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The waves of the technological innovations of the modern age and the present crisis as the end of the wave of the informational technological revolution

The article is about new views on the theory of "long waves" and specially from the point of view of technological progress importance of which is stressed. It developed a new conception of waves of technological innovations in a modern society (from 1600 AD). The last- 5th wave (based on a progress in informatics and telecomunications) is just coming to an end. Today economic crisis 2008() must be seen also as the crisis of the end of the cycle of innovations. It could be overcome by a new technological revolution (post-informational technological revolution) which could start about 2015.

Key words: Crisis, innovation, invention, Kondratieffs cycles, long waves, post-informational technological revolution, technological progress, waves of technological innovation.

1. Introduction

The term "information revolution"[1], which achieved widespread currency in the period 1960–80, reflected the penetration of computers and information technology into the economy and everyday life. This revolution was sometime supposed to represent a change in the structure of society as momentous as the Neolithic revolution 9 000 years ago, or the industrial revolution at the start of the nineteenth century.[2]

Since 1980 the society that developed as a result of this change has been known as the post-industrial society, initially as a result of the influence of the American professor of Sociology Daniel Bell (born 1919)[3]. Later, under the influence of Heidi and Alvin Toffler, the terms third wave society[4], super-industrial society and information society came into use. According to their concept, which has become a commonplace, humanity has passed through four societies or stages of development[5]:

1 FREEMAN, C.: *Die Computerrevolution in den langen Zyklen der ökonomischen Entwicklung*, München, Carl Friedrich von Siemens Stiftung, 1985, p. 31

2 See: TOFFLER, A.: *The Third Wave*, New York, Bantam Books, 1980, pp. 5-11

3 *Daniel Bell*, http://en.wikipedia.org/wiki/Daniel_Bell

4 TOFFLER, A.: *The Third Wave*, New York, Bantam Books, 1980, pp. 5-11

5 TOFFLER, A.: *Šok z budoucnosti (Future Shock)*, Praha, Práce, 1992, pp.13-15 and TOFFLER, A.: *The Third Wave*, New York, Bantam Books, 1980, pp. 13-16

1. hunter-gatherer,
2. agrarian (first wave society),
3. industrial (second wave society)
4. informational (third wave society)

In each case the catalyst for change was a new form of technology: agriculture, mechanical production and information-communication technologies.

There are legitimate grounds for criticizing such a model:

The division of history into such stages is somewhat oversimplified. It is clear that the so-called industrial society continued to be dependent on agriculture, just as the informational society was dependent on industry and in fact the birth of every new sector depends on and is accompanied by progress in other sectors: the industrial revolution would not have been possible without a significant increase in the productivity of agriculture, which freed the labour force, and the information revolution includes progress in industry (new production technologies without which the mass production of computers would be impossible, while at the same time information technology permits entirely new procedures in production, breeding and so on). At any given time the model over-generalizes previous experience while making excessive extrapolations from current developments.

And- what is more- since 18th century every generation has believed that in its own present time it was experiencing "the eve of the new age"- and more just, "better" and democratic, of course[6]. We simply have a natural tendency to exaggerate an importance of changes of our own era. [7] Many expectations laid in the "Third wave" simply failed.[8]

It would be more correct to say that since the seventeenth- eighteenth centuries we[9] have lived in a modern society which is characterized by a non-stop stream of technological innovations (and economic growth[10]) and that industrial and information society are both just stages in the development of modern society. Technological progress[11] and innovations is integral and constant part of such modern society and its economy.

However the first "modern" or "western" countries were Netherlands[12] and England (in 17th and 18th centuries) and the area of modernity had to spread step by step: Western Europe and

[6] For example, Tofflers illusions on decline of power of elites in the Third wave society. See: Toffler, Alvin, *The Third Wave*, New York, Bantam Books, 1980, pp. 67-68

[7] ARON, R.: *Opium intelektuálů*, Praha, Mladá fronta, 2001, p. 208

[8] See for example: TOFFLER, A.: *The Third Wave*, New York, Bantam Books, 1980, pp. 100-361

[9] At least Europeans, because this modernization started in Europe – from reason which are out of scope of this article. See: LANDES, D. S.: *Bohatství a bída národů (The Wealth and Poverty of Nations)*, Praha, BB/art s.r.o., 2004, p. 493, Jourdin, Michel Mollat du, *Evropa a moře (L´ Europe et la mer)*, Bratislava, Archa, 1994, pp. 128-164, 274-285 and KENNEDY, P.: *Vzestup a pád velmocí (The Rise and Fall of the Great Powers)*, Praha, Nakladatelství Lidové noviny, 1996, pp. 21-52

[10] FREEMAN, C. L.: *As Time Goes By*, Oxford, Oxford University Press, 2001, pp.26-27

[11] For definition of technological progress see: Dosi, Giovanni, Orsenigo, Luigi, „Coordination and transformation: an overview of structures, behaviours and change in evolutionary environmnets", in Dosi, Giovanni, Freeman, Christopher, NELSON, R.: Silverberg, Gerald, Soete, Luc (editors), *Technical Change and Economic Theory*, London, Pinter Publishers, 1988, pp. 15-16

[12] KENNEDY, P.: *Vzestup a pád velmocí (The Rise and Fall of the Great Powers)*, Praha, Nakladatelství Lidové noviny, 1996, p. 94

Northern America in 1800-1850, Scandinavia and Germany[13] in 1850-1900, Japan[14], Latin America[15], South, Central and Eastern Europe in 1900-2000 (This process was in Central and Eastern Europe delayed by the communist experiment.)[16] and several former Third world countries in 1980- 2005 (Hong- cong, Taiwan, Singapore, South Korea, Turkey, parts of China, and India).[17] All following description of economic and technical developments concerns parts of the world which were "in" the modern society in a given time.

A new technology or innovation (in the broadest meaning)[18] makes possible to exploit much more natural resources in more effective way. It is fully equivalent to "…a gigantic expansion of resource supplies".[19]

A rapid and long-term economic growth is therefore usually a result of new technological innovations in industry and economy.[20] It is almost generally accepted, that technology (in proper social conditions) is the critical factor in the long term economic development of modern industrial societies.[21] And in the economy without additional sources from "outside" (what our planet today is- all parts of the planet are discovered and distributed) a progress of technologies (in the broadest meaning) has stayed as the only significant engine of long-term economic growth.[22] All manipulations with low taxation, inflation, low interest rates etc. (instruments of the "business cycle") can really speed up an economic growth – but without innovations in technology they can not help to shift the maximal potential limit of production on conditions of the given natural sources and existing technologies[23] -this limit will be reached only more quickly. (Of course, presented financial "tricks" almost always stimulate even a demand for new technologies and their development- especially of the economy is approaching to the described maximal potential limit of production.)

In this context a more accurate model would be the so-called Kondratieffs long cycles[24]. These cycles in the modern post-agrarian economy were reinforced in the work of the Russian econo-

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13 LANDES, D. S.: *Bohatství a bída národů (The Wealth and Poverty of Nations)*, Praha, BB/art s.r.o., 2004, pp. 292-305

14 Tamže, 2004, pp. 371

15 Tamže, pp.322

16 BEREND, I. T.: *An Economic History of Twentieth-Century Europe*, Cambridge, Cambridge University Press, 2006, pp. 172-189

17 KENNEDY, P.: *Svět v 21. století (Preparing for the Twenty-First Century)*, Praha, Nakladatelství Lidové noviny, 1996, 35

18 As a new technical device, organizational method, financial instrument etc. which enable higher efficiency and better exploiting of sources. See: Freeman, Christopher, Perez, Carlota, „Structural crisis of adjustment, business cycles and invetment behaviour." in Dosi, Giovanni, Freeman, Christopher, Nelson, Richard, Silverberg, Gerald, Soete, Luc (editors), *Technical Change and Economic Theory*, London, Pinter Publishers, 1988, pp. 45-49

19 ROSENBERG, N.: „The Impact of Technological Innovation: A Historical View" in Landau, Ralph, Rosenberg, Nathan (editors), *The Positive Sum Strategy*, Washington, National Academy Press, 1986, p. 22

20 FREEMAN, C.: *Die Computerrevolution in den langen Zyklen der ökonomischen Entwicklung*, München, Carl Friedrich von Siemens Stiftung, 1985, pp.18-20 and Kondratieff, Nikolai, *The Long Wave Cycle*, New York, Richardson&Snyder, 1984, p. 66

21 LANDAU, R., ROSENBERG, N. (editors): *The Positive Sum Strategy*, Washington, National Academy Press, 1986, p.vi and 7-10

22 BOSKIN, J. M.: „Macroeconomics, Technology, and Economic Growth: An Intraduction to Some Important Issues" in Landau, Ralph, Rosenberg, Nathan (editors), *The Positive Sum Strategy*, Washington, National Academy Press, 1986, p. 36

23 REEDER, C. B.: „The Effect of Recent Macroeconomic Policies on Innovation and Productivity" in Landau, Ralph, ROSENBERG, N. (editors): *The Positive Sum Strategy*, Washington, National Academy Press, 1986, pp. 89-91

24 KONDRATIEFF, N.: *The Long Wave Cycle*, New York, Richardson&Snyder, 1984, pp. 25-29

mist Nikolai Dmitriyevich Kondratieff (or Kondratyev, 1892–1938)[25] and the Austrian economist Joseph Alois Schumpeter (1883–1950)[26].

The first of the cycles defined by Kondratieff and later by Schumpeter and their other followers[27] was the age of coal and steam (1780–1840), which was facilitated by the first wave of the industrial revolution, followed by the age of railways and mass production (1840–1890), the second industrial revolution and the age of electricity (1890–1940) the start of which was the so-called technical revolution. Later theorists added a fourth wave – the age of electronics and microelectronics (1940–80) beginning with the so-called scientific-technological revolution. The current age, which began around 1980, should be the age of information and telecommunications trigged by the information and telecommunications revolution[28].

But Kondratieffs and Schumpeters cycles must be modified in order to correspond to modern experience.

2. Stages in the development of humanity

For the reasons given above, it clearly is useful to divide the development of humanity into four stages:

- hunter-gatherer (foraging) society,
- a society in transition to a production economy and a settled lifestyle,
- agrarian (traditional) society
- modern society

Our current modern society can be characterized by the following phenomena[29]:

- development of the natural sciences,
- application of scientific knowledge in technology[30],
- formation of modern states,
- capitalism,
- industrialism,
- secularism (freedom from religious concepts in politics, economics and science),
- expansion of education,
- economic development and growth[31],

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[25] See: KONDRATIEFF, N.: *The Long Wave Cycle*, New York, Richardson&Snyder, 1984, Freeman, Chris, Louçâ, *As Time Goes By*, Oxford, Oxford University Press, 2001, p.67 and Freeman, Christopher, *Die Computerrevolution in den langen Zyklen der ökonomischen Entwicklung*, München, Carl Friedrich von Siemens Stiftung, 1985, pp.13-15 and 62

[26] FREEMAN, C., L.: *As Time Goes By*, Oxford, Oxford University Press, 2001, pp.42-55 and Freeman, Christopher, *Die Computerrevolution in den langen Zyklen der ökonomischen Entwicklung*, München, Carl Friedrich von Siemens Stiftung, 1985, pp. 16-27

[27] DUIJN, J. J. van: *The Long Wave in Economic Life*, London, George Allen&Unwin, 1983, p. 163

[28] Freeman, Christopher, *Die Computerrevolution in den langen Zyklen der ökonomischen Entwicklung*, München, Carl Friedrich von Siemens Stiftung, 1985, p.17

[29] See: GIDDENS, A.: *Důsledky modernity (The Consequences of Modernity),* Praha, Slon, 1998, pp. 17-67, KENNEDY, P., *Svět v 21. století (Preparing for the Twenty-First Century)*, Praha, Nakladatelství Lidové noviny, 1996, p. 23 and LANDES, D. S. *Bohatství a bída národů (The Wealth and Poverty of Nations)*, Praha, BB/art s.r.o., 2004, pp. 208-226

[30] CAMERON, R.: *A Concise Economic History of the World,* New York, Oxford University Press, 1989, p. 195

[31] LANDAU, R., ROSENBERG, N. (editors): *The Positive Sum Strategy*, Washington, National Academy Press, 1986, p. 1

– growth of democracy,
– affluent society,
– liberalism,
– globalization (overseas discoveries, colonialism, development of trade and communications).

This society has its origins in the seventeenth century Netherlands. In all previous societies also some progress existed[32]- but from the point of view of time span of a human life it was almost invisible.

As regards the use of technology in economic life, in this modern society the **interests of the individual** become increasingly important and interest in their **material being** and the well-being of society is entirely legitimate and no longer considered to be a sin or pride. Further, there is a belief that material well-being can be achieved **through participation in the production of material assets and trade** in them (not only in plunder and primitive accumulation).

Likewise, the potential for production can be developed **through investment** (rather than by seizing the property of others) and one of the possible forms of investment is in **technological innovation[33]** (in the broadest sense of the term). These technological innovations are **the product of scientific development and the application of scientific thought in practice**.[34]

Or more simply: a difference between the society of the Tofflers "first wave" and the "second wave" is much more radical than between society of the "second" and "third wave". The "second" and the "third" waves are only the parts of one more global process.

3. Waves of technological innovations

As the first step the difference between inventions and innovations should be explained: The notion of invention describes the technological and scientific aspects of any novelty and the notion "the innovation" its economic (and social) aspects.[35] The novelties (new discoveries or new patents) are not socially and economically relevant in the moment of their invention, but from the moment when they are in a form applicable in industry and social life and the society is prepared to utilize them (in this moment they become innovations).[36]

The frequency and radicality of technological innovations are not distibuted uniformly in the course of time[37]. Revolutionary innovations in such modern society tend to come in **waves** rather than continuously.[38] Each of these waves has its **innovation phase** (inventions occure in a form

[32] See: DIAMOND, J.: Osudy lidských společností (Guns, Germs, and Steel/The fates of Human Societies), Praha, Columbus, 2000 and Toffler, Alvin, Šok z budoucnosti (Future Shock), Praha, Práce, 1992, p. 13

[33] TOFFLER, A.: *Šok z budoucnosti (Future Shock)*, Praha, Práce, 1992, p. 19

[34] BAKER, W. O.: „Te Physical Sciences As the Basis for Modern Technology" in Landau, Ralph, Rosenberg, Nathan (editors), *The Positive Sum Strategy*, Washington, National Academy Press, 1986, pp. 227-231

[35] (only) „Application is economics", MENSCH, G.: *Stalemate in Technology*, Cambridge, Balling Publishing Company, 1979, p. 116 and 123

[36] DUIJN, J. J. van: *The Long Wave in Economic Life*, London, George Allen&Unwin, 1983, 94

[37] KLINE, S. J. and ROSENBERG, N.: „On Overview of Innovation" in Landau, Ralph, Rosenberg, Nathan (editors), *The Positive Sum Strategy*, Washington, National Academy Press, 1986, pp. 275-305

[38] DUIJN, J. J. van: *The Long Wave in Economic Life*, London, George Allen&Unwin, 1983, pp. 23-25 and Landes, David S. Bohatství a bída národů (The Wealth and Poverty of Nations), Praha, BB/art s.r.o., 2004, p. 200

applicable in practical life and their first real application[39]- which we call a technological revolution) followed by an **application phase** in which the number of revolutionary innovations falls and attention focuses on exploiting and extending existing innovations.

This is comparable even with Simon Kuznets´ or Gabriel Tardes "S-curve" of technological development:[40] small and slow successes during the first ("shadow") phase, the second phase of the quick progress and then the third phase of slowing down because the limits were reached.[41] The first Kuznets´ phase runs in a shadow without any direct impacts on the society and economy (for example, the first steam engine of Thomas Newcomen was constructed already in 1705 but the real applicable engines emerged only 70 years later)- we are authorized to speak more on inventions than on innovations[42]. The rapid second phase corresponds to the technological revolution and the slow third phase to the application phase.

The cause of this boosting and slowing-down of technological development is the fact that the majority of inventions or reforms are the result of the need to improve something, solve a problem, earn more than a competitor, to increase the efficiency of work and so on. However, it is necessary (during innovation phase) to do more innovations in the almost same time, because they depend on each other (f.g.: a spinning machine and a weaving machine or a personal computer and an internet). We can speak on a "chain of innovations".

As soon as an innovation (or a "chain of innovations") becomes available, however, it becomes more efficient to invest in its adoption, extension and use than in creating new innovations. This continues until the one-time innovation becomes a fact of everyday life[43]. (Howevever even in a period of a relative stagnation of technologic progress the economic progres and profites from the new technologies can continue.). The key role in a process of a transfer of a progress in technologies into economy is probably played by the big investments[44] (f.g.: construction of roads, channels, railways[45], highwayes, airports, internet nets etc.)

Every wave of innovations lasts approximately until the rate of return on the new innovation or sector falls to the level of other, older, more traditional sectors. We may describe it also as a situation when the originally new technology, which increased a capacity to utilize new sources from nature, reached its limits and we need to invent a new technology.[46]

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[39] TOFFLER, A.: *Šok z budoucnosti (Future Shock)*, Praha, Práce, 1992, p. 20

[40] DUIJN, J. J. van: *The Long Wave in Economic Life*, London, George Allen&Unwin, 1983, p. 21 and Landes, David S. *Bohatství a bída národů (The Wealth and Poverty of Nations)*, Praha, BB/art s.r.o., 2004, p. 194

[41] See also: FREEMAN, C. L.: *As Time Goes By*, Oxford, Oxford University Press, 2001, p. 146

[42] MENSCH, G.: *Stalemate in Technology*, Cambridge, Balling Publishing Company, 1979, pp. 143-150

[43] For example: the diffusion of Televisions in West Germany in 1955-1990., see: MENSCH, G.: *Stalemate in Technology*, Cambridge, Balling Publishing Company, 1979, p. 55

[44] KONDRATIEFF, N.: *The Long Wave Cycle*, New York, Richardson&Snyder, 1984, p. 92 and DUIJN, J.J. van, *The Long Wave in Economic Life*, London, George Allen&Unwin, 1983, p. 118

[45] FREEMAN, C. L.: *As Time Goes By*, Oxford, Oxford University Press, 2001, p. 36

[46] CAMERON, R.: *A Concise Economic History of the World,* New York, Oxford University Press, 1989, p. 18, KENNEDY, P., *Svět v 21. století (Preparing for the Twenty-First Century)*, Praha, Nakladatelství Lidové noviny, 1996, p. 113 and MENSCH, G.: *Stalemate in Technology*, Cambridge, Balling Publishing Company, 1979, p. 7

This creates new pressure for further innovations[47] because a more efficient utilization of a given sources (inputs) can be reached only by further new technologies….[48]

There is also a natural limit on technical development set by the laws of nature. The development of technology during a technological revolution cannot be extrapolated into the future without limit. (e.g. to imagine that planes can continue to get faster and faster without any limit). An attention is therefore after some time re-oriented to areas where a more significant progress can be reached. And a progress in this new areas (new materials etc.) may enable after 40-60 years to reach a new progress in an old stagnating area.). Of course, also during an application phase or a crisis the process of innovation is not stopped- it is only slower.

Each wave (each age) of technological innovations can be characterized by the area in which the most revolutionary changes took place ("leading sectors"). Obviously, this does not mean that development in other areas stagnates (for example the industrial revolution had its own "informational" revolution (mass newspapers and school systems) and progressive changes in agriculture and banking did not stop). But a long-term economic success of any nation in any period depends the most on the success in the leading sectors of a given era[49].

The waves of innovation – technological revolutions follow each other in logical sequence. One technological revolution creates the conditions for the next one.[50] It also appears that the periods between begins of technological revolutions (lengths of waves of technological innovation) are getting shorter as a result of acceleration of technological progress and economical growth[51].

For the end of any wave and its application phase is typical an economic crisis and stagnation („a stalemate in technology")[52]- and a demand for new inventions and innovations. This assumption known as a "depression- trigger effect"[53] is practically impossible to prove by statistical methods because of a strong relativism in the evaluation of inventions and innovations. But this type of crisis – the crisis of the end of application phase should be probably (from psychological reasons) good for new inventions (and non- conventional inventors)[54] – and on the other hand probably not automatically alike good for investments and new inventions therefore sometime needs time to become innovations (and in this way they may start a new technological revolutions).

From business point of view for the beginning of every wave of technological innovation there are typical relative small firms with various innovative approaches. As "times goes by" the process of concentration forms only a few semi-monopolistic companies (which must be to some extend regulated by the State) and the original large diversity of technological methods is reduced in the favour of several most efficient.[55]

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47 FREEMAN, C.: *Die Computerrevolution in den langen Zyklen der ökonomischen Entwicklung*, München, Carl Friedrich von Siemens Stiftung, 1985, pp. 22-25

48 BOSKIN, J. M.: „Macroeconomics, Technology, and Economic Growth: An Intraduction to Some Important Issues" in Landau, Ralph, Rosenberg, Nathan (editors), *The Positive Sum Strategy*, Washington, National Academy Press, 1986, p. 36

49 DUIJN, J. J. van: *The Long Wave in Economic Life*, London, George Allen&Unwin, 1983, p. 26

50 FREEMAN, C. L.: *As Time Goes By*, Oxford, Oxford University Press, 2001, p. 221

51 See: TOFFLER, A.: *Šok z budoucnosti (Future Shock)*, Praha, Práce, 1992, pp. 17-25

52 See: MENSCH, G.: *Stalemate in Technology*, Cambridge, Balling Publishing Company, 1979, p. 8

53 See: DUIJN, J. J. van: *The Long Wave in Economic Life*, London, George Allen&Unwin, 1983, p. 181

54 MENSCH, G.: *Stalemate in Technology*, Cambridge, Balling Publishing Company, 1979, p. 9

55 FREEMAN, C. L.: *As Time Goes By*, Oxford, Oxford University Press, 2001, p. 330

During the modern age in society, **five of waves of technological innovations begun by technological revolutions** can be identified:

	Technological revolution	Period of technological revolution	Length of the whole wave of technological innovations	The leading sectors
1.	Financial-agricultural revolution	1600–1740	180 years	finance agriculture, trade
2.	Industrial revolution	1780–1840	100 years	textile, iron, coal, railways, channels
3.	Technical revolution	1880–1920	60 years	chemistry electrotechnical industry, machinery
4.	Scientific-technical revolution	1940–1970	45 years	air-industry, nuclear industry astronautics synthetic materials, oil industry cybernetics
5.	Information and telecommunications revolution	1985–2000	30 years?	telecommunications cybernetics informatics internet

(Obviously, the years given, are for guidance purposes only)

It is not easy to evaluate the importance a number of innovations by means of qualitative indicators.[56] The potential concept of so called "basic innovations"[57] is not very clear. But most theorists accept (maybe, more intuitively than scientifically) certain concentration of innovations in periods of generally accepted technological revolutions.[58] („the discontinuity hypothesis")[59]

The chronology of technological progress is not fully corresponding with economical cycles and development. But theoretically, in compliance with this model the end of technological revolution and the begin of the application phase should be accompanied by rapid economic progress and the end of the application phase by stagnation or crisis. During thebegin of the phase of technological revolution the economic growth is moderate. And the history confirms this supposition. The great crisis or periods of stagnation (cca1760-1780[60], 1870s-80[61], 1930s[62],

[56] See: DUIJN, J. J. van: *The Long Wave in Economic Life*, London, George Allen&Unwin, 1983, p. 173-4

[57] See: MENSCH, G.: *Stalemate in Technology*, Cambridge, Balling Publishing Company, 1979, p. 47

[58] MENSCH, G.: *Stalemate in Technology*, Cambridge, Balling Publishing Company, 1979, p. 130 and Duijn, J.J. van, *The Long Wave in Economic Life*, London, George Allen&Unwin, 1983, p. 109

[59] MENSCH, G.: *Stalemate in Technology*, Cambridge, Balling Publishing Company, 1979, p, 135

[60] KENNEDY, P.: *Vzestup a pád velmocí (The Rise and Fall of the Great Powers)*, Praha, Nakladatelství Lidové noviny, 1996, pp. 153-160 and Kennedy, Paul, *Svět v 21. století (Preparing for the Twenty-First Century)*, Praha, Nakladatelství Lidové noviny, 1996, p. 12

[61] KENNEDY, P.: *Vzestup a pád velmocí (The Rise and Fall of the Great Powers)*, Praha, Nakladatelství Lidové noviny, 1996, p.282 and Freeman, Chris, Louçâ, *As Time Goes By*, Oxford, Oxford University Press, 2001, p. 93

[62] BEREND, I. T.: *An Economic History of Twentieth-Century Europe*, Cambridge, Cambridge University Press, 2006, pp. 61-72

1973-82[63]) usually emerged to the end of the application phases and were overcome also by help of a new technological revolution.[64]

The ideal picture of order of waves and periods of quicker and slower growth is deformed by other relevant factors[65] (problems with row materials, wars, political crisis, social, cultural and mental conditions, legal restrictions etc.)[66] and by an uneven development in different countries.

The mutual relation of the waves of technological innovations with "long waves" of the economic cycles defined by Schumpeter and Kondratieff is strong but not absolute. In case of later waves (both technological and economical) their mutual cohesion is more visible than in a case of earlier ones- probably because of higher rebound between counties which enabled a quicker spread of technological innovation and economic tendencies in the international framework. Therefore we can for example with a higher confidence define whether the world capitalistic economy is in a conjuncture or crisis.[67] The other cycles (inventory, investment, building)[68] described in an economic literature are much shorter and do not depend directly on principal technological revolutions.[69]

Probably the most important modification of Kondratieffs idea is that original Kondratieffs long waves were approximately equally long (50-60 year)[70]- but these waves of technological innovations not- each new wave is shorter than previous one. It is a result of acceleration of the technological progress[71] and it is strange that most economists have insisted on cycles with equally long periods

I addition, Kondratieff and his followers did not yet recognize the importance of the agrarian, commercial and financial changes in 1600-1780.

Freeman modified Kondratieffs theory into a form of 5 waves[72]:

1.	Water-powered mechanisation of industry	1780 – 1848
2.	Steam powered mechanisation of industry	1848 – 1895
3.	Electrification of industry, transport and the home	1895 – 1940
4.	Motorisation of transport, economy and war	1941 – 1973
5.	Computerisation of economy	1973 –

63 BEREND, I. T.: *An Economic History of Twentieth-Century Europe*, Cambridge, Cambridge University Press, 2006, p. 280 and Freeman, Christopher, *Die Computerrevolution in den langen Zyklen der ökonomischen Entwicklung*, München, Carl Friedrich von Siemens Stiftung, 1985, p. 21

64 See: KENNEDY, P.: *Svět v 21. století (Preparing for the Twenty-First Century)*, Praha, Nakladatelství Lidové noviny, 1996, p. 17

65 FREEMAN, C.: *Die Computerrevolution in den langen Zyklen der ökonomischen Entwicklung*, München, Carl Friedrich von Siemens Stiftung, 1985, p.39 and Kondratieff, Nikolai, *The Long Wave Cycle*, New York, Richardson&Snyder, 1984, pp. 82-88

66 DUIJN, J. J. van: *The Long Wave in Economic Life*, London, George Allen&Unwin, 1983, pp. 77-80

67 See also: FREEMAN, C., L.: *As Time Goes By*, Oxford, Oxford University Press, 2001, p. 149

68 DUIJN, J. J. van: *The Long Wave in Economic Life*, London, George Allen&Unwin, 1983, p. 6

69 The study of the theory of economic cycles evokes a strange question: Why economic theorists believe that their cycles discovered by them must be periodical? (it means with the same lenght- 4, 7, 22 years etc.)

70 KONDRATIEFF, N.: *The Long Wave Cycle*, New York, Richardson&Snyder, 1984, p. 38 and 101

71 See: MENSCH, G.: *Stalemate in Technology*, Cambridge, Balling Publishing Company, 1979, p. 161

72 FREEMAN, C., L.: *As Time Goes By*, Oxford, Oxford University Press, 2001, p. 141

Also in this system there are similarities with the chronology of the theory of waves of technological innovations which is presented in this article. But Freeman was probably so fascinated by the potential of "computerized economy" that the first steps in 1960s-1970s (in a "shadow phase") he took for its start – but a real boom started little bit later. And his division of the period of industrial revolution in a two parts (1. and 2. waves) is a result of a misunderstanding of the character of the crisis, stagnation and economic problems having occurred about 1800-1815[73]. However, this stagnation was a result of non- technological and non- economical factors: Napoleonic wars and by the fact that in that time the modern capitalistic economy was limited only to a few countries and still was quite vulnerable (it means that accidental and very local factors could change a whole picture dramatically) . The same mistake was done by more authors including Kondratieff himself.

4. Financial-agricultural revolution

The industrial revolution and the subsequent revolutions are relatively well known. The industrial revolution gave birth to mass production, the steam engine, railways, the telegraph and son on. The technical revolution (known also as a "second industrial revolution"[74]) created the radio, the automobile, the aeroplane, electrical devices and modern chemical industry.[75] The scientific-technical revolution lead to nuclear power, electronics, space flight and so on. The information and telecommunications revolution gave us the internet, mobile phones, satellite broadcasting…

As a forerunner of the industrial revolution, the agricultural revolution is somewhat in its shadow but awareness of its importance is gradually increasing[76]. It began in Flanders and Holland at the end of the seventeenth century but later Britain became the centre of activity. From our modern point of view the growth of the agricultural production was not very fascinating, but it came after hundreds year of stagnation.[77] During this period the enclosure process culminated, the institution of the private ownership of land became established (which increased interest in investment in the cultivation of land), the first agricultural machines were invented (sowing machine 1701, commercially successful iron plough 1730)[78], the four field or so-called rotation system was introduced, the importance of fertilization increased, the first scientific and systematic breeding systems were developed and new foodstuffs were introduced from America (notably potatoes). Between 1600-1750 in England and Netherlands output per worker in agriculture raised for 50-90%.[79] And

[73] DUIJN, J. J. van: *The Long Wave in Economic Life*, London, George Allen&Unwin, 1983, pp. 74-77

[74] LANDES, D. S.: *Bohatství a bída národů (The Wealth and Poverty of Nations)*, Praha, BB/art s.r.o., 2004, p. 431

[75] CAMERON, R.: *A Concise Economic History of the World,* New York, Oxford University Press, 1989, p. 199 and LANDES, D. S.: *Bohatství a bída národů (The Wealth and Poverty of Nations)*, Praha, BB/art s.r.o., 2004, pp. 282

[76] CAMERON, R.: *A Concise Economic History of the World,* New York, Oxford University Press, 1989, pp. 106-112

[77] MOKYR, J.: *The Oxford Encyklopedia of Economic History*, Oxford University Press, 2003, p.95

[78] See: Overton, Mark: *Agricultural Revolution in England 1500 – 1850* (http://www.bbc.co.uk/history/british/empire_seapower/agricultural_revolution_01.shtml) and British Agricultural Revolution (http://en.wikipedia.org/wiki/British_Agricultural_Revolution)

[79] MOKYR, J.: *The Oxford Encyklopedia of Economic History*, Oxford University Press, 2003, p. 43. It does not seem to be too much, but the social and economic impact was far-reaching: Such growth of the efficiency in agriculture in conditions of traditional pre – modern society reduced the necessity to keep work power in the agricultural sector from, let us suppose, 90% of the whole population to 60%. And the amounts of people active in the other sectors (industry, services, administrative, army, educational system) could increase four times…

increased food production created conditions in which workers were freed from the land to work in cities or to leave to overseas.

The agricultural revolution was also closely linked to changes in trade and financing.[80] This process has been described as the "Financial revolution"[81]. The modern method of managing capital and finances emerged in Holland in the seventeenth century. It involved the separation of business from household management. Dependence on metal money began to decline (widespread acceptance of promissory notes, the first efforts to introduce paper money). Banking together with its basic instruments and procedures (they are also a technology in its basic meaning[82]- technologies of manipulation with money and capital) began to develop and the charging of interest on loans and credit was recognized to be legitimate. Credit began to be seen as a source of capital (rather than loans for consumption). The first joint stock companies were established (e.g. the Dutch East India company, 1602)[83] as a means of concentrating capital and stock exchanges and capital markets emerged (Amsterdam 1602). Another important factor was the development of rational international trade and colonization and the development of sea trade in European waters.[84]

The result was the establishment of the financial foundations for the further development of the economy and technology.

It is therefore appropriate to speak of a **financial-agricultural revolution**.

The industrial revolution[85], technical revolution (or the second industrial revolution) and scientific- technical revolution[86] were sufficiently described in the existing literature (although mostly as isolated events without a "roof" conception of greater cycles or waves.)

5. The importance of the term information society and information revolution

The 5th wave of the technological innovations started in 1980s´ when the cheap computers emerged on the market[87] and TV-satellites and internet began to be a matter of course ("communication revolution")[88]. This process was accompanied by a quick growth of global financial

[80] CAMERON, R.: *A Concise Economic History of the World,* New York, Oxford University Press, 1989, pp. 122- 127 and LANDES, D. S.: *Bohatství a bída národů (The Wealth and Poverty of Nations)*, Praha, BB/art s.r.o., 2004, p. 148-150

[81] Kennedy, Paul, *Vzestup a pád velmocí (The Rise and Fall of the Great Powers)*, Praha, Nakladatelství Lidové noviny, 1996, pp. 105-117

[82] KLINE, S. J. and ROSENBERG, N.: „On Overview of Innovation" in Landau, Ralph, Rosenberg, Nathan (editors), *The Positive Sum Strategy*, Washington, National Academy Press, 1986, pp. 279

[83] *Dutch East India Company*, (http://en.wikipedia.org/wiki/Dutch_East_India_Company)

[84] FLYNN, D. O., GIRÁLDEZ: „Globalization began in 1571" in Gills, Barry K., Thompson, William R. *Globalisation and Global History*, London and New York, Routledge, 2006, pp. 232-247.

[85] CAMERON, R.: *A Concise Economic History of the World,* New York, Oxford University Press, 1989, pp. 163-188 and Toffler, Alvin, *The Third Wave*, New York, Bantam Books, 1980, pp. 25-46

[86] CAMERON, R.: *A Concise Economic History of the World,* New York, Oxford University Press, 1989, pp. 331-333 and TOFFLER, A., *The Third Wave*, New York, Bantam Books, 1980, p. 9

[87] MOKYR, J.: *The Oxford Encyklopedia of Economic History*, Oxford University Press, 2003, p. 499

[88] KENNEDY, P.: *Svět v 21. století (Preparing for the Twenty-First Century)*, Praha, Nakladatelství Lidové noviny, 1996, p. 58

markets[89] and is seen as a unique "globalization"[90]. This technological revolution helped to overcame the economic crisis of 1970s and this effect of it was already predicted.[91] This new technological revolution with its dramatic changes in the society[92] was sometime even seen as the eve of a new – information- society or information economy[93] and changes, which it brought, really stimulated the economic growth and enriched our lives.

But there is no reason to dramatize those changes and the more proper notion for them would be the "**Informational and telecommunications technological revolution**"- it means only one of more technological revolutions during the modern age. It real position was more adequately described from the perspective of one of the Kondratieffs waves (fifth).[94]

But the vision of an information society (which emerged in 190s and 1970s – before the informational and communications technological revolution really started) was an excellent stimulant that played a mobilizing role for business and political structures in the 1980s and 1990s during the rise of the mass use of computers[95], the internet, mobile telephones and the like. It made possible a clear definition of the ongoing changes and made it possible to obtain political support for them.[96]

It is time to note that the innovation phase of the wave of the information technology and telecommunications has already finished and even its application phase has slowly come to an end. Our existing situation characterized by economic stagnation, financial crisis, high prices for oil and agricultural products[97] we can describe also as a crisis which is typical for end of every technological wave. Information technology is already a fully integrated part of everyday life (which is not to say that for example Central and South – East Europe does not still have some catching up to do in this area) and it is necessary to get ready for the appearance of the next wave of new technologies, which is already appearing on the horizon. This does not mean, of course, that development in the area of information technologies and telecommunications is going to come to an end or that computers be replaced by something else – rather, that the largest profits and the most revolutionary, life-changing ideas will emerge in other sectors. These will, however, often be things that would be unthinkable without computer technology.

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89 BEREND, I. T.: *An Economic History of Twentieth-Century Europe*, Cambridge, Cambridge University Press, 2006, pp. 267-269

90 KENNEDY, P.: *Svět v 21. století (Preparing for the Twenty-First Century)*, Praha, Nakladatelství Lidové noviny, 1996, 64

91 MENSCH, G.: *Stalemate in Technology*, Cambridge, Balling Publishing Company, 1979, pp.13- 37

92 BEREND, I. T.: *An Economic History of Twentieth-Century Europe*, Cambridge, Cambridge University Press, 2006, pp. 270-275

93 ROACH, S.: „Macrorealities of the Information Economy" in Landau, Ralph, Rosenberg, Nathan (editors), *The Positive Sum Strategy*, Washington, National Academy Press, 1986, p. 93

94 FREEMAN, C. L.: *As Time Goes By*, Oxford, Oxford University Press, 2001, pp. 307+-330

95 TOFFLER, A.: *The Third Wave*, New York, Bantam Books, 1980, p. 140

96 For example see: Toffler, Alvin, *Šok z budoucnosti (Future Shock)*, Praha, Práce, 1992

97 See: BONCIU, F.: „2008-Some Global Issues and Their Impact on the Prospects of Further Euroepan Union Integration", *Romanian Journal of European Affaires*, Vol.8, No.3. September 2008, Buchurest, European Institute of Romania, pp. 43-50.

6. The post-information technological revolution

The term post-information society, or even better, the post-information technological revolution, can provide a fairly simple and attractive reminder of this coming wave of innovation and modernization. A more fitting name will probably still be found.

It would be useful to try to predict (although it is an extraordinarily risky task[98]) which areas of science and technology will experience the most dynamic growth in this expected wave of innovation and give the best return on investments:

The greatest progress will probably be made in the pharmaceutical, biotechnical[99] and **biomedical sciences** (Because of a process of a population ageing there is a big demand for innovations in this area.): genetic engineering, cloning and also new pharmaceuticals and the possibility for direct connections between machines and living organisms, which will make it possible to modify and improve the properties of living beings, including people (so-called cyborgs – the preferred term for research in this area is transhumanism).

The development of **nanotechnology** (the manipulation of objects at a molecular level) and biotechnology (the use of living organisms in the production process) is radically changing our understanding of production in industry and treatment in the medical sphere.

There will be a greater emphasis on various alternatives to current production processes that will be less ecologically harmful.

Traditional fuels (diesel, gasoline) will be supplemented and lately replaced by alternative fuels (hydrogen and fuels made from agricultural produce and vegetable waste). This will not, of course, be any "cheap" fuel. For example, the changeover to **hydrogen** and oxygen as the basic fuel for transport will mean increased consumption of electricity in their production from water. The hydrogen engine is already invented – but it needs proper social, economic and political circumstances to convert from the invention (an "unexploited technology"[100]) to an innovation.

The easiest way to produce this electricity will probably be to develop **nuclear power**. So-called alternative sources of energy: water, wind, and solar power simply do not have the capacity to cover our electricity requirements. These will be even greater when the use of hydrogen engines takes off.

Future of development of **industrial robotics** (outside of Japan an East Asia) is unclear- also because of social and legal barriers.[101]

But probably the main reason why industrial robots are (and will be) less wide-spread (the exception is Japan) than it was expected in 1970s and 1980s is- the globalization! It is now still cheaper to remove less-effective and dirty production processes from the USA and Europe to Asia, Latin America and former socialist countries or to employ cheaper workers from poor countries (immigrants) than to develop and to introduce new automated technologies! But every

[98] See: ROSENBERG, N.: „The Impact of Technological Innovation: A Historical View" in Landau, Ralph, Rosenberg, Nathan (editors), *The Positive Sum Strategy*, Washington, National Academy Press, 1986, pp. 17-31

[99] KENNEDY, P.: *Svět v 21. století (Preparing for the Twenty-First Century)*, Praha, Nakladatelství Lidové noviny, 1996, p. 79

[100] See: MENSCH, G.: *Stalemate in Technology*, Cambridge, Balling Publishing Company, 1979, p. 154

[101] KENNEDY, P.: *Svět v 21. století (Preparing for the Twenty-First Century)*, Praha, Nakladatelství Lidové noviny, 1996, p. 95

technological revolution in past changed the position of countries in the world economy[102] and a leeway in introducing of robotics in mass industry could be a reason for potential economical "peripherisation" of the West.

It would perhaps be fair to call this hypothetical technological revolution of the future the biological-hydrogen revolution or even better the **biomedical-hydrogen revolution**.

It can be expected to come into effect in the years 2015–2020 and this predicted 6th wave of technological innovations together with its application phase might last till cca 2035.

7. Effects of the new wave of technological innovation

The social, political and economic effects will be large – like the leap after every technological revolution. It could lead to a fall in the importance of oil as a factor in global economics and politics. At least in the developed Western states, China and India (as developing nations) may keep their consumption at a high level. There are particularly strong fears with regard to procedures and methods that could certain changes in human nature (transhumanism): to extend human life, improve characteristics or create new forms of communication (e.g. electronic "brain to brain" connections) etc.

This could open an range of possibilities for social and economic exploitation that are hard for us to fully imagine at present.

It is clear that human society will look little bit different tomorrow than it does today. This why voices are raised calling for the regulation or even the prevention of development in certain areas. Experience in the past shows, however, that it is not possible to stop technological and scientific progress. If any countries try to do so, the only result will be that they are left behind. No ban can permanently suspend the spread and use of new knowledge if its use benefits the society or community where it is implemented. An society that rejects an innovation on, for example, moral or ideological grounds usually ends up paying for it. (Remember, for example, how the socialist countries rejected cybernetics in the 1940es). On the other hand, innovations that are not of long-term benefit to society and do not create any particular effect will not have a long-term impact because the society that they begin to impede will become handicapped. So there is no need to prohibit certain directions in advance and matters should be left to natural selection.

It is better to accommodate a level of social change, and maybe even apparent crises, and come to terms with them through social transformation than to put brakes on scientific and technological progress in the name of preserving the status quo or old ideological dogmas.

Since the potential rapid progress should emerge in areas which are morally and politically sensitive there is a danger that a start of the post-informational technological revolution could be temporary slowed down by artificial legal and political steps.

There is also a very realistic fear that western countries will not be able to keep their industrial production- the main reason is their unwillingness (because of social tensions) to adopt modern methods of industrial production based on robotics.[103] The centre of industrial production and modern development therefore could be moved to Japan, Korea, China and India…

[102] TOFFLER, A.: *The Third Wave*, New York, Bantam Books, 1980, p. 23

[103] KENNEDY, P.: *Svět v 21. století (Preparing for the Twenty-First Century)*, Praha, Nakladatelství Lidové noviny, 1996, p. 100

On the other hand- from a post-informational technological revolutions we should not expect "too much" (solutions of all problems of the mankind or a creation of a really "new man" and a "new better society"). It will be only next technological revolution in a sequence of more technological revolution. And logically it will be sometime about 2030-40 followed by a next (7th) wave… Idealistic expectations connected with "informational revolution" or the "informational society" are still warning.[104]

8. A vision of the future

A good name for the new wave (sixth) of technological innovations a start of which can be expected approximately in the period 2015–2020 would be the biomedical-hydrogen revolution. But a progress could be so rapid that this technological revolution could last only 10-15 years and together with its application phase could be completed till 2035. And after 2035-40 hypothetically a following – in this case the seventh – wave of innovations can begin.

Today economic crisis we should see as the crisis of the end of the 5th wave of technological innovations which started about 1985 with the **Information and telecommunications revolution** (or as the crisis of the end of the one of Kondratieffs economic "long waves"). And as the foreshadow of a next coming wave….

Therefore governments can not help to overcame this crisis clearly by financial instruments but they have to support science, education, development of new technologies and their application- it means factors which can make an oncoming of the new technological ("post-informational") revolution more fast.

It is perhaps rather bold to talk about a post-information revolution when the revolution in information technology and telecommunications has still not reached its crest in many middle and low developed countries. Nevertheless, all high developed or middle developed countries must be prepared for the next wave of technological innovation.

And the lesson for their national government is clear: if it is their long-term ambition to rank amongst the most developed countries (or stay in this group) they should not concentrate too much on the advanced technology of the recent past (the automobile industry) or the present (information technology) but even on the technologies of the next future: nanotechnology, biomedical sciences, transhumanism, biotechnology, the pharmaceutical industry and alternative fuels (above all hydrogen) and maybe even robotics. They should utilize this opportunity well. Any technological revolutions can be seen even as a redistribution of cards and a chance to overcome a technological leeway is given even for outsiders[105]. The counties have a chance to improve their position in the world economy much more than in a phase of a stabile predictable development (an application phase)- or they are in a danger to lose it. In a process of every technological revolution (an innovation phase) advantages of existing favorites are being questioned.

The vision of a knowledge economy or a knowledge society is therefore no longer just a matter of information technology and telecommunications as it may have recently seemed. The fields of information technology and telecommunications obviously still have plenty of room to

[104] See, for example: TOFFLER, A.: *Šok z budoucnosti (Future Shock)*, Praha, Práce, 1992, pp.95-120

[105] See: MALPAS, R.: „Harnessing Technology for Growth" in Landau, Ralph, Rosenberg, Nathan (editors), *The Positive Sum Strategy*, Washington, National Academy Press, 1986, pp. 105-113

develop and grow. But they are no longer so rich in innovations as they were in the 1990es. For this reason attention must focus on other longer-term possibilities as well.

9. Conclusion

1) A real long-term growth of economy is without additional sources from "outside" (discovery of new counties or geological deposits) possible only under the condition of the permanent technological progress- new technologies increase the efficiency of utilization of given natural (and human) sources.
2) Technological progress is typical for a modern society which was first formed in 17th century in Netherlands and later in England.
3) However the speed of this progress is not constant. We can identify periods of the acceleration of new inventions and periods in which a dynamism is oriented from innovating and new inventions more to their practical application.
4) These periods of the history we can rank to the 5 waves of technological innovations each with its two phases: the phase of technological revolution (an innovative phase) and the following phase of application.
5) Due to acceleration of scientific and technological progress each new wave is shorter then a previous one.
6) Each technological revolution in past can be characterized by technologies in which the most striking and the most progress was reached (leading sectors). It does not mean that in other areas there must have been stagnation, but an economic, technological and power success of a nation can be defined by the terms of a success in leading sectors of a given wave of technological innovations.
7) The first of this technological revolution was the Financial-agricultural revolution, the importance of which is not still fully recognized.
8) The other technological revolutions are well known in economic and technical history (the Industrial revolution, the Technical revolution, Scientific- technical revolution and Information and telecomunication revolution)
9) Now (2008) we are in the 5th wave and in its application phase which followed after Information and telecommunications technological revolution (1985-2000).
10) The present economic crisis is a confirmation of the fact that Information and telecommunication revolution is over.
11) A new significant long-time economic boom can come only with a new (6th) technological revolution.
12) The 6th wave with its technological revolution could start about 2015 and could be rather quick (only 20-25 years?).
13) We can expect that the most rapid progress will be done in biomedical sciences, nuclear technologies, hydrogen engines and maybe in robotics.
14) The 7th wave (after 2035-40) and the following next waves (8th, 9th etc.) will be even shorter an probably in one moment (cca after 2080-90) the technological development will be so rapid that it will lose its character of waves distinguishable from shorter cycles (for example "business" cycle).
15) The best recommendation for governments how to overcome the existing crisis is to speed up a birth of the post-informational technological revolution (6th wave) by supporting an scientific and technical progress.