post-Kondratieff' long waves and their phases

Long wave number	*Long wave phase*	*Dates of the beginning*	*Dates of the end*
Third	A: upswing	1890–1896	1914–1920
	B: downswing	From 1914 to 1928/29	1939–1950
Fourth	A: upswing	1939–1950	1968–1977
	B: downswing	1968–1974	1984–1991
Fifth	A: upswing	1984–1991	2008–2010?
	B: downswing	2008–2010?	?

Sources: Mandel 1980; Dickson 1983; Van Duijn 1983: 155; Wallerstein 1984; Goldstein 1988: 67; Modelski and Thompson 1996; Bobrovnikov 2004: 47; Pantin and Lapkin 2006: 283–285, 315; Ayres 2006; Linstone 2006: fig. 1; Tausch 2006b: 101–104; Thompson 2007: table 5; Jourdon 2008: 1040–1043. The last date is suggested by the authors of the present paper. It was also suggested earlier by Lynch 2004; see also Akaev and Sadovnichy 2010; Akaev *et al.* 2011.

A considerable number of explanations for the observed Kondratieff wave (or just K-wave [Modelski and Thompson 1996; Modelski 2001]) patterns have been proposed. At at the initial stage of K-wave research, the respective pattern was detected in the most secure way in terms of the price indices (see below). Most explanations proposed during that period were monetary, or monetary-oriented. For example, K-waves were connected with the inflation shocks caused by major wars (*e.g.*, Åkerman 1932; Bernstein 1940; Silberling 1943, *etc.*). In recent decades such explanations became less popular, as the K-wave pattern stopped being traced in the price indices after the Second World War (*e.g.*, Goldstein 1988: 75; Bobrovnikov 2004: 54).

Kondratieff himself accounted for the K-wave dynamics first of all on the basis of capital investment dynamics (see Kondratieff 1928, 1984; 2002: 387–397). This trend was further developed by Jay W. Forrester and his colleagues (see, *e.g.*, Forrester 1978, 1981,

1985; Senge 1982, *etc.*), as well as by A. van der Zwan (1980), Hans Glisman, Horst Rodemer, and Frank Wolter (1983), *etc.*

However, in the recent decades the most popular explanation of K-wave dynamics was the one connecting them with the waves of technological innovations.

Kondratieff himself noticed that 'during the recession of the long waves an especially large number of important discoveries and inventions in production and communication technologies are made, which, however, are usually applied on a large scale only at the beginning of the next long upswing' (Kondratieff 1935: 111, see also, *e.g.*, *Idem* 2002: 370–374).

Schumpeter (1939) used this argument to develop a rather influential 'cluster-of-innovation' version of K-waves theory, according to which, Kondratieff cycles were predicted primarily due to discontinuous rates of innovation (for more recent developments of the Schumpeterian version of K-wave theory see, *e.g.*, Mensch 1979; Dickson 1983; Freeman 1987; Berry 1991; Tylecote 1992; Glazyev 1993; Maevski 1997; Modelski and Thompson 1996; Modelski 2001, 2006; Devezas and Modelski 2003; Yakovets 2001; Ayres 2006; Dator 2006; Hirooka 2006; Papenhausen 2008; Perez 2011; for the most recent presentation of empirical evidence supporting Schumpeter's cluster-of-innovation hypothesis see Kleinknecht and van der Panne 2006). Within this approach every Kondratieff wave is associated with a certain leading sector (or leading sectors), technological system or technological style. For example, the third Kondratieff wave is sometimes characterized as 'the age of steel, electricity, and heavy engineering. The fourth wave takes in the age of oil, the automobile and mass production. Finally, the current fifth wave is described as the age of information and telecommunications (Papenhausen 2008: 789); whereas the forthcoming sixth wave is sometimes supposed to be connected first of all with nano- and biotechnologies (*e.g.*, Lynch 2004; Dator 2006).

There were also a number of attempts to combine capital investment and innovation theories of K-waves (*e.g.*, Rostow 1975, 1978; van Duijn 1979, 1981, 1983; Akaev 2010, *etc.*). Of special interest is Devezas – Corredine model based on biological determinants (generations and learning rate) and information theory that explains (for the first time) the characteristic period (50–60 years) of Kondratieff cycles (Devezas and Corredine 2001, 2002; see also Devezas, Linstone, and Santos 2005).

Many social scientists consider Kondratieff waves as a very important component of the modern world-system dynamics. As has been phrased by one of the most important K-wave students:

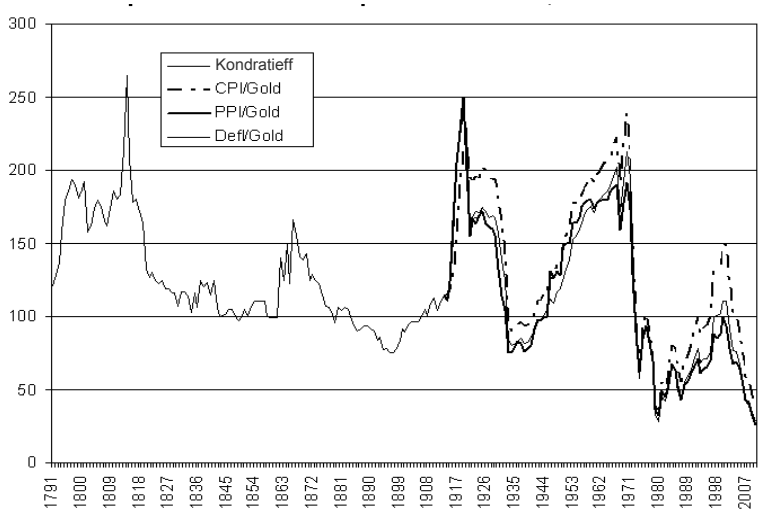
> Long waves of economic growth possess a very strong claim to major significance in the social processes of the world system… Long waves of technological change, roughly 40–60 years in duration, help shape many important processes… They have become increasingly influential over the past thousand years. K-waves have become especially critical to an understanding of economic growth, wars, and systemic leadership... But they also appear to be important to other processes such as domestic political change, culture, and generational change. This list may not exhaust the significance of Kondratieff waves but it should help establish an argument for the importance of long waves to the world's set of social processes (Thompson 2007).

Against this background it appears rather significant that evidence of the very presence of the Kondratieff waves in the world dynamics remains rather controversial. The presence of K-waves in price dynamics (at least before the Second World War) has a rather wide empirical support (see, *e.g.*, Gordon 1978: 24; van Ewijk 1982; Cleary and Hobbs 1983,

etc.). However, as has been mentioned above, the K-wave pattern stopped being traced in the price indices after the Second World War (*e.g.*, Goldstein 1988: 75; Bobrovnikov 2004: 54).

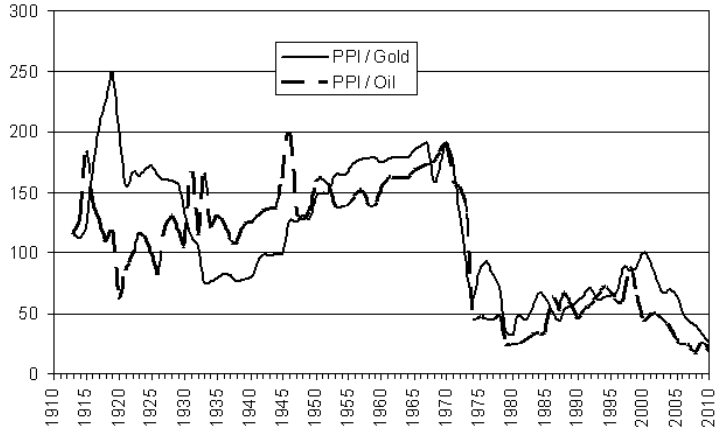
On the other hand, as has already been demonstrated (Scheglov 2009; Grinin, Korotayev, and Tsirel 2011: 75–77), when inflation is taken into account and the price indices are expressed in grams of gold rather than in dollars, those indices continue to correlate with the K-wave pattern (see Fig. 1). Starting from the early 1970s, energy resources (oil in the first place) served as a sort of 'reserve currency' comparable with gold, and Kondratieff waves started to be traced in the price index dynamics when expressed in oil equivalent (see Fig. 2).

Fig. 1. The USA producer price index used by Kondratieff and extended up to 2010 in the gold equivalent (100 = 1900–10 level)



Sources: Scheglov 2009; Grinin, Korotayev, and Tsirel 2011: 76.

Fig. 2. The USA producer price index in gold and oil equivalent (100 = 1900–10 level)



Sources: BP 2010; Scheglov 2009; Grinin, Korotayev, and Tsirel 2011: 77.

Regarding long waves in production dynamics we will restrict ourselves to analyzing evidence for the presence of K-waves in the world production indices. As Kondratieff waves tend to be considered an important component of the world-system social and economic dynamics, one would expect to detect them in terms of the major world macroeconomic indicators; first of all with respect to the world GDP dynamics (Chase-Dunn and Grimes 1995: 405–411). However, until now the attempts to detect them in the dynamics of the-world GDP (or similar indicators) have brought controversial results.

Kondratieff himself claimed to have detected long waves in the dynamics of world production of coal and pig iron (*e.g.*, Kondratieff 1935: 109–110). However, his evidence of the presence of long waves in these series (as well as in all the production dynamics series on national levels) was criticized most sharply:

> Foremost among the methodological criticisms have been those directed against Kondratieff's use of trend curves. Kondratieff's method is first to fit a long-term trend to a series and then to use moving averages to bring out long waves in the residuals (the fluctuations around the trend curve).

But 'when he eliminated the trend, Kondratieff failed to formulate clearly what the trend stands for' (Garvy 1943: 209). The equations Kondratieff uses for these long-term trend curves… include rather elaborate (often cubic) functions.[2] This casts doubt on the theoretical meaning and parsimony of the resulting long waves, which cannot be seen as simple variations in production growth rates (Goldstein 1988: 82; see also, *e.g.*, Barr 1979: 704; Eklund 1980: 398–399, *etc.*).

However, quite a few scientists presented later new evidence supporting the presence of long waves in the dynamics of the world economic indicators. For example, Mandel (1975: 141; 1980: 3) demonstrated that, in full accordance with Kondratieff's theory, between 1820 and 1967 during Phases A of K-cycles the annual compound growth rates in world trade were on average significantly higher than in adjacent Phases B. David M. Gordon (1978: 24) got similar results with respect to world *per capita* production for 1865–1938 based on world production data from Dupriez (1947: 567), world industrial dynamics (for 1830–1980) taken from Thomas Kuczynski (1982: 28), and average growth rates of the world economy (Kuczynski 1978: 86) for 1850–1977; similar results were obtained by Joshua Goldstein (1988: 211–217).

Of special interest are the works by Marchetti and his co-workers at the International Institute for Advanced System Analysis who have shown extensively the evidence of K-waves using physical indicators, as for instance energy consumption, transportation systems dynamics, *etc.* (Marchetti 1980, 1986, 1988, *etc.*). Arno Tausch claims to have detected K-waves in the world industrial production growth rates dynamics using polynomial regression methods (Tausch 2006a: 167–190). However, empirical tests produced by a few other scholars failed to support the hypothesis of presence of the K-waves in the world production dynamics (see, *e.g.*, van der Zwan 1980: 192–197; Chase-Dunn and Grimes 1995: 407–409, reporting the results of Peter Grimes' research).

There were a few attempts to apply spectral analysis in order to detect the presence of K-waves in the world production dynamics. Thomas Kuczynski (1978) applied spectral analysis in order to detect K-waves in world agricultural production, total exports, inventions, innovations, industrial production, and total production for the period between 1850

[2] For example, for the trend of English lead production the function used by Kondratieff looks as follows: $y = 10^{(0.0278 - 0.0166x - 0.00012x^2)}$.

and 1976. Though Kuczynski suggests that his results 'seem to corroborate' the K-wave hypothesis, he himself does not find this support decisive and admits that 'we cannot exclude the possibility that the 60-year-cycle… is a random cycle' (Kuczynski 1978: 81–82); note that Kuczynski did not make any formal test of statistic significance of the K-waves tentatively identified by his spectral analysis. K-waves were also claimed to have been found with spectral analysis by Rainer Metz (1992) both in GDP production series on eight European countries (for the 1850–1979 period) and in the world production index developed by Hans Bieshaar and Alfred Kleinknecht (1984) for 1780–1979; however, later he denounced those findings (Metz 1998, 2006).

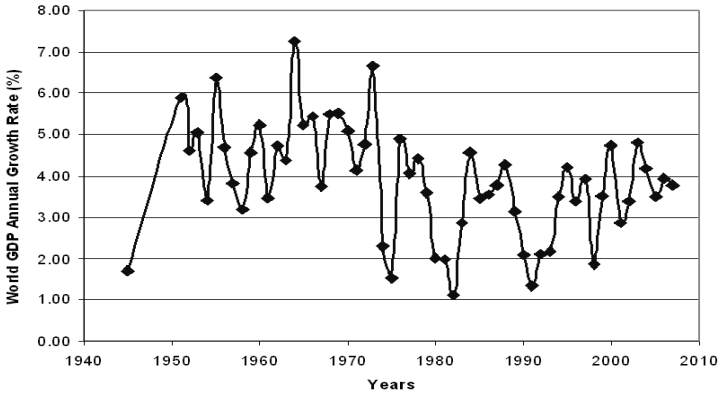
A few scientists using spectral analysis have failed to detect K-waves in production series on national levels of quite a few countries (*e.g.*, van Ewijk 1982; Metz 1998, 2006; Diebolt and Doliger 2006).

Against this background we (together with Sergey Tsirel) have found it appropriate to check the presence of K-waves in the world GDP dynamics using the most recent datasets on this variable dynamics covering the period between 1870 and 2007 (Maddison 1995, 2001, 2003, 2009; World Bank 2012) and applying an upgraded methodology for the estimation of statistical significance of detected waves (see, *e.g.*, Korotayev and Tsirel 2010a, 2010b, 2010c; Grinin, Korotayev, and Tsirel 2011); it is worth emphasizing that our analysis made it possible for the first time to estimate statistical significance of the Kondratieff waves in the world GDP dynamics, as will be demonstrated in the following sections.

Kondratieff Waves in the Post-Second World War GDP Data

Note that the Kondratieff-wave component can be seen quite clearly in the post-World War II dynamics of the world GDP growth rates even directly, without application of any special statistical techniques (see Fig. 3):[3]

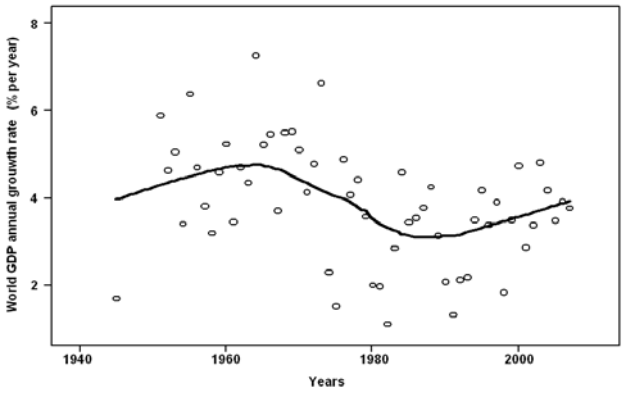
Fig. 3. Dynamics of the annual world GDP growth rates (%), 1945–2007; 1945 point corresponds to the average annual growth rate in the 1940s. Initial series: Maddison/World Bank empirical estimates



[3] Note that K-waves (as well as Juglar cycles) are also quite visible for recent decades in the world dynamics of such important macroeconomic variables as the world gross fixed capital formation (as % of GDP) and the investment effectiveness (it indicates how many dollars of the world GDP growth is achieved with one dollar investments) – see Appendix, Figs S1 and S2. The dynamics of both variables are connected to the world GDP dynamics. Actually, the world GDP dynamics is determined to a considerable extent by the dynamics of those two variables.

However, the Kondratieff wave component becomes especially visible if a LOWESS (= *LOcally WEighted Scatterplot Smoothing*) line is fitted (see Fig. 4).

Fig. 4. Maddison/World Bank empirical estimates with fitted LOWESS line. Kernel: Triweight. % of points to fit: 50



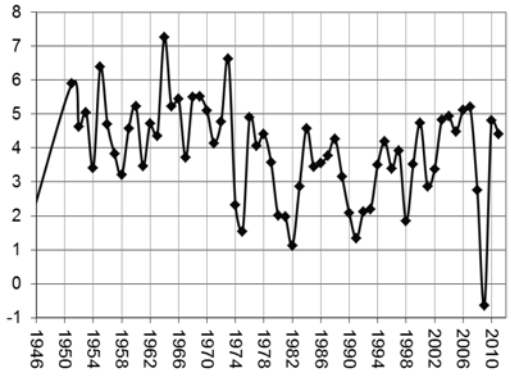
As can be seen, Figs 3–4 indicate:

1) that the Kondratieff-wave pattern can be detected up to the present in a surprisingly intact form (though, possibly, with a certain shortening of its period, suggested by a few authors [see, *e.g.*, van der Zwan 1980; Bobrovnikov 2004; Tausch 2006a; Pantin and Lapkin 2006]);

2) that the present world financial-economic crisis might really mark the beginning of a new Kondratieff Phase B (downswing). Indeed, consider the post-World War II dynamics of the world GDP growth rates taking into account the two years, 2008 and 2009 (using the World Bank forecast figure for the year 2012) (see Fig. 5).

As we see, according to its magnitude the current financial-economic crisis does not appear to resemble a usual crisis marking the end of a Juglar cycle amidst an upswing phase (or a downswing) of a Kondratieff cycle (which one would expect with the second interpretation). Instead it resembles particularly deep crises (similar to the ones of 1973–1974, 1929–1933, mid-1870s or mid-1820s) that are found just at the border of Phases A and B of the K-waves (see, *e.g.*, Grinin and Korotayev 2010).

Fig. 5. Dynamics of the Annual world GDP Growth Rates (%), 1945–2011

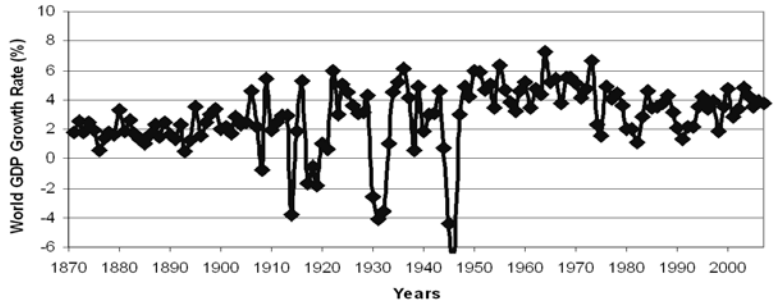


Sources: World Bank 2011: NY.GDP.MKTP.PP.KD; Maddison 2010; Conference Board 2011.

Kondratieff Waves in the World GDP Data before 1945–1950

As Fig. 6 shows, for the 1870–1945/50 period the K-wave pattern is not as easily detectable as after 1945/50. The turbulent second, third and fourth decades of the twentieth century are characterized by enormous magnitude of fluctuations of the world GDP growth rates (not observed either in previous or subsequent periods). The lowest (for 1871–2007) figures of the world GDP annual rates of change are observed just in these decades (during the Great Depression, World Wars I and II as well as immediately after the end of those wars). On the other hand, during the mid-20s and mid-30s booms the world GDP annual growth rates achieved historical maximums (they were only exceeded during the K-wave 4, Phase A, in the 1950s and 1960s, and were generally higher than during both the pre-World War I and recent [1990s and 2000s] upswings). This, of course, complicates the detection of the long-wave pattern during those decades.

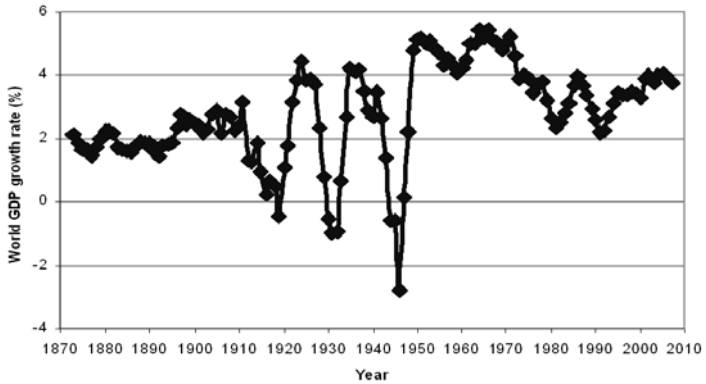
Fig. 6. Dynamics of the World GDP Annual Growth Rates (%), 1871–2007



Source: Korotayev and Tsirel 2010c: 6.

Actually, this pattern is somehow better visible in the diagrams for 5-year moving average, and, especially, for simple 5-year averages (see Figs 7 and 8).

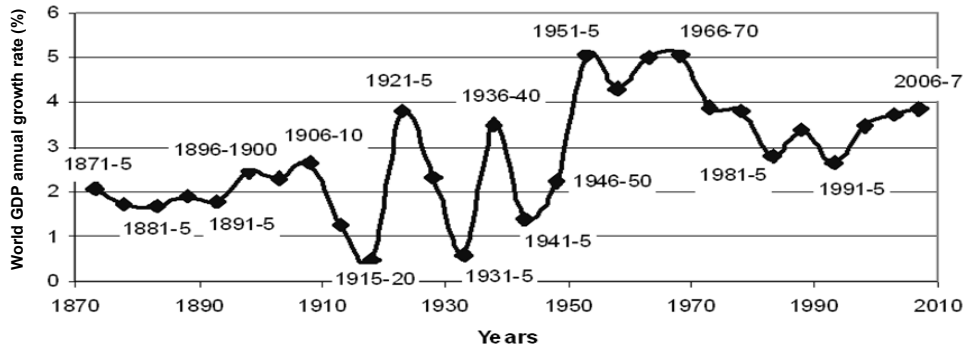
Fig. 7. Dynamics of the world GDP annual growth rates (%), moving 5-year averages, 1871–2007



Sources: World Bank 2012; Maddison 2009.

Note: 1873 point corresponds to the average annual growth rate in 1871–1875, 1874 to 1872–1876, 1875 to 1873–1877… 2005 to 2003–2007; 2006 and 2007 points correspond to the annual growth rates in years 2006 and 2007 respectively.

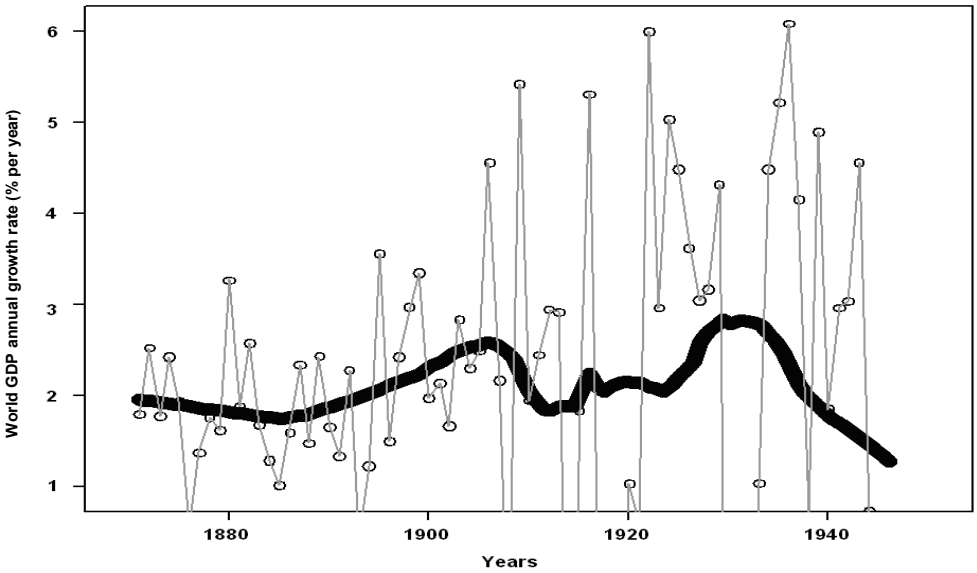
Fig. 8. Dynamics of the world GDP annual growth rates (%), 5-year averages, 1871–2007



Sources: World Bank 2012; Maddison 2009.

The application of the LOWESS technique reveals a certain K-wave pattern in the pre-1950 series (see Fig. 9).

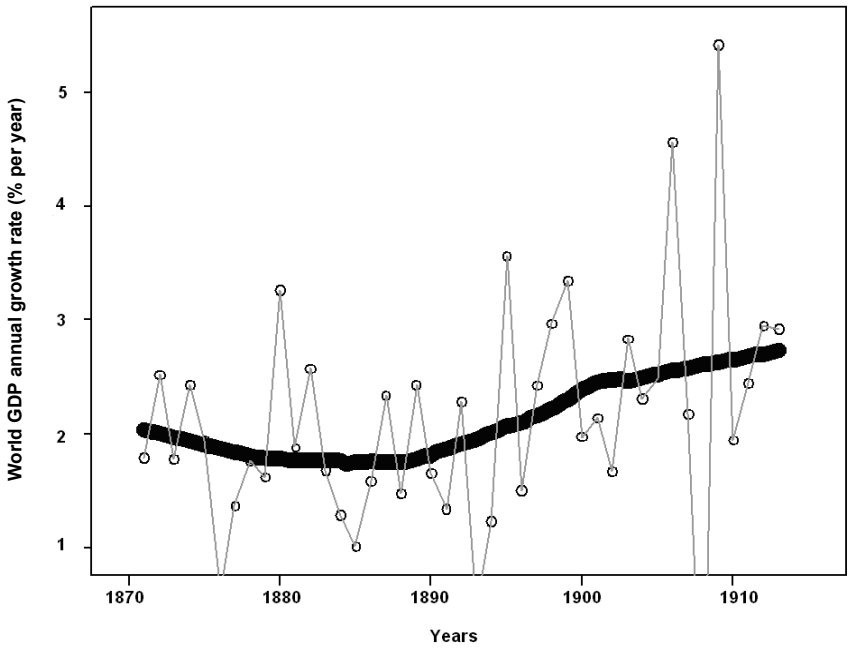
Fig. 9. World GDP annual growth rate dynamics (1870–1946): Maddison empirical estimates with fitted LOWESS line



Note: Maddison-based empirical estimates with fitted LOWESS line. Kernel: Triweight. % of points to fit: 40.

In fact, the LOWESS technique reveals quite clearly the K-wave pattern prior to World War I (in the period corresponding to Phase B of the 2nd Kondratieff wave and major part of Phase A of the 3rd wave) (see Fig. 10).

Fig. 10. World GDP annual growth rate dynamics: Maddison-based empirical estimates with fitted LOWESS line. Phase B (Downswing) of the 2nd Kondratieff Wave and Phase A (Upswing) of the 3rd Wave, 1871–1913

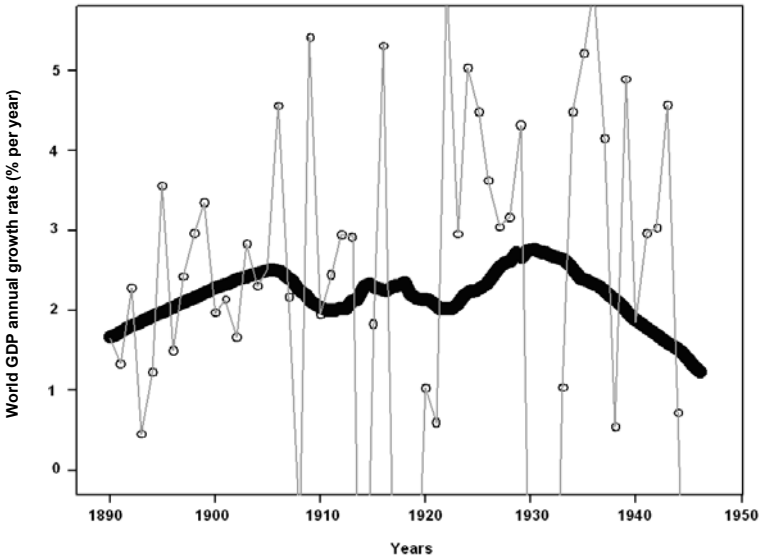


Note: Maddison-based empirical estimates with fitted LOWESS line. Kernel: Triweight. % of points to fit: 50.

However, the 3rd K-wave (apparently strongly deformed by World War I) looks much less accurate (see Fig. 11).

Phase B of the 3rd Kondratieff cycle presents the main problem as the timing of its start remains unclear (1914, or mid-1920s?). Our analysis does not make it possible to make the final choice between two options – either K3 Phase B started in 1914 and was interrupted by the mid-1920s boom; or K3 Phase A continued till the mid-1920s having been interrupted by the WWI bust.

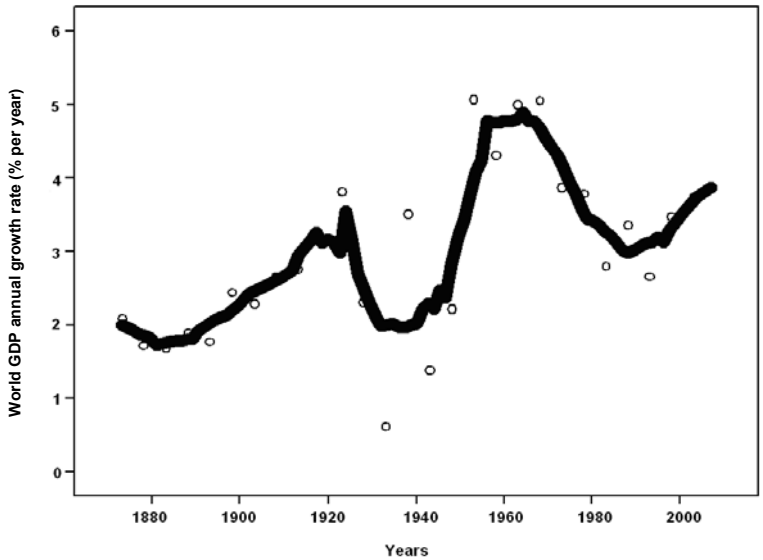
Fig. 11. World GDP annual growth rate dynamics: Maddison-based empirical estimates with fitted LOWESS line. *The 3rd Kondratieff Wave*



Note: Maddison-based empirical estimates with fitted LOWESS line. Kernel: Triweight. % of points to fit: 60.

However, the LOWESS technique produces an especially neat K-wave pattern with the second assumption – that is we get it when we omit the WWI influence (see Fig. 12).

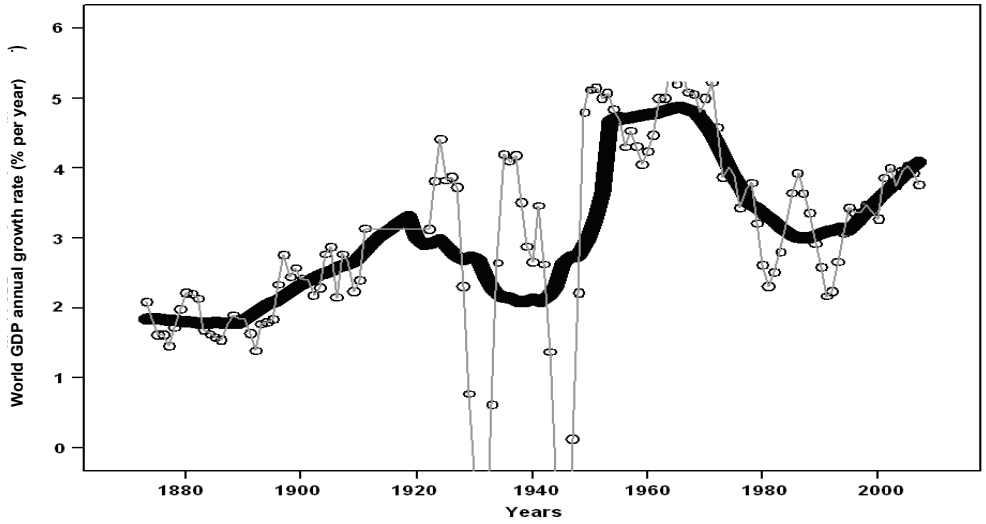
Fig. 12. World GDP annual growth rate dynamics, *5-year averages*: Maddison-based empirical estimates with fitted LOWESS line. *1870–2007, omitting World War I influence*



Note: Maddison-based empirical estimates with fitted LOWESS line. Kernel: Triweight. % of points to fit: 20.

This figure reveals rather distinctly double peaks of the upswings. With a stronger smoothing (see Fig. 13) the form of the peaks becomes smoother, whereas the waves themselves become more distinct.

Fig. 13. World GDP annual growth rate dynamics, *5-year moving average*: Maddison-based empirical estimates with fitted LOWESS line. *1870–2007, omitting World War I influence*



Note: Maddison-based empirical estimates with fitted LOWESS line. Kernel: Triweight. % of points to fit: 20.

Hence, it looks a bit more likely that K3 Phase A lasted till the mid-1920s (having been interrupted by WWI). Incidentally, if we take the WWI influence years (1914–1921) out, we arrive at a quite reasonable K3 Phase A length – 26 years, even if we take 1929 as the end of this phase:

$$1929 - 1895 = 34$$
$$34 - 8 = 26$$

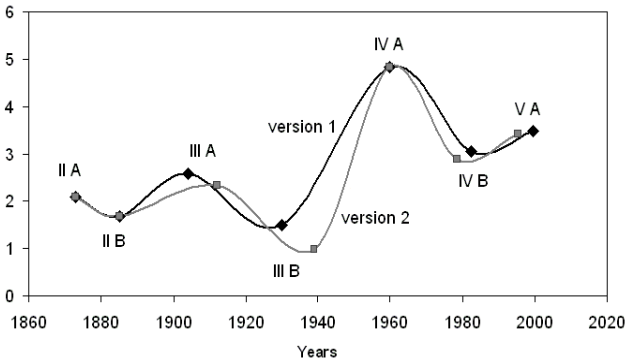
Note that with the first assumption (K3 Phase B started in 1914 and was interrupted by the mid-1920s boom) we would have an excessive length of K3 Phase B – 32 years (that would, however, become quite normal, if we take out the mid-1920s boom years).

Yet, it seems necessary to stress that we find overall additional support for the Kondratieff pattern in the world GDP dynamics data for the 1870–1950 period. First of all, this is manifested by the fact that both Phases A of this period have relatively higher rates of world GDP growth, whereas both Phases B are characterized by relatively lower rates. Note that this holds true without taking out either the World War I, or the 1920s boom influence, and irrespective of whatever dating for the beginnings and ends of the relevant phases we choose (see Table 3 and Fig. 14).

Table 3. Average annual world GDP growth rates (%) during phases A and B of Kondratieff waves, 1871–2007

Kondratieff wave number	*Phase*	*Years*		*Average annual World GDP growth rates (%) during respective phase*	
		Version 1	*Version 2*	*Version 1*	*Version 2*
II	End of Phase A	1871–1875	1871–1875	2.09	2.09
II	B	1876–1894	1876–1894	1.68	1.68
III	A	1895–1913	1895–1929	2.57	2.34
III	B	1914–1946	1930–1946	1.50	0.98
IV	A	1947–1973	1947–1973	4.84	4.84
IV	B	1974–1991	1974–1983	3.05	2.88
V	A	1992–2007	1984–2007	3.49	3.42

Fig. 14. Average annual world GDP growth rates (%) during phases A and B of Kondratieff waves, 1871–2007



With different dates for beginnings and ends of various phases we have somehow different shapes of long waves, but the overall Kondratieff wave pattern remains intact. Note that the difference between the two versions can be partly regarded as a continuation of controversy between two approaches ('the K-wave period is approximately constant in the last centuries' *vs.* 'the period of K-waves becomes shorter and shorter').[4] The first approach correlates better with the results of the spectral analysis that have been presented above and the optimistic forecast, whereas the second approach correlates better with the interpretation of the current crisis with the beginning of the downswing phase of the 5th K-wave.

Kondratieff Waves in the World GDP Dynamics before 1870

There are some grounds to doubt that Kondratieff waves can be traced back in the world GDP dynamics for the pre-1870 period (though for this period they appear to be detected for the GDP dynamics of the West).

Note that for the period between 1700 and 1870, Maddison provides world GDP estimate for one year only – for 1820. What is more, for the period before 1870, Maddison does not provide annual (or even per decade) estimates for many major economies, which

[4] See, *e.g.*, van der Zwan 1980; Bobrovnikov 2004; Tausch 2006a; Pantin and Lapkin 2006.

makes it virtually impossible to reconstruct the world GDP annual (or even per decade) growth rates for this period. However, it appears possible to reconstruct the world GDP estimate for 1850, as for this year Maddison does provide his estimates for all the major economies. Thus, it appears possible to estimate the world GDP average annual growth rates for 1820–1850 (*i.e.,* the period that more or less coincides with K1 Phase B) and for 1850–1870/1875 (*i.e.,* K2 Phase A), and, consequently, to make a preliminary test whether the Kondratieff wave pattern can be observed for the 1820–1870 period.

The results look as follows:

Table 4. Average annual world GDP growth rates (%) during phases A and B of Kondratieff waves, 1820–1894

Kondratieff wave number	*Phase*	*Years*		*Average annual world GDP growth rates (%) during respective phase*		*Average annual World GDP growth rate predicted by Kondratieff wave pattern*	*Observed*
		Version 1	*Version 2*	*Version 1*	*Version 2*		
I	B	1820–1850	1820–1850	0.88	0.88		
II	A	1851–1875	1851–1870	1.26	1.05	To be significantly higher than during the subsequent phase	Significantly lower than during the subsequent phase
II	B	1876–1894	1871–1894	1.68	1.76	To be significantly lower than during the subsequent phase	Significantly higher than during the subsequent phase

Thus, whatever dating of the end of K2 Phase A we choose, we observe a rather strong deviation from the K-wave pattern. Indeed, according to this pattern, one would expect that in the 1850–1870/5 period (corresponding to Phase A of the 2nd Kondratieff wave) the World GDP average annual growth rate should be higher than in the subsequent period (corresponding to Phase B of this K-wave). However, the actual situation turns out to be quite opposite – in 1870/75–1894 the world GDP average annual growth rate was significantly higher than in 1850–1870/75.

Note, however, that the K-wave pattern still seems to be observed for this period with respect to the GDP dynamics of the West (see Table 5 and Fig. 15).[5]

[5] What is more, this pattern appears to be observed in the socio-economic dynamics of the European-centered world-system for a few centuries prior to 1820 (see, *e.g.*, Beveridge 1921, 1922; Goldstein 1988; Jourdon 2008; Modelski 2006; Modelski and Thompson 1996; Pantin and Lapkin 2006; Thompson 2007).

Table 5. Average annual world GDP growth rates (%) of the West during phases A and B of Kondratieff waves, 1820–1894

Kondratieff wave number	*Phase*	*Years*	*Average annual world GDP growth rates (%) during respective phase*	*Average annual world GDP growth rate predicted by Kondratieff wave pattern*	*Observed*
I	B	1820–1850	2.04	To be significantly lower than during the subsequent phase	Significantly lower than during the subsequent phase
II	A	1851–1875	2.45	To be significantly higher than during the subsequent phase	Significantly higher than during the subsequent phase
II	B	1876–1894	2.16	To be significantly lower than during the subsequent phase	Significantly lower than during the subsequent phase
III	A	1895–1913	2.94	To be significantly higher than during the previous phase	Significantly higher than during the previous phase

Note: Data are for 12 major West European countries (Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Sweden, Switzerland, and the United Kingdom) and four 'Western offshoots' (the United States, Canada, Australia, and New Zealand).

Fig. 15. Average annual world GDP growth rates (%) of the West during phases A and B of Kondratieff waves, 1820–1913

We believe that the fact that K-wave pattern can be traced back in the GDP dynamics of the West for the pre-1870 period and that it is not found for the world GDP dynamics is not coincidental, and cannot be accounted for just on the basis of the unreliability of the world GDP estimates for this period. In fact, it is not surprising that the Western GDP growth rates were generally higher in 1851–1875 than in 1876–1894, and the world growth

rates were not. The proximate explanation is very simple. The world GDP growth rates in 1851–1875 were relatively low (in comparison with 1876–1894) mostly due to the enormous economic decline observed in China in 1852–1870 due to social-demographic collapse in connection with the Taiping Rebellion and accompanying events of additional episodes of internal warfare, famines, epidemics and so on (Ilyushechkin 1967; Perkins 1969: 204; Larin 1986; Kuhn 1978; Liu 1978; Nepomnin 2005, *etc.*) that resulted, for example, in the human death toll as high as 118 million human lives (Huang 2002: 528). Note that in the mid-nineteenth century China was still a major world economic player, and the China's decline of that time affected the world GDP dynamics in a rather significant way. According to Maddison's estimates, in 1850 the Chinese GDP was about 247 billion international dollars (1990, PPP), as compared with about 63 billion in Great Britain, or 43 billion in the USA. By 1870, according to Maddison, it declined to less than $190 billion, which to a large degree compensated the acceleration of economic growth observed in the same years in the West (actually, Maddison appears to underestimate the magnitude of the Chinese economic decline in this period, so the actual influence of the Chinese 1852–1870 sociodemographic collapse might have been even much more significant). K2 Phase A in the Western GDP dynamics started to be felt at the world level only in the very end of this phase, in 1871–1875, after the end of the collapse period in China and the beginning of the recovery growth in this country.

In more general terms, it seems possible to maintain that in the pre-1870 epoch the Modern World System was not sufficiently integrated, and the World System core was not sufficiently strong yet – that is why the rhythm of the Western core's development was not quite felt at the world level. Only in the subsequent era does the World System reach such a level of integration and its core acquires such strength that it appears possible to trace quite securely Kondratieff waves in the world GDP dynamics.[6]

Kondratieff Waves in the World Technological Innovation Dynamics

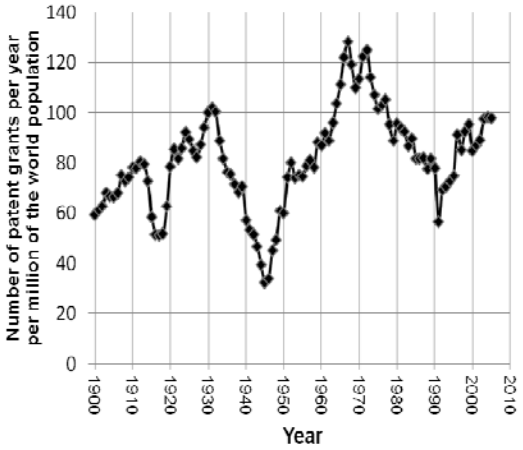
Naturally, the connection between the K-waves and technological innovation processes deserves special attention. In order to re-test the Kondratieff – Schumpeter hypothesis for the presence of K-waves with regard to the world invention activities, we have used the World Intellectual Property Organization (WIPO) Statistics Database on the number of patents granted annually in the world per million of the world population in 1900–2008 (see Korotayev, Zinkina, and Bogevolnov 2011 for more details). For 1985–2008 WIPO publishes direct data on the total number of patent grants in the world per year (WIPO 2012a). For the 1900–1985 we calculated this figure by summing up the data for all the countries (that are

[6] The fact that K-waves can be traced in Western economic dynamics earlier than at the world level has already been noticed by Reuveny and Thompson (2008) who provide the following explanation: if one takes the position that the core driver of K-waves is intermittent radical technological growth primarily originating in the system leader's economy, one would not expect world GDP to mirror K-wave shapes as well as the patterned fluctuations that are found in the lead economy and that world GDP might correspond more closely to the lead economy's fluctuations over time as the lead economy evolves into a more predominant central motor for the world economy. Reuveny and Thompson also argue that to the extent that technology drives long-term economic growth, the main problem (certainly not the only one) in diffusing economic growth throughout the system is that the technology spreads unevenly. Most of it stays in the already affluent North and the rest fell farther behind the technological frontier. Until recently very little trickled down to the global South (Reuveny and Thompson 2001, 2004, 2008, 2009). Our findings also seem to match this interpretation.

provided by the WIPO in a separate dataset [WIPO 2012b]). We used the databases of Maddison (2010), UN Population Division (2012), and U.S. Bureau of the Census (2012) as our sources of data on the world population dynamics.

The results of our calculations are presented in Fig. 16.

Fig. 16. Dynamics of number of patent grants per year per million of the world population, 1900–2008



It is evident that the figure above reveals an unusually distinct K-wave pattern (note that a similar pattern has been detected in the dynamics of patent applications by Plakitkin [2011] who, however, did not appreciate that he dealt with K-wave dynamics). In general, we see rather steady increases in the number of patent grants per million during K-wave A-phases ('upswings'), and we observe its rather pronounced decreases during K-wave B-phases ('downswings'). Thus, the first period of the growth of the variable in question revealed by Fig. 16 more or less coincided (with a rather slight, about 2–3 years, lag) with A-phase of the 3rd K-wave (1896–1929); it was only interrupted by the First World War when the number of patent grants per million experienced a precipitous but rather short decline, whereas after the war the value of the variable in question returned as fast to the A-phase-specific trend line. The first prolonged period of decline of the number of patent grants per million corresponds rather accurately (except for the above mentioned 2–3 year lag) to B-phase of this wave (1929–1945); the second period of steady increase in the value of the variable in question correlates almost perfectly with A-phase of the 4th K-wave (1945–1968/74), whereas the second period of decline corresponds rather well to its B-phase (1968/74–1984/1991); finally, the latest period of the growth of the number of patent grants per million correlates with A-phase of the 5th K-wave.

Note, however, that this pattern apparently goes counter the logic suggested by Kondratieff, Schumpeter and their followers who expected increases in invention activities during B-phases and decreases during A-phases. Yet, this contradiction is only apparent. Indeed, as we have mentioned above, Kondratieff maintained that 'during the recession of the long waves, an especially large number of *important* discoveries and inventions in the technique of production and communication are made, which, however, are usually applied on a large scale only at the beginning of *the next long upswing*' (Kondratieff 1935: 111, our emphasis).

It has been suggested that it is necessary to distinguish between 'breakthrough' and 'improving' inventions (*e.g.*, Akaev 2010); breakthrough inventions are those that during a B-phase of a given K-wave create foundations for a new technological system corresponding to a new K-wave. As Kondratieff suggested, they find their large-scale application during the A-phase of the new K-wave based on this new technological system, which is accompanied by a flood of improving innovations that are essential for the diffusion of technologies produced by breakthrough inventions made during the B-phase of the preceding K-wave (*Ibid.*; Hirooka 2006).

Note that among the total number of patents a negligible proportion has been granted for breakthrough inventions, whereas the overwhelming majority of all the inventions is constituted just by 'improving' inventions. The exhaustion of the potential of the given K-wave's technological system leads to a decrease of the number of inventions that realize the potential created by the breakthroughs, which created the respective technological system. On the other hand, this very exhaustion of the previous technological system's potential for improvement creates powerful stimuli for new breakthrough inventions. However, the increase in the number of breakthrough inventions in no way compensates the dramatic decrease of the number of innovations improving the potential of the previous technological system. Hence, on the basis of this logic there are theoretical grounds to expect that during the B-phases of K-waves the total number of inventions (and patent grants) per million of population should decrease, whereas during A-phases we should observe a pronounced increase in this number (as some decrease in the number of breakthrough inventions is by far compensated by a dramatic increase in the number of improving inventions).

Therefore, our test has revealed this pattern.

World System Effects and K-Wave Dynamics

As has been already mentioned above, the adherents of the world-system approach consider K-waves as one of the most important components of the World System dynamics.

We quite agree with Thompson (2007) who maintains that K-waves may help to clarify many important points in the World System processes. However, one could also trace another kind of logic – the analysis of the World System processes can contribute a lot to the clarification of the nature of the Kondratieff waves. We believe that the driving forces of the K-waves can be adequately understood if only we take into account the dynamics, phases, and peculiarities of the World-System development. That is why we have tried to analyze K-waves on a World-System scale. Such an approach can integrate different points of view on the nature of Kondratieff waves.

Actually, we can consider the following five points:

1. Kondratieff waves are most relevant when considered at the System scale. As those waves always manifest themselves at supra-societal scales, the World System processes turn out to be very important for the understanding of the K-wave dynamics.

2. The expansion and intensification of the World-System economic links lead to the formation of preconditions of new upswings. Note that Kondratieff himself noticed that 'the new long cycles usually coincide with the expansion of the orbit of the world economic ties' (Kondratieff 2002: 374). We would add that the begining of new cycles implies not only expansion of those ties, but also the change of their nature (we will discuss this in more details below).

3. The World System processes are bound to influence economic processes (including medium period business cycles [*e.g.*, Grinin and Korotayev 2009b]), hence, they are bound to influence K-wave dynamics. However, we also observe a reverse influence of those waves on World System development (which was actually noticed by Thompson). Kondratieff himself noticed the growth in the intensity of warfare and revolutionary activities during K-wave upswings (Kondratieff 2002: 373–374). On the other hand, it is quite clear that those processes themselves influenced K-wave dynamics in a very significant way and world wars provide salient illustrations). It is quite clear that those K-wave students who pointed to an important role of military expenses (and inflation shocks they produce) identified a significant (though in no way sole) cause of price growth (and decline) in the course of Kondratieff cycles.

4. As we have already mentioned above, the breakthrough inventions (producing new technological systems) tend to be made during downswings, whereas their wide implementation is observed during subsequent upswings. The diffusion of those innovations throughout the World System significantly affects the course of K-waves, as the opening of new zones of economic development can change the world dynamics in general. Thus, in Chapter 1 of our monograph on periodic economic crises (Grinin and Korotayev 2009b) we paid considerable attention to the point that the vigorous railway construction of the last decades of the nineteenth century produced a major vector in world economic development (see, *e.g.*, Tugan-Baranovsky 2008 [1913]; Mendelson 1959, vol. 2; Trakhtenberg 1963; Lan 1975). Large-scale investments of British capital in the railway construction in the United States, Australia, India, *etc.* contributed to stagnation within the World System hegemon (and, finally, the change of the center of this hegemony). Technological changes that start in one zone of the World System after their diffusion to other zones may produce such consequences that could hardly be forecasted. Thus, the development of oceanic and railway transportation led to vigorous exportation of cereal crops from the USA, Russia, and Canada that caused in the 1870s, 1880s, and 1890s the so-called world agrarian crisis (which affected significantly the 2nd K-wave downswing but helped several countries to escape from the Malthusian trap [see, *e.g.*, Grinin, Korotayev, and Malkov 2010]).

5. Important events that take place within the World System sooner or later can lead to a switch from downswing to upswing (or, naturally, from upswing to downswing) within K-wave dynamics. As is well-known, the discovery of gold in California and Australia contributed in a rather significant way to the world economic (and price) growth during the 2nd K-wave upswing, which was already noticed by Kondratieff (Kondratieff 2002: 384–385).

Change of K-Wave Phases against the Background of the Interaction between the World-System Core and Periphery

Core and Periphery. We contend that the change of K-wave upswing and downswing phases correlates significantly with the phases of fluctuations in the relationships between the World System Core and Periphery, as well as with World System Core changes (the growth or decline of its strength, emergence of competing centers, their movements, and so on). Below we present our ideas on the possible causes of such a correlation. However, it turns out necessary to study the following questions: does this correlation emerge as

a result of the casual link between the two processes? Is it caused by some other processes? Is not the causation pattern here even more complex? In any case this correlation appears especially important, as in the recent years one can observe an evident change in the interaction between the Core and Periphery of the World System. In particular, the World-System Periphery (in contrast with what was observed not so long ago) tends to develop more rapidly than the core (see, *e.g.*, Korotayev *et al.* 2011; Khaltourina and Korotayev 2010; Korotayev, Khaltourina, Malkov *et al.* 2010; Malkov *et al.* 2010; Grinin and Korotayev 2009b, 2010). This has become especially salient during the current global economic crisis.

Thus, what is the correlation between structural changes of the World System and periodic fluctuations within the K-wave dynamics?

We suggest that during the K-wave downswings the Core tends to subjugate, integrate, and pull up the Periphery to a greater extent than it is observed during the K-wave upswings. It is during the K-wave downswings that the Core tends to expand vigorously (in various way) to the Periphery by investing resources into the latter and by actively modernizing it. Those efforts and resource flows contribute to the slow-down of the Core growth rates.

In contrast, during K-wave upswings the Core's activities are concentrated within the core part of the World System; in the meantime the balance of resource movement turns out to be in favor of the Core. Such a situation leads to the acceleration of growth rates of the Core countries (note, however, that this situation was not observed during the most recent [5th K-wave] upswing).

The resource flow from the World-System Core to the Semiperiphery and Periphery may proceed in various forms (military expenditures, FDI, aid, emigration, and so on). Of course, such actions were usually undertaken by the Core countries in order to obtain certain concrete gains: to get colonies, to obtain profits, to get influence in certain countries, to open markets, to get access to raw materials and so on (though the philanthropic component tended to become more and more pronounced with the course of time). However, it takes any long-term investments a long time to pay for themselves (and sometimes they do not – especially when they are made by politicians rather than businessmen). Often such a resource flow proceeded in the form of loans many of which were never paid back.

The resource flow to the Core could be also achieved in various forms – ranging from a direct plunder of colonies to importing very cheap commodities from them; it was also achieved through monopoly prices, unfair loans, and so on. The 2nd K-wave upswing (the late 1840s to the 1870s) was supported to a very considerable extent by the flow of gold from such peripheral areas as California and Australia. In recent years one could observe certain exportation of capitals from the Periphery and Semiperiphery to the Core, as has been observed for China, Brazil, and Russia as regards the U.S. securities; one may also note cheap Chinese exports, brain drain from India, *etc.*

Let us study how this works with respect to particular K-waves and their phases.

The First Wave: The Late 1780s / Early 1790s – 1844/1851

Phase A: the late 1780s / early 1790s – 1810/1817. By that period the main colonial conquests of the pre-industrial epoch had been already finished, the independence wars of the New World colonies began, and the main interests of the European powers were focused on internal affairs. In this period the resource flow from the Core to the Periphery was rather

insignificant, whereas the one from the Periphery to the Core remained quite substantial. The Periphery and Semiperiphery (the USA in the first place) acted as suppliers of raw materials (cotton) for the development of the most advanced industrial sectors (Burstin 1993a, 1993b; Sevostyanov 1983; DiBacco *et al.*1992; Zinn 1995).

Phase B (downswing): 1810/1817–1844/1851. Europe (primarily Britain and France) engaged in rather active expansion on the Periphery – China, Algeria, Egypt, Turkey, and Latin America. British loans and investments went to Latin America and the USA (Tugan-Baranovsky 2008 [1913]; Mendelson 1959). There was a massive emigration from Europe (and especially Britain) to the West European offshoots; one could observe the active opening of Australia (*e.g.*, Malakhovski 1971), the South and the West of the USA. In this period resources moved from Britain rather than to Britain. This partly accounts for relatively bad conditions of the working class in Britain at this time (vividly described by Engels 2009 [1845]).

The Second Wave: 1844/1851–1890/1896

Phase A: 1844/1851–1870/1875. Europe again concentrated on its internal affairs (including the Crimean War, the unification of Germany and Italy and so on). The USA was tied by internal struggles, and Russia was focused on internal reforms. A free trade system is established (*e.g.*, Held *et al.* 1999). The flow of Australian and Californian gold reached Europe; one could observe a rather active catch-up of the European Semiperiphery (Grinin and Korotayev 2009b).

Phase B: 1870/1875–1890/1896. Europe actively expanded to the Periphery, actually the world was mostly divided between the Core powers that accomplish the final wave of colonial conquests (this involves some semiperipheral countries, first of all Russia conquered most part of Central Asia). One could observe an active opening of agricultural lands in the American West (Burstin 1993a, 1993b; Sevostyanov 1983; DiBacco, Mason, and Appy 1992; Zinn 1995) and a very rapid development of Australia (*e.g.*, Malakhovski 1971), as well as significant investments in the Periphery (especially in the railroad construction). Actually, during this period resources moved rather actively from Britain and some other European countries to the Periphery – for example, as loans for Latin America (*e.g.*, Tugan-Baranovsky 2008 [1913]; Mendelson 1959).

The Third Wave: 1890/1896–1945

Phase A: 1890/1896–1914/1928. Europe is concentrated on internal competition within itself (resulting finally in an outright warfare), the USA is also concentrated on its own internal affairs (with the exception of a war with Spain); the preparations for the war and competition between Germany and Britain stimulate the technological race and economic growth (*e.g.*, Grenville 1999). One could observe a significant flow of resources from the Periphery, as well as the start of the transition of the World System hegemony to the USA that, however, continued to be an importer of capital for a long time (*e.g.*, Lan 1975). Resources also flowed actively to Russia, Japan and some other semiperipheral countries where investors could find opportunities to introduce new technologies and get high profits.

Phase B: 1914/1928–1939/1950. Activation of the Periphery and Semiperiphery, its struggle with the Core in various forms (India, China, Egypt, the USSR, Japan, *etc.*), the finalizing of the transition of the World System hegemony from Europe to the USA

(see, *e.g.*, Modelski and Thompson 1996; Grinin and Korotayev 2009b; Lan 1976). The continuation of the Core countries control over their colonies requires more and more efforts and expenses.

The Fourth Wave: 1939/1950–1984/1991

Phase A: 1939/1950–1968/1974. The Core lost direct political control over the Periphery and was concentrated on its own internal affairs (including the West European integration); as a result of this concentration and the redistribution of capitals and technologies within the World-System Core one could observe the Japanese, German, Italian, and Spanish economic miracles, as well as the consolidation of the Western world under the US hegemony (*e.g.*, Lan 1978); one could also observe the emergence of new centers of development, including the Eastern Block and Japan (*e.g.*, Popov 1978).

Phase B: 1968/1974–1984/1991. The Periphery 'attacked' the Core in terms of economy – first of all through a radical increase in oil and some other raw material prices. In the meantime the West invests rather actively in the Periphery (especially, through loans to the developing countries).

The Fifth Wave: 1984/1991–2015/20 (?)

Phase A: 1984/1991–2001/2007. This phase displays certain peculiarities in comparison with previous upswings, as during this period the main economic growth was generated not by the Core, but rather by the Periphery whose strongest countries moved to the Semi-periphery and even became new centers of growth.[7] Many Core countries (especially in Europe) were concentrated on their internal affairs. In the meantime one could observe a rather active exchange of resources between the Core and the Periphery. On the one hand, industrial production moved from the Core to the Periphery; on the other hand, one can observe a vigorous flow of cheap manufactured products from the Periphery to the Core, whereas the Western countries became financial net importers (especially, through the movement of petrodollars). The USA actively exchanged 'paper' dollars for manufactured goods from the periphery, which contributed to the explosive growth of the US public debt (see, *e.g.*, Akaev, Korotayev, and Fomin 2012). One may also take into account the Periphery – Core labor migration. Thus, at the first glance the balance of exchange looked as if being in favor of the Core. On the other hand, one should take into account the fact that those processes were accompanied by the acceleration of the economic growth in the Periphery and its slowdown in the Core – so, actually the Periphery favored from them more than the Core. One may suppose that this was supported by a substantial transformation of national sovereignty that opened borders for the flows of foreign capitals and technologies (see Grinin 2005, 2008a, 2008b, 2008c, 2008d; Grinin and Korotayev 2009a, 2009b, 2010; see Grinin 2008e, 2008f, 2009b on the processes of decrease of sovereignty prerogatives).

Phase B: 2001/2007–2015/2020. By now we observe the weakening of the Core and the activation of new centers; one may expect a search for a new balance of power and new coalitions (see Grinin 2009a, 2010, 2011; Grinin and Korotayev 2010 for more details).

Now let us consider some characteristics and causes of those processes.

[7] This somehow resembles the situation during the 3rd K-wave upswing, when the growth was generated in still semi-peripheral Germany, the USA, and Russia, rather than in still hegemonic Britain.

Possible causes of the expansion. It is natural to suppose that particular strong Juglar crises and depressions typical for K-wave downswings in the Core countries stimulate the Core expansion on the Periphery.[8] Such an expansion can be considered a result (and as a part) of counter-crisis measures undertaken by the Core countries. In addition, one may take into account the imitation competition effect – the intensification of expansion efforts by one state tend to provoke such an intensification on the part of competing states.

In what way does the expansion contribute to the additional slow-down of the economic development during the downswing?

1. In the course of such an expansion the energy of the Core tended to become exhausted.

2. In addition, the Core powers could be exhausted by their struggles over their control over the World System Periphery. In any case the growth of this control involved substantial expenses (and sometimes serious destruction). In the previous periods this could additionally weaken the Periphery. On the other hand, results of mutually beneficial expansion may be felt with a substantial lag.

3. On the other hand, the fast development was often hindered by the insufficient congruence of the economic structures of the Core and Periphery, a huge gap in the levels of economic development that was observed in many cases.

4. One cannot exclude that we deal here with a sort of positive feedback: the worsening of the economic situation in the Core stimulated its expansion to the Periphery, whereas the growing expenses to support this expansion may have worsened the situation in the Core.

5. As a result of the active integration of the Periphery into the World System, the transformation of the Hinterland into Periphery, a part of the Periphery into Semiperiphery, and the formation of new centers in the Semiperiphery the World System expanded, the number of links and contact intensity within it increased explosively, *etc.*; this, however, led to a certain slowdown of the World System economic growth.

6. Downswings are also connected with the weakening of the old Hegemon. This weakens the structural congruence of the World System and supports the trend toward the slowdown of the economic growth rates. We are likely to observe such a pattern in the forthcoming years. On the other hand, it appears virtually impossible to replace the USA as the Word System Hegemon, because the USA is a multifunctional Hegemon, whereas no other power will be able to play such a role in the forthcoming decades. That is why there are grounds to expect the reconfiguration of the World System as a whole (see Grinin 2009a, 2010; Grinin and Korotayev 2010 for more details).

Slowdowns of the world economic growth are often connected with the slowdown of the economic growth of the Hegemon.

During upswings the resource movement balance tends to be in favor of the Core.

1. During the upswing, the World System Core tends to concentrate on its internal affairs (including the struggles between the Core countries), and consequently it tends to move less resources to the Periphery.

[8] On the other hand, the weakening of the Core makes it possible for the Periphery to undertake counter-expansion, as was observed in the 1970s and early 1980s as regards fuel prices. Their explosive growth led to the flow of resources from the Core to the Periphery.

2. Resource accumulation, restructuring of relationships within the core, as well as the emergence of new (and especially military) technologies stimulate the escalation of hegemonic struggles within the Core.

3. By themselves those struggles and wars contribute to the acceleration of both inflation and economic growth (thus, we are dealing here with a certain positive feedback).

4. An important factor of the change of the resource movement balance in favor of the Core was constituted by the fact that the previous investment started to produce returns; in particular, the long-term investments in the infrastructure started to produce results; the trade-financial links started to work, scarcely populated territories were peopled (as was observed, *e.g.*, in Australia in the first half of the nineteenth century), and so on.

5. On the other hand, new peripheral regions were involved in global trade. Those regions in order to do this often had to export their commodities with reduced prices (which often implied non-equivalent exchange – see Grinin and Korotayev 2012 for more details).[9]

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[9] Note, however, that during the 4th K-wave downswing and the 5th K-wave upswing one could observe the change of the World System trend toward the growing divergence between the Core and Periphery to the trend toward convergence. Before this switch of the global trends the gap between the Core and the Periphery tended to increase; now it tends to decrease (Korotayev *et al.* 2011; Korotayev and Khaltourina 2009; Khaltourina and Korotayev 2010; Malkov *et al.* 2010; Korotayev, Khaltourina and Bogevolnov 2010). As a result, as has been mentioned above, we could observe the decrease of the gap between the Core and the Periphery already during the 5th K-wave upswing. Note, that if the hypothesis that we have spelled out above is true, then we should expect the acceleration of the Core – Periphery convergence during the current (5th) K-wave.

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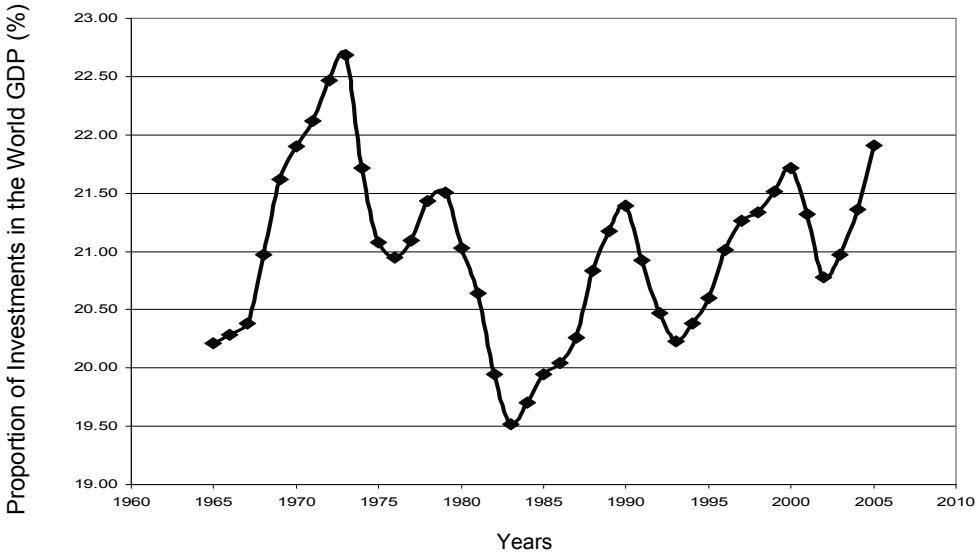
Appendix

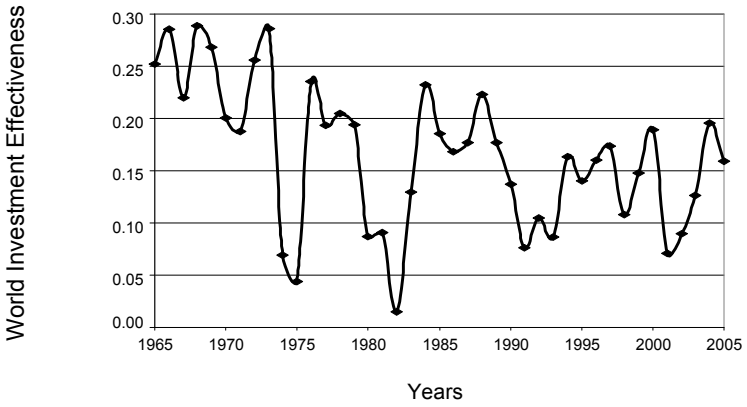
Supplementary Figures

Fig. S1. Dynamics of Proportion of Investments in the World GDP (%), 1965–2005



Source: World Bank 2012.[10]

Fig. S2. Dynamics of the World Investment Effectiveness, 1965–2005



Source: World Bank 2009a.[11]
Note: This variable indicates how many dollars of the world GDP growth are achieved with one dollar of investments.

[10] Dynamics of this variable has been calculated by Justislav Bogevolnov (Moscow State University, Department of Global Studies) with the World Bank database by dividing the world gross fixed capital formation indicator (in constant international 2000 dollars) for a given year by the world GDP (in constant international 2000 dollars) for the same year.
[11] Dynamics of this variable has been calculated by Justislav Bogevolnov.