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Review Paper

Waves of technological innovations and the end of the information revolution

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The article is about new views on the theory of "long waves" and especially 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.

Keywords: Crisis, innovation, invention, Kondratieffs cycles, long waves, post-information technological revolution, technological progress, waves of technological innovation.

INTRODUCTION

The term "information revolution"(Freeman, Christopher, Die Computerrevolution in den langen Zyklen der ökonomischen Entwicklung, München, Carl Friedrich von Siemens Stiftung, 1985, p.31), which achieved wide-spread currency in the period 1960 – 1980, 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 9000 years ago, or the industrial revolution at the start of the nineteenth century (Toffler, Alvin, The Third Wave, New York, Bantam Books, 1980, pp.5-11).

However, it would be more correct to say that since the seventeenth- eighteenth centuries we (At least Europeans, because this modernization started in Europe – from reason which are out of scope of this article (Landes, David 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, Paul, Vzestup a pád velmocí; The Rise and Fall of the Great Powers*)*, Praha, Nakladatelství Lidové noviny, 1996, pp. 21-52) have lived in a modern society which is characterized by a non-stop stream of technological innovations (and economic growth (Freeman, Chris, Louçâ, As Time Goes By, Oxford, Oxford University Press, 2001, pp.26-27) and that industrial and information society are both just stages in the development of modern society. Technolo-gical progress (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, Richard, Silverberg, Gerald, Soete, Luc (editors), Technical Change and Economic Theory, London, Pinter Publishers, 1988, pp. 15-16) and innovations is integral and constant part of such modern society and its economy.

The first "modern" or "western" countries were Netherlands (Kennedy, Paul, Vzestup a pád velmocí (The Rise and Fall of the Great Powers*)*, Praha, Nakladatelství Lidové noviny, 1996, p.94) and England (in 17th and 18th centuries) and the area of modernity had to spread step by step: Western Europe and Northern America in 1800 -1850, Scandinavia and Germany (Landes, David S. Bohatství a bída národů (The Wealth and Poverty of Nations*)*, Praha, BB/art s.r.o., 2004, pp.292-305) in 1850 -1900, Japan(Landes, David S. Bohatství a bída národů (The Wealth and Poverty of Nations*),* Praha, BB/art s.r.o., 2004, pp.371), Latin America(Landes, David S. Bohatství a bída národů (The Wealth and Poverty of Nations), Praha, BB/art s.r.o., 2004, pp.322), South, Central and Eastern Europe in 1900 - 2000 (This process was in Central and Eastern Europe delayed by the com-

munist experiment) (Berend, Ivan T, An Economic History of Twentieth-Century Europe, Cambridge, Cambridge University Press, 2006, pp.172-189) and several former Third world countries in 1980 - 2005 (Hong-cong, Taiwan, Singapore, South Korea, Turkey, parts of China and India)(Kennedy, Paul, Svět v 21. století *(*Preparing for the Twenty-First Century*)*, Praha, Nakladatelství Lidové noviny, 1996, 35). 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) (As a new technical device, organizational method, financial instrument etc. which enable higher efficiency and better exploiting of sources (Freeman, Christo-pher, Perez, Carlota, „Structural crisis of adjustment, business cycles and invetment behaviour." in Dosi, Giovanni, Freeman, Christopher, Nelson, Richard, Silver-berg, Gerald, Soete, Luc (editors), Technical Change and Economic Theory, London, Pinter Publishers, 1988, pp.45-49) makes possible to exploit much more natural resources in more effective way. It is fully equivalent to "…a gigantic expansion of resource supplies" (Rosenberg, Nathan, „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). A rapid and long-term economic growth is therefore usually a result of new technological innovations in industry and economy (Freeman, Christopher, Die Computer revolution 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). 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 (Landau, Ralph, Rosenberg, Nathan (editors), The Positive Sum Strategy, Washington, National Academy Press, 1986, p.vi and 7-10). 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 (Boskin, J. Michael, "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). 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 cannot help to shift (enhance) the maximal potential limit of production on conditions of the given natural sources and existing technologies (Reeder, Charles B., „The Effect of Recent Macroeconomic Policies on Innovation and Productivity" in Landau, Ralph, Rosenberg, Nathan (editors), The Positive Sum Strategy, Washington, National Academy Press, 1986, pp.89-91), 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 if the economy is approaching the described maximal potential limit of production.

In this context, a more accurate model would be the so-called Kondratieffs long cycles (Kondratieff, Nikolai, The Long Wave Cycle, New York, Richardson and Snyder, 1984, pp. 25-29). These cycles in the modern post-agrarian economy were reinforced in the work of the Russian economist Nikolai Dmitriyevich Kondratieff (Kondratyev, 1892 – 1938) (Kondratieff, Nikolai, The Long Wave Cycle, New York, Richardson and 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) and the Austrian economist Joseph (1883 –1950) (Freeman, Chris, Louçâ, As Time Goes By, Oxford, Oxford University Press, 2001, pp.42-55 and Freeman, Christopher, *Die* Computer revolution in den langen Zyklen der ökonomischen Entwicklung, München, Carl Friedrich von Siemens Stiftung, 1985, pp.16-270.

The first of the cycles defined by Kondratieff and later by Schumpeter and their other followers (Duijn, J.J. van, The Long Wave in Economic Life, London, George Allen and Unwin, 1983, p.163) 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 (Freeman, Christopher, Die Computerrevolution in den langen Zyklen der ökonomischen Entwicklung, München, Carl Friedrich von Siemens Stiftung, 1985, p.17). But Kondratieffs and Schumpeters cycles must be modified in order to correspond to modern experience.

STAGES IN THE DEVELOPMENT OF HUMANITY

For the reasons given above, it is clearly useful to divide the development of humanity into four stages:
1. Hunter-gatherer (foraging) society.
2. A society in transition to a production economy and a settled lifestyle.
3. Agrarian (traditional) society.
4. Modern society.

Our current modern society can be characterized by the following phenomena (Giddens, Anthony, Důsledky

modernity (The Consequences of Modernity), Praha, Slon, 1998, pp. 17-67, Kennedy, Paul, Svět v 21. století (Preparing for the Twenty-First Century), Praha, Nakladatelství Lidové noviny, 1996, p.23 and Landes, David S. Bohatství a bída národů (The Wealth and Poverty of Nations), Praha, BB/art s.r.o., 2004, pp.208-226):

1. Development of the natural sciences.
2. Application of scientific knowledge in technology (Cameron, Rondo, A Concise Economic History of the World, New York, Oxford University Press, 1989, p.195).
3. Formation of modern states.
4. Capitalism.
5. Industrialism.
6. Secularism (freedom from religious concepts in politics, economics and science).
7. Expansion of education.
8. Economic development and growth (Landau, Ralph, Rosenberg, Nathan (editors), The Positive Sum Strategy, Washington, National Academy Press, 1986, p.1).
9. Growth of democracy.
10. Affluent society.
11. Liberalism.
12. 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 (Diamond, Jared, 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), 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 (Toffler, Alvin, Šok z budoucnosti (Future Shock), Praha, Práce, 1992, p.19) (in the broadest sense of the term). These technological innovations are the product of scientific development and the application of scientific thought in practice (Baker, William 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).

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 (only „Application is economics“, Mensch, Gerhard: Stalemate in Technology, Cambridge, Balling Publishing Company, 1979, p.116 and 123). 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) (Duijn, J.J. van, The Long Wave in Economic Life, London, George Allen and Unwin, 1983, 94).

The frequency and radicality of technological innovations are not distributed uniformly in the course of time (Kline, Stephen J. and Rosenberg, Nathan, „On Overview of Innovation“ in Landau, Ralph, Rosenberg, Nathan (editors), The Positive Sum Strategy, Washington, National Academy Press, 1986, pp.275-305). Revolutionary innovations in such modern society tend to come in waves rather than continuously (Duijn, J.J. van, The Long Wave in Economic Life, London, George Allen and 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). Each of these waves has its innovation phase (inventions occuring in a form applicable in practical life and their first real application (Toffler, Alvin, Šok z budoucnosti (Future Shock), Praha, Práce, 1992, p.20). 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 (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): 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 (Freeman, Chris, Louçâ, As Time Goes By, Oxford, Oxford University Press, 2001, p.146). 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 (Mensch, Gerhard: Stalemate in Technology, Cambridge, Balling Publishing Company, 1979, pp.143-150). 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 almost same time, because they depend on each other (e.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(For example: the diffusion of Televisions in West Germany in 1955-1990., (Mensch, Gerhard: Stalemate in Technology, Cambridge, Balling Publishing Company, 1979, p.55). However, even in a period of a relative stagnation of technologic progress, the economic progress and profits 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 (Kondratieff, Nikolai, The Long Wave Cycle, New York, Richardson and Snyder, 1984, p.92 and Duijn, J.J. van, The Long Wave in Economic Life, London, George Allen and Unwin, 1983, p.118) (construction of roads, channels, railways (Freeman, Chris, Louçâ, As Time Goes By, Oxford, Oxford University Press, 2001, p.36), highways, 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 and 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(Cameron, Rondo, A Concise Economic History of the World, New York, Oxford University Press, 1989, p.18, Kennedy, Paul, Svět v 21. století (Preparing for the Twenty-First Century), Praha, Nakladatelství Lidové noviny, 1996, p.113 and Mensch, Gerhard: Stalemate in Technology, Cambridge, Balling Publishing Company, 1979, p.7).

This creates new pressure for further innovations (Freeman, Christopher, Die Computer revolution in den langen Zyklen der ökonomischen Entwicklung, München, Carl Friedrich von Siemens Stiftung, 1985, pp.22-25) because a more efficient utilization of a given sources (inputs) can be reached only by further new technologies (Boskin, J.Michael, „Macroeconomics, Technology, and Economic Growth: An Introduction to Some Important Issues" in Landau, Ralph, Rosenberg, Nathan (editors), The Positive Sum Strategy, Washington, National Academy Press, 1986, p. 36). 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 again 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 (Duijn, J.J. van, The Long Wave in Economic Life, London, George Allen and Unwin, 1983, p.26).

The waves of innovation – technological revolutions follow each other in logical sequence. One technological revolution creates the conditions for the next one (Freeman, Chris, Louçâ, As Time Goes By, Oxford, Oxford University Press, 2001, p. 221). 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 (Toffler, Alvin, Šok z budoucnosti (Future Shock), Praha, Práce, 1992, pp.17-25).

For the end of any wave and its application phase is typical an economic crisis and stagnation "(a stalemate in technology)" (Mensch, Gerhard: Stalemate in Technology, Cambridge, Balling Publishing Company, 1979, p. 8), and a demand for new inventions and innovations. This assumption known as a "depression- trigger effect" (Duijn, J.J. van, The Long Wave in Economic Life, London, George Allen and Unwin, 1983, p.181) 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) (Mensch, Gerhard: Stalemate in Technology, Cambridge, Balling Publishing Company, 1979), and on the other hand probably not automatically good for investments and therefore new inventions 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(Freeman, Chris, Louçâ, As Time Goes By, Oxford, Oxford University Press,

Table 1. Waves of technological innovations.

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

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

2001, p.330).

During the modern age in society, five waves of technological innovations begun by technological revolutions and can be identified as shown in Table 1. It is not easy to evaluate the importance a number of innovations by means of qualitative indicators (Duijn, J.J. van, The Long Wave in Economic Life, London, George Allen and Unwin, 1983, p.173-4). The potential concept of so called “basic innovations” (Mensch, Gerhard: Stalemate in Technology, Cambridge, Balling Publishing Company, 1979, p.47) is not very clear. But most theorists accept (maybe, more intuitively than scientifically) certain concentration of innovations in periods of generally accepted technological revolutions (Mensch, Gerhard: Stalemate in Technology, Cambridge, Balling Publishing Company, 1979, p. 130 and Duijn, J.J. van, The Long Wave in Economic Life, London, George Allen and Unwin, 1983, p.109) “(the discontinuity hypothesis)” (Mensch, Gerhard: Stalemate in Technology, Cambridge, Balling Publishing Company, 1979, p, 135).

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 beginning of the application phase should be accompanied by rapid economic progress and the end of the application phase by stagnation or crisis. During the beginning 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 (Kennedy, Paul, 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), 1870s-80 (Kennedy, Paul, 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), 1930s (Berend, Ivan T, An Economic History of Twentieth-Century Europe, Cambridge, Cambridge University Press, 2006, pp.61-72), 1973-82 (Berend, Ivan T, An Economic History of Twentieth-Century Europe, Cambridge, Cambridge University Press, 2006, p.280 and Freeman, Christopher, Die Computer revolution in den langen Zyklen der ökonomischen Entwicklung, München, Carl Friedrich von Siemens Stiftung, 1985, p.21) usually emerged to the end of the application phases and were overcome also by help of a new technological revolution (Kennedy, Paul, Svět v 21. století (Preparing for the Twenty-First Century), Praha, Nakladatelství Lidové noviny, 1996, p.17). The ideal picture of order of waves and periods of quicker and slower growth is deformed by other relevant factors (Freeman, Christopher, Die Computer revolution 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) (problems with row materials, wars, political crisis, social, cultural and mental conditions, legal restrictions etc.) (Duijn, J.J. van, The Long Wave in Economic Life, London, George Allen and Unwin, 1983, pp. 77-80) 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 (Freeman, Chris, Louçâ, As Time Goes By, Oxford, Oxford University Press, 2001, p. 149). The other cycles (inventory, investment and building) (Duijn, J.J. van, The Long Wave in Economic Life, London, George Allen and Unwin, 1983, p.6) described in an economic literature

Table 2. Freeman's modification of Kondratieff cycles.

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 – ?

are much shorter and do not depend directly on principal technological revolutions(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 length- 4, 7, 22 years etc). Probably the most important modification of Kondratieffs idea in this article is that the original Kondratieffs long waves were approximately equally long (50 - 60 year (Kondratieff, Nikolai, The Long Wave Cycle, New York, Richardson and Snyder, 1984, p.38 and 101), 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 (Mensch, Gerhard: Stale-mate in Technology, Cambridge, Balling Publishing Company, 1979, p. 161) and it is strange that most economists have insisted on cycles with equal long periods. In 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 (Freeman, Chris, Louçâ, As Time Goes By, Oxford, Oxford Univer-sity Press, 2001, p.141) (Table 2). 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 a 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 (Duijn, J.J. van, The Long Wave in Economic Life, London, George Allen&Unwin, 1983, pp. 74-77). 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.

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 (Mokyr, Joel, The Oxford Encyclopedia of Economic History, Oxford University Press, 2003, p.499) and TV-satellites and internet began to be a matter of course "(communication revolution") (Kennedy, Paul, Svět v 21. století (Preparing for the Twenty-First Century), Praha, Nakladatelství Lidové noviny, 1996, p.58). This process was accompanied by a quick growth of global financial markets(Berend, Ivan T, An Economic History of Twentieth-Century Europe, Cambridge, Cambridge University Press, 2006, pp.267-269) and is seen as a unique "globalization" (Kennedy, Paul, Svět v 21 století (Preparing for the Twenty-First Century), Praha, Nakladatelství Lidové noviny, 1996, 64). This technological revolution helped to overcame the economic crisis of 1970s and this effect was already predicted(Mensch, Gerhard: Stalemate in Technology, Cambridge, Balling Publishing Company, 1979, pp.13-37). This new technological revolution with its dramatic changes in the society(Berend, Ivan T, An Economic History of Twentieth-Century Europe, Cambridge, Cambridge University Press, 2006, pp.270-275) was sometime even seen as the eve of a new–information-society or information economy(Roach, Stephen, „Macrorealities of the Information Economy" in Landau, Ralph, Rosenberg, Nathan (editors), The Positive Sum Strategy, Washington, National Academy Press, 1986, p.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 there was only one more technological revolution during the modern age. Its real position was more adequately described from the perspective of one of the Kondratieffs waves (fifth)(Freeman, Chris, Louçâ, As Time Goes By, Oxford, Oxford University Press, 2001, pp.307+-330). 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(Toffler, Alvin, The Third Wave, New York, Bantam Books, 1980, p.140), 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 (For example: Toffler, Alvin, Šok z budoucnosti (Future Shock), Praha, Práce, 1992).

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 (Bonciu, Florin: „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), 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.

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 (Rosenberg, Nathan, „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) which area 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(Kennedy, Paul, Svět v 21. století (Preparing for the Twenty-First Century*)*, Praha, Nakladatelství Lidové noviny, 1996, p.79) 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 maybe by electromobiles. This will not, of course, be any "cheap" fuel. For example, the change-over 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" (Mensch, Gerhard: Stalemate in Technology, Cambridge, Balling Publishing Company, 1979, p. 154) 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 barrier(Kennedy, Paul, Svět v 21. století (Preparing for the Twenty-First Century*)*, Praha, Nakladatelství Lidové noviny, 1996, p.95). 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 technological revolution in past changed the position of countries in the world econom (Toffler, Alvin, The Third Wave, New York, Bantam Books, 1980, p.23) 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.

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 West-

ern states. China and India (as developing nations) may keep their consumption of oil at a high level. There are particularly strong fears with regard to procedures and methods that contain 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 a 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 a little bit different tomorrow than it does today. This is 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. A 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 1940s). 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 temporarily 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(Kennedy, Paul, Svět v 21. století (Preparing for the Twenty-First Century*)*, Praha, Nakladatelství Lidové noviny, 1996, p.100). The centre of industrial production and modern development therefore could be moved to Japan, Korea, China and India. 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 - 2040 followed by a next (7th) wave. Idealistic expectations connected with "informational revolution" or the "informational society" are still warning (Toffler, Alvin, Šok *z* budoucnosti *(*Future Shock*)*, Praha, Práce, 1992, pp. 95-12).

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 – 2040 hypothetically 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 one of Kondratieffs economic "long waves)". And as the foreshadow of a next coming wave. Therefore governments can not help to overcome 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-information") 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 (Malpas, Robert, „Harnessing Technology for Growth" in Landau, Ralph, Rosenberg, Nathan (editors), The Positive Sum Strategy, Washington, National Academy Press, 1986, pp. 105-113). The countries 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 develop and grow. But they are no longer so rich in innovations as they were in the 1990s. For this reason, attention must focus on other longer-term possibilities as well.

CONCLUSION

1. A real long-term growth of economy is without additional sources from "outside" (discovery of new counties or geological deposits) possibly 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 telecommunication 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 - 2040) and the following next waves (8th, 9th etc.) will be even shorter and probably in one moment (cca after 2080 - 2090) 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 on how to overcome the existing crisis is to speed up a birth of the post-informational technological revolution (6th wave) by supporting a scientific and technical progress.

REFERENCES

Berend IT (2006). An Economic History of Twentieth-Century Europe, Cambridge, Cambridge University Press.

Bonciu, Florin: (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.

British Agricultural Revolution, (http://en.wikipedia.org/wiki/British_Agricultural_Revoluti)

Cameron R (1989). A Concise Economic History of the World, New York, Oxford University Press.

Daniel Bell, (http://en.wikipedia.org/wiki/Daniel_Bell)

Diamond J (2000). Osudy lidských společností (Guns, Germs, and Steel/The fates of Human Societies), Praha, Columbus.

Dosi G, Freeman C, Nelson R, Silverberg G, Soete L (1988). Technical Change and Economic Theory, London, Pinter Publishers,

Duijn JJv (1983). The Long Wave in Economic Life, London, George Allen and Unwin.

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

Freeman C (1985). Die Computerrevolution in den langen Zyklen der ökonomischen Entwicklung, München, Carl Friedrich von Siemens Stiftung.

Freeman, C (2001). Louçâ, As Time Goes By, Oxford, Oxford University Press.

Giddens A (1998).Důsledky modernity (The Consequences of Modernity), Praha, Slon.

Jourdin M M d (1994). Evropa a moře (L´ Europe et la mer), Bratislava, Archa.

Kennedy P (1996). Svět v 21. století (Preparing for the Twenty-First Century), Praha, Nakladatelství Lidové noviny.

Kennedy P (1996). Vzestup a pád velmocí (The Rise and Fall of the Great Powers), Praha, Nakladatelství Lidové noviny.

Kondratieff N (1984). The Long Wave Cycle, New York, Richardson&Snyder.

Landau R, Rosenberg N (1986). (editors), The Positive Sum Strategy, Washington, National Academy Press.

Landes D S (2004). Bohatství a bída národů (The Wealth and Poverty of Nations), Praha, BB/art s.r.o.

Mensch G (1979). Stalemate in Technology, Cambridge, Balling Publishing Company.

Overton, Mark, Agricultural Revolution in England 1500 –1850 (http://www.bbc.co.uk/history/british/empire_seapower/agricultural_revolution_01.shtml)

Toffler A (1980). The Third Wave, New York, Bantam Books.
Toffler A (1992).Šok z budoucnosti (Future Shock), Praha, Práce.