Chapter 4. Cyclic mode of human development

The cyclic mode of human development is as important as such phenomena of human development as hyperbolic growth and demographic transition. In chapter 1, it was pointed that different authors identified different reasons behind the cyclic mode of development and it is hard to identify which dominates. I now will attempt to discover reasons of both the cyclic mode and the current economic crisis in the course of considering development of mankind as a system.

4.1. Technology revolution

To identify a pattern featuring emergence of technological shifts, let's consider crisis, turning and revolutionary dates of long-term nature distinguished by different authors in Common Era (see Table 4.1).

Table 4.1. Dates of technology revolutions distinguished by different authors

Author	1	2	**3**	4	**5**	6	**7**	8	9	10	11
Kondratiev N.D[1]					1789	1845	1898	1949	1985	2018	
Schumpeter J.A.[2]					1785	1845	1900	1950	1990	2020	
Glaziev S.Yu.[3]					1770	1830	1880	1930	1970	2010	
Yakovets Yu.V.[4]	450	1350			1731				1973		2130
Tateishi K.[5]	700	1302			1765	1876		1945	1974	2005	2025
Diyakonov I.M.[6]	540		1540			1845		1945			
Kapitsa S.P.[7]	500		1500			1840		1955		2000	2050
Molchanov A.V.[8]	630	1325		1674		1848		1934	1978		
Orekhov V.D.[9]	630	1325		1674		1848		1935	1978	2010	2040
Bunch, B *et al*.[10]	530		1453	1660	1735	1820	1895	1945	1972	2003	
Podlazov A.V.[11]	250	1350			1770			1930	1990		
Average (rounded)	530	1330	1500	1670	1770	1845	1890	1940	1980	2010	2038

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1 Cited from: Экономическая теория: Учеб. / Под ред. В.И. Видяпина и др. М., 2007. – С. 472.
2 Cited from: Агарков С.А., Кузнецова Е.С., Грязнова М.О. Инновационный менеджмент и государственная инновационная политика. – М., 2011. – Рис. 3.1. http://www.monographies.ru/112-3768
3 Глазьев С.Ю., Львов Д.С. Теоретические и прикладные аспекты управления НТП // Эконом. и мат. методы. – 1986. – № 5. – С. 793-804.
4 Яковец Ю.В. Циклы. Кризисы. Прогнозы. – М., 1999. – Табл. 9. http://abuss.narod.ru/Biblio/jakovets.htm
5 Татеиси К. Вечный дух предпринимательства. Практическая философия бизнесмена. – М., 1990. – С. 192.
6 Cited from: Панов А.Д. Сингулярность Дьяконова. Русс. физ. мысль. – 2011. – С. 71.
7 Капица С. П. Парадоксы роста: законы глобального развития человечества. – М., 2012. – С. 79.
8 Молчанов А.В. Развитие теории С. П. Капицы. Гипотеза сети сознания // Око планеты. – 2009 // Естествознание. – 2009 // Наука и техника. – 2009. http://oko-planet.su/science/ scienceclassic/page,1,3371-a.v.-molchanov-razvitie- teorii-s.p.-kapicy.html
9 Орехов В.Д. Инновационный процесс и его роль в развитии человечества // Матер. 2-й междунар. научн.-практ. конф.: Шумпетеровские чтения. – Пермь, 2012. – С. 85. http://www.sr.pstu.ru/files/SchumpeterianReadings2012.pdf
10 Bunch, B., Hellemans, A. The history of science and technology. Houghton Mifflin company, Boston – New York, 2004. http://eknigi.org/nauchno_populjarnoe/138496-the-history-of-science-and-technology.html
11 Подлазов А.В. Теоретическая демография как основа математической истории. – М., 2002.

The Table shows some dates are considered important for human development by most authors whereas other dates, far from everyone. Note also that some authors implicitly appraise different technology revolutions inequivalently. For example, in figure 1.1 which represents current periodization of long waves the depth of the first and the third Kondratiev's waves is apparently less than this of the second and the fourth ones. The similar pattern is evident in figure 4.1 which represents a relative annual rate of global GDP growth in percentage[12]. The depth of recession pertaining to the crisis of 1880-1900 is relatively small by contrast to 1931-1935 crisis (recessions in 1915-1920 and 1940-1945 pertain to World Wars).

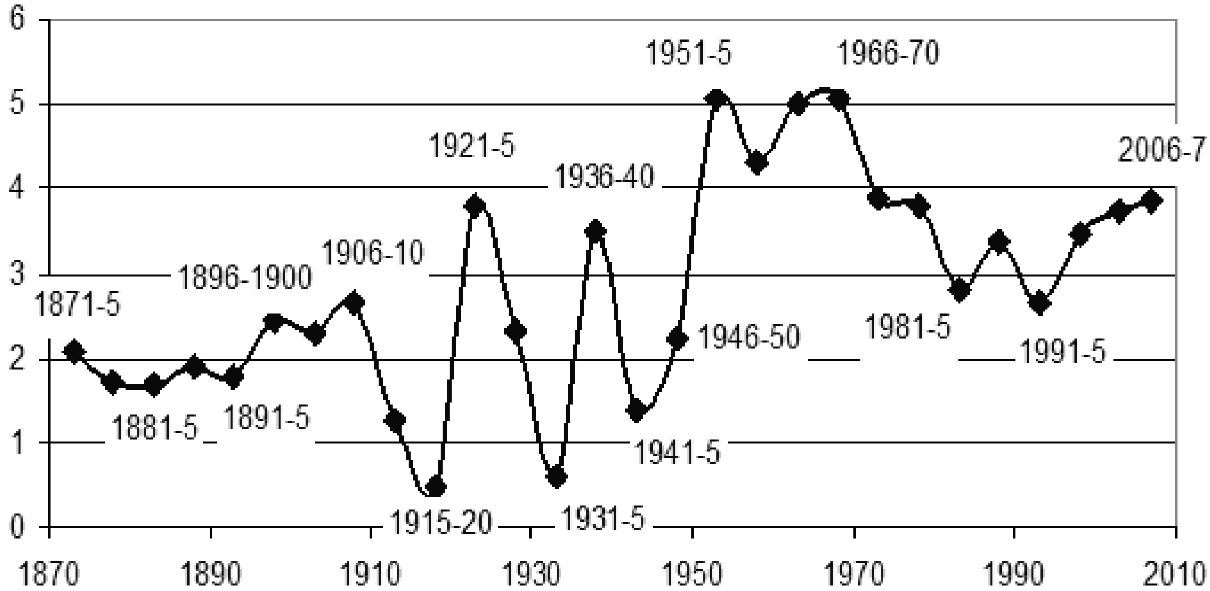

Figure 4.1 Global GDP growth rate, %

Note another interesting fact: if columns 3, 5, and 7 are excluded since few authors distinguish appropriate dates (see Table 4.1), the rest columns form a sequence of dates $\mathbf{T_n}$ with the inter-date periods $\Delta\mathbf{T_{n+1}} = \mathbf{T_{n+1}} - \mathbf{T_n}$ representing a geometric progression with a ratio of 1/2. In this sequence, the duration of n+1 epoch equals $\Delta\mathbf{T_{n+1}} = \Delta\mathbf{T_1} / \mathbf{2^n}$. If a conditional date of the feudal revolution, $\mathbf{T_0}$ = year 630, is taken as the date of the initial revolution and the sequence is summed up with $\Delta\mathbf{T_1}$ = 696 years, dates of next revolutions will be given by the following formula

$$\mathbf{T_n = T_0 + 2 \cdot \Delta T_1 \cdot (1 - 2^{-n}).} \qquad (4.1)$$

Such a pattern is based on the hyperbolic growth of mankind up to 1960 – the fact considered in more details below. The $\mathbf{T_n}$ sequence may be prolonged into the past down to the mankind origin[13].

4.2. Waves-indicators

Let's turn back to the waves (revolutions, shifts) that we have excluded from the sequence (4.1). They are also quite powerful and the history of mankind knows some of them well, for

[12] Системный мониторинг. Глобальное и региональное развитие / Отв. ред.: Д. А. Халтурина, А. В. Коротаев. – М., 2010. – С. 211. http://cliodynamics.ru/download/M02Korotayev_Tsirel_kondratyevskie_volny.pdf

[13] Панов А.Д. Сингулярность Дьяконова // Русс. физ. мысль. – 2011. – № 1–12. – С. 76. http://www.rusphysics.ru/files/Panov.Singulyarnost-%20.pdf

example, the First Industrial Revolution around 1770. As shown in Table 4.2, they happen approximately between more powerful waves. And these additional waves serve somewhat ‘indicators’ of a next more powerful technology revolution. From now on I will use prefixes ‘pre’ or ‘post’ as appropriate to substitute the word ‘wave (revolution)-indicator’.

Table 4.2. Dates of technology revolutions including indicators

n	**T_n**	**Revolution (era)**	**Kondratiev N.D.**	**Glaziev S.Yu.**	**Tateishi K.**	**Diakonov I.M.**	**Kapitsa S.P.**	**Molchanov A.V.**	**Bunch B.**
0	52	Pre-feudal							
1	**630**	**Feudal**			700	540	500	630	530
2	1038	Pre-handicraft							
3	**1326**	**Handicraft**			1302			1325	1453
4	1530	Renaissance				1540	1500		
5	**1674**	**Classic science**						1674	1660
6	1776	First Industrial	1789	1770	1765				1735
7	**1848**	**Second Industrial**	1845	1830		1845	1840	1848	1820
8	1899	S&TR indicator	1898	1880	1876				1895
9	**1935**	**S&TR**	1949	1930	1945	1945		1934	1945
10	1961	Pre-cybernetic					1955		
11	**1979**	**Cybernetic**	1985	1970	1974			1978	1972
12	2005	Pre-biotechnologic	2018	2010	2005		2000		2003
13	**20XX**	**Biotechnologic**			2025		2050		

I may logically assume that these indicators split technological epochs into periods ΔT_n that form a single sequence, namely a geometric progression of a ratio of the square root of 0.5, i.e. $0.5^{0.5} \approx 0.707$**.** And the duration of epochs between revolutions is expressed by a formula $\Delta T_{n+1} = \Delta T_n / 2^{1/2} = \Delta T_1 / 2^{n/2}$. Thus, dates of revolutions fit a sequence similar to (4.1):

$$\mathbf{T_n = 52.5 + 1970 \cdot (1 - 2^{-n/2}).} \qquad (4.2).$$

Table 4.2 shows dates of technology shifts including waves-indicators in Common Era. To allow comparison, the Table provides also dates from the appropriate classic works (see Table 4.1). Notably, according to formulas (4.1) and (4.2) $\mathbf{T_n} \rightarrow$ year **2022**, i.e. the conditional date of singularity, if $\mathbf{n} \rightarrow \infty$**.**

The dates of revolutions are shown here accurate to a year since formulas (4.1) and (4.2) give a significant rounding error within long time periods. However real technology shifts occur evidently not precisely in a specified time so it is reasonable to round their dates to decades and I will do so below if necessary.

The dates of revolutions No 6 and No 8 (see Table 4.2: revolution numbering is changed) fit quite well two Kondtratiev’s waves and the date of revolution No 4 fits the beginning of Renaissance.

However there are three other dates not identified previously: beginning of Common Era (~year 52) and years 1038 and 1961 that might be treated as indicators of feudal, handicraft and cybernetic revolutions correspondingly. The fact that our chronology is calculated from the beginning of Common Era confirms the importance of the former of these three dates for all of mankind.

No significant crisis accompanied the revolution of 1961; it was the time when global population and economy grew most rapidly and this might smooth adverse effects. Moreover, it is the date when the demographic transition and transition of mankind to a new situation in the system began. Many authors name the appropriate technology shift 'postindustrial'[14]; its distinguishing feature is that tertiary industry excesses commodity production and innovation is an important element of economic progress.

Formula (4.2) does not determine dates of revolutions after 1979 because afterwards essential is the fact that population growth and knowledge accumulation are declining following the demographic transition. So here I show conditional dates that are close to those represented in Table 4.1 and will consider this aspect in more details below.

4.3. Content of technology revolutions

The idea of two types of technology revolutions (major and indicators) proposed above requires validity testing. To do so, Table 4.3 represents major technical, technological and organisational achievements typical to revolutions in question and next epochs[15, 16, 17]. Similar lists are often called a technological mode but I here consider also life-supporting technology and dissemination of knowledge rather than just technology achievements.

A date of an innovation is the time when its application spread most intensively, i.e. near the inflection point of the logistic curve (dates are rounded to decades). Since I am interested in most recent technology shifts, I restrict myself to the events started in the Handicraft revolution onwards. Description of technology achievements includes the following factors as appropriate: the name of a revolution, mode of production, a key factor, an engine, energy supplier, transportation, tools, material, weapon, innovator, healthcare technology, information communication technology, learning technology, etc.

Table 4.3. Innovations specific to technology epochs

n	Period	Technical, technological and other achievements
3	**1330–1530**	**Handicraft revolution (proto-renaissance):** handicraft production, hand labour, shopfloor system, bank, windmill, only wind-driven vessels, navigation, astrolabe, medical tools, flat glass, arbalest, gunpowder, artillery, inventions by Leonardo da Vinci, painting technique, principles of perspective, university, discovery of America
4	**1530–1680**	**Renaissance:** commodity production, proprietary and patent rights, geographic discoveries, humanities, horse plow, turning machine, mirror, fire-arm, analytic geometry, logarithmic tables, works by N. Copernicus, G. Galilei, J. Kepler, E. Torricelli, Ph. Paracelsus, book printing, emergence of a world-system theory by I.M. Wallerstein
5	**1680–1780**	**Classic science:** science-based approach, telescope, microscope, pendulum clock, thermometer, arithmometer, milling machine, steam engine, silicon-

[14] Bell, D. The coming of post-industrial society: A venture of social forecasting. N.Y.: Basic Books, 1973.
[15] Bunch, B., Hellemans, A. The history of science and technology. 2004.
[16] Ошарин А.В., Ткачев А.В., Чепагина Н.И. История науки и техники: Учеб.-метод. пособие. –СПб., 2006. – 143 с. http://www.gaudeamus.omskcity.com/PDF_library_humanitarian_15.html
[17] Черный А.А. История техники: Учеб. пособие. – Пенза, 2005. – 189 с. http://www.gaudeamus.omskcity.com/PDF_library_humanitarian_15.html

n	Period	Technical, technological and other achievements
		bolt guns, differential calculus, Newton's laws, academy of science, science journal, pedagogy
6	**1780–1850**	**First Industrial Revolution (К1):** manufacturing system, textile machine, reaping machine, coal and hydro power, transportation channel, bicycle, Montgolfier, iron, malleable iron, voltaic pile, rifled gun, pen point, typewriter
7	**1850–1900**	**Second Industrial Revolution (К2):** manufacturing, machine-based systems, industrial machines, machinery building, coal mining, ferrous industry, kerosene, electric generator, electric lamp, turbine, railway transportation, steam vessel, concrete, telegraph service, postal service
8	**1900–1935**	**S&TR indicator (К3):** automated production, electric engine, combustion engine, electricity, petrol, steel, heavy machine building, nonferrous industry, inorganic chemistry, automobile, airship, airplane, tank, automated gun, electronic tube, learning in correspondence
9	**1935–1960**	**Science &Technology Revolution (К4):** modern science, serial production, conveying system, automation, diesel engine, turbojet engine, aviation, oil products, organic chemistry, plastic products, alloys, aluminum, X-ray unit, radar, air conditioner, refrigerator, telephone, television, computer, transistor, radiotechnics, relativity theory, quantum physics, nuclear weapon, sputnik, mass media, vaccines, antibiotics, extramural studies
10	**1960–1980**	**Pre-cybernetic Revolution (postindustrial)**: innovative economy, service industry prevails, network-based production, demographic transition, emerging economies revive, quality of living increases sharply, electronics, cybernetics, informatics, software languages, integrated circuits, supercomputer, rocketry, space flights, nuclear energy, gas, synthetic fibre, membranes, supermarket chains, mass culture, programmed learning, business games, brain storm, TIPS
11	**1980–2010**	**Cybernetic (information) revolution (К5)**: informatization, telecommunications, flexible production, personal computer, Internet, optic fibre, microchip, appliance electronics, mobile communications, laser, LED, high temperature superconductivity, robotics, communications satellite, space shuttle, space telescope, dark matter, Higgs bosons, composite materials, cardio surgery, tomograph, payment systems, e-tail, corporate information systems, search engines, identification systems, sequenation, human genome analysis, GMO, cloning, distance learning, computer literacy
12	**2010–2038**	**Pre-biotechnology revolution (К6)**: globalization, nanotechnology, new pharmaceutics, biomedicine, implantation, cellular technology, renewable energy, shale gas, nanomaterials, multimedia, 3D-printing, knowledge management, elements of knowledge-based economy, e-learning
13	**2038 …**	**Biotechnology revolution**: term of human life prolonged up to ~150 years, even most serious diseases are curable, regeneration of organs, genetically modified individuals, first never dying people, revival of extinct animals, bearing within an artificial medium, intellective animals, telepathy, demography management, artificial intellect, quantum computer, thermonuclear reactor, bioenergy

Table 4.3 shows that innovative shifts attributed to a certain date evidently combine pairs as to their content. For example, Renaissance of 1530-1680 and the shift in 1680-1780 consequent upon the emergence of classic science are essentially interrelated in their content and both followed the science formation.

The first and the second industrial revolutions followed the development of industrial production which rested on the success achieved earlier by science and mechanics principles. Though technology achievements in these epochs differ from each other, there is a lot of common among them.

Two next innovative shifts of 1900-1935 and 1935-1960 stem from the science and technology revolution. Automated production and achievements of science actively applied to technology distinguish them.

The next pair of innovative shifts in 1960-1980 and 1980-2010 rest on achievements of cybernetics, information technology, microelectronics, computer technology, etc. According to K. Tateishi, the ‘three Cs’[18] (computer, communication, control) technologies are at the heart of these revolutions. However there is a series of crucial science and technology innovations developed in these periods especially in the former of them. Nuclear technology and rocketry are worth special mentioning.

The authors who identify postindustrial society as succeeding the industrial one also distinguish these two epochs[19, 20]. Postindustrial society is progressing into information (cybernetic) and further into knowledge society[21]. However the term ‘postindustrial’ fails to specify driving forces of the technology revolution, so the word ‘pre-cybernetic’ seems more meaningful here.

Meanwhile authors normally describe the revolution of the end of the 20-th century as ‘information’ rather than ‘cybernetic’. Noting that information is an everlasting factor, I would identify cybernetics as the key agent of this revolution though some authors name it the fourth information revolution.

As to the most recent technology shifts of 2010-2038, different authors present different views though currently majority of publications in the world consider medicine and biotechnology[22, 23]: medicine ~35%; biochemistry, genetics, molecular biology ~13%; biology and agriculture ~5%; pharmacology and toxicology ~4%; immunology and microbiology ~3%. These fields deliver most of revolutionary achievements though they have not changed human life and economy yet. It is the next technology shift that might be expected to do this but the results may no more than be anticipated now.

Meanwhile the cybernetic revolution continues delivering a flow of new technology solutions. Nanotechnology is another important development factor. And just few results may be attributed to the science and technology revolution. Note also that all the identified shifts-indicators deliver the amount of innovation comparable to this of the major shift. Nevertheless achievements of the second in the pair of shifts are normally more influential for mankind for they allow to take full advantage of the revolution’s potential.

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[18] Татеиси К. Вечный дух предпринимательства. Практическая философия бизнесмена. – М., 1990. – С. 179.
[19] Bell, D. The coming of post-industrial society: A venture of social forecasting. N.Y.: Basic Books, 1973.
[20] Белл Д. Социальные рамки информационного общества // Новая технократическая волна на Западе. – М., 1986. – С. 330–342.
[21] Миндели Л.Э., Пипия Л. К. Концептуальные аспекты формирования экономики знаний. – 2007.
[22] Главачева Ю.Н. SciVerse Scopus – продукт компании Elsevier. – 2013. http://library.kpi.kharkov.ua/Prezent/2_scopus.pdf
[23] Scopus reference database. http://www.elsevier.com/online-tools/scopus/content-overview#content-overview

4.4. Technology waves profile

It is interesting to investigate the invention rate as a function of suggested dates of technology revolutions. Let us use World Intellectual Property Indicators[24] that give the number of patents granted per annum H per population N in the period from 1883 to 2008. To extend this function down to 1450, E.F. Nemtsov[25] involved statistic data on landmark inventions from J. Huebner's work[26] (see fig.1.4) which in their turn are based on data from B. Bunch and A. Hellemans[27]. However two functions give contradictory trends in the period after 1900: according to J. Huebner's data (see fig. 4.1), human ability to invent declines whereas it rises according to patents granted (fig. 4.2).

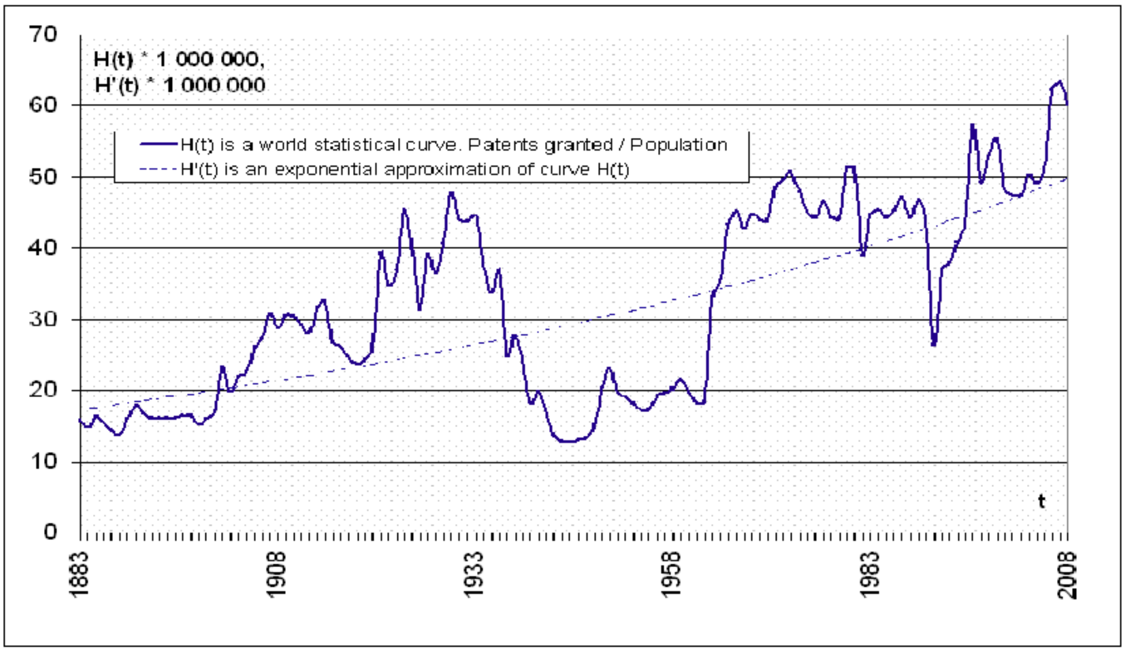

Figure 4.2. Patents granted per million of global population

Data on patents granted over the last 100 years are assumed more objective so to 'align' two curves applied were data on year 1905 that prove that one landmark invention is equivalent to 1,700 inventions patented. Figure 4.3 represents the adjusted curve of landmark inventions[28].

To identify the profile of innovation activity within a technology epoch, I use data on major inventions represented in Table 4.2. Appropriate revolutions are considered in pairs, a revolution-indicator and a revolution itself. To allow comparison of patenting activity profiles, let us normalize value H against the mean across the profile for each pair of waves and set the mean H to the 50%-level. On abscissa, let us put a point from the beginning of the revolution with point 1 marking the beginning of the revolution-indicator, point 11 – the beginning of the major technology revolution and point 21 – the end of the cycle and beginning of the next revolution-indicator (the scale is uniform). Figure 4.4 represents these profiles.

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[24] Мировые показатели интеллектуальной собственности за 2012 год: Докл. Всемир. орг. интел. собст. – Женева. PR/2012/726, 2012. (World Intellectual Property Indicators – 2012/ Edition. http://www.wipo.int/ipstats/en/wipi/index.html

[25] Cited from: Немцов Э.Ф. Человечество становится всё изобретательнее. – 2011. http://nemtsov.ners.ru/articles/chelovechestvo-stanovitsya-vs-izobretatelnee.html

[26] Huebner, J. A. Possible Declining Trend for Worldwide Innovation. 2005.

[27] Bunch, B., Hellemans, A. The history of science and technology. 2004.

[28] Cited from: Немцов Э.Ф. Человечество становится всё изобретательнее. – 2011.

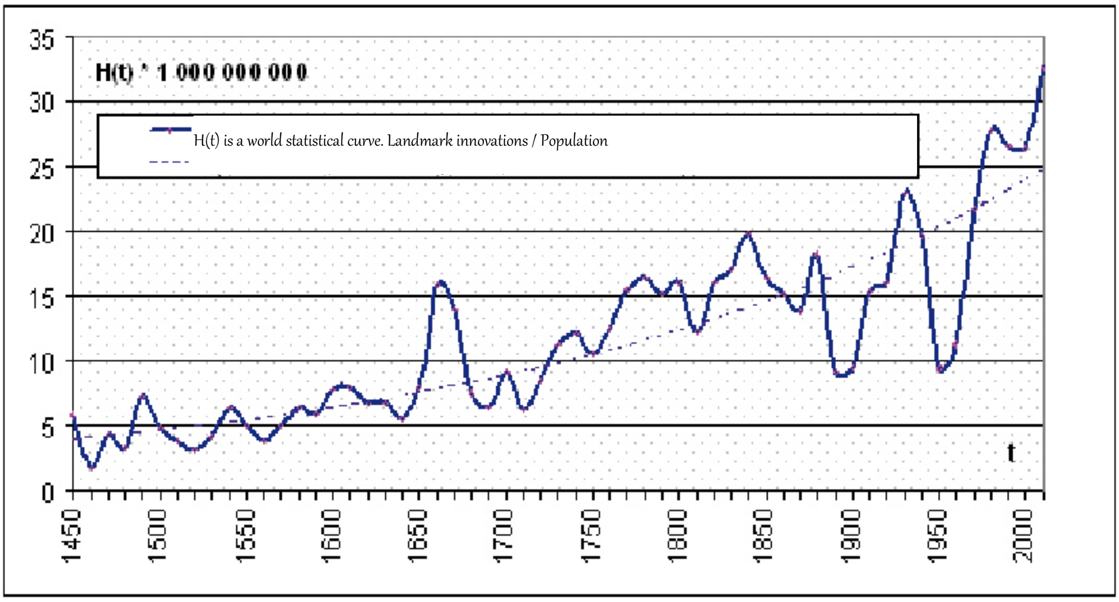

Figure 4.3. Landmark inventions per billion of population

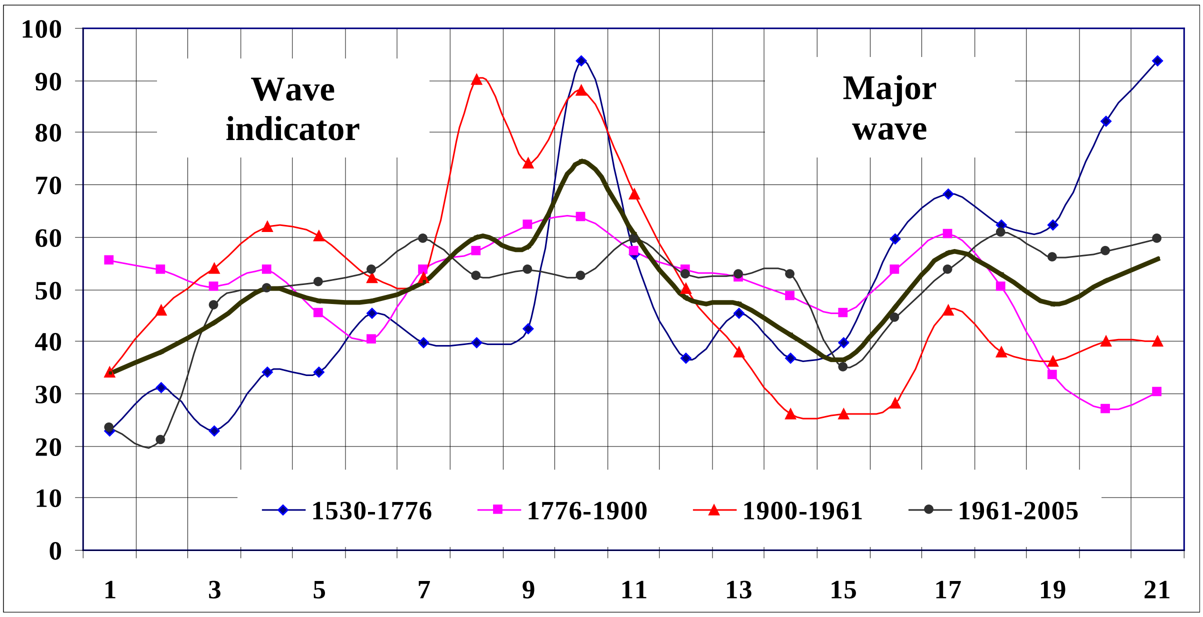

Fig. 4.4. Relative profiles of inventive activity within technology epochs

Specific to these profiles is that revolutions-indicators start normally with a relatively small number of inventions and innovations reach maximum by the end of the epoch. A major revolution starts with a decline in innovation activity and then, prior to the next revolution-indicator, inventive activity rises[29].

Profiles of different technology epochs differ from each other quite evidently and this proves the presence of a significant random component and assumes the presence of shorter economic cycles. At the same time profiles of epochs/waves-indicators and major ones differ from each

[29] Орехов В.Д. О парной взаимосвязи длинных волн: Тр. XV междунар. научн.-практ. конф. «Качество дистанционного образования: концепции, проблемы, решения». – М., 2013. – С. 168.

other significantly and are quite similar within a single type that allows to identify them as pair waves.

Many inventions that sprang by the end of wave-indicators presumably are not implemented in full maybe because of the lack of appropriate resources (investment, consumer demand, understanding technology trends by investors, qualified specialists in relevant areas). Meanwhile businessmen adopt decisions and produce pilot products specific to the next technology epoch to offer them in the market.

The major wave then observes a decline in innovative activity with innovations tried and tested previously being implemented. By the end of the major wave, innovative activity rises due to new ideas generated in advance of the next pair of technology revolutions.

Summary of chapter 4

Beyond the time period investigated by Kondratiev, Kondratiev's long waves turn out to be of a more complex structure than they would be assumed basing on the three waves he studied. This wave structure is relevant for both the past and the future, however time periods between waves are not constant. Past waves form a geometrical progression that fits the hyperbolic growth of population. The shortest wave corresponds to the beginning of the demographic transition (year 1960).

Technology revolutions occur in pairs that are tightly interrelated in their content, for example the First and the Second Industrial Revolutions.

Time periods between major technology revolutions fit a geometric progression with the ratio of 0.5 for major revolutions, dates of these revolutions fit the formula

$$\mathbf{T_n = 630 + 1392 \cdot (1 - 2^{-n}).}$$

Revolutions-indicators precede major revolutions and the total sequence of revolutions fits a geometric progression with a ratio being equal to a square root of 0.5

$$\mathbf{T_n = 52 + 1970 \cdot (1 - 2^{-n/2}).}$$

Inventive activity permanently increases as waves-indicators progress whereas major waves start with activity decline and activity grows by the end of an epoch.