Information and communications technology development and its Economic context

Ales Pajgrt

Department of Information Technology,

University of Economics, Prague, Czech Republic

apajgrt@iol.cz

Abstract*: The contribution deals with economic context of Information a Communications Technology (ICT) development's analysis. Historical data of ICT revenue in USA for last 53 years were analyzed and were compared with the historical data in Czech Republic, Germany, China, India, Japan and Brazil for last 13 years. The ratio of ICT revenues to GDP was used as proper indicator in the examined countries to reflect the influences of the surrounding progress and define the individual progress stages. The formulation of the progress' general rules and its prediction was done. It was monitored the dynamics of ICT sales, depending on its form and the influence of global economy.*

Keywords: Business cycle, Development, Gross Domestic Product (GDP), Information and Communication Technology (ICT), Innovation, Technological progress

1. Introduction

The development of the ICT (Information and Communication Technology) is one of significant representatives of technological development that is described by empirical general technology laws: Moore's law of microprocessors' speed and memories' capacity growth (Moore, 1965), (Vobecky, 2005) and Gilder's law of transmission rate (Gilder, 1993). Technological development allows subsequent development of hardware and software applications, which are reflected in innovative cycles. The dynamics of technological development leads to rapid moral aging, a price drop and mass expansion of a number of users.

This situation tends to search for new economic context (Vacek, 1998), (Zlatuska, 2000), (Loesch, 2012) and the need for the formulation of trends that are necessary for predicting the future state.

The objective of the paper is the validation of the published technology laws and the examination of coincident economic and social context, generalized formulation of rules and corresponding models.

2. Analysis

2.1 Methodology

The methodological approach of the work was based on the epistemological approach to the development of the surrounding world in a broader context (technological, economic and social) and the need to predict the future.

The observations assume historical data collection and their analysis. Testing of hypotheses was performed with quantitative research, which requires a strong standardization and ensures higher reliability. The logic of quantitative research is deductive.

The evaluation of the economic growth of the ICT sector in a specific market (country or region) uses following indicator of ICT sector spending in examined countries, with further division to:

- ICT investments (commercial software, computers and communication equipment)
- ICT services (IT and telecommunications services)

With regard to the need for particular highlight of business (innovation) cycle is used the ratio of ICT investments (or IT services revenue) to GDP as the most sensitive indicator in this work.

Input primary data for mentioned ratio calculation were used from (Gartner, 2010), (OVUM, 2011), (IDC, 2010), (CSU, 2009) and (CSU, 2010) analyses.

ICT spending in these analyses of analytical companies (OVUM and others) is derived from microeconomic sources, from companies' public financial statements and company guidance. Data were annually reviewed with various companies to ensure accuracy. While ICT spending in analysis of CSU is partially derived from microeconomic sources (annual investigation of selected companies) and partially from macroeconomic sources (Ministry of Finance, Ministry of Industry and other institutions).

Analyses do not explicitly account for inflation or adjust for inflation in its forecast results. Revenue and spending forecasts are expressed in nominal (current-year) dollars. Exchange rates from the Bank of England, resp. Czech National Bank were used to convert data from non-US native currency to US dollars. Historical data analyses use the historical rate for each period.

The connection of several ICT spending numerical series for different time periods from different sources was realized with correction method of trend component and no change of cycling component.

With reference to ICT development trend in USA explanation using innovation theory (Schumpeter, 1982) and its worldwide validity extension these initial hypotheses of ICT development were formulated and consequently evaluated:

- There is different dynamics of ICT development in their provision of services compared to the form of products (investments),
- Global ICT development has dominant dependence over local economies' influence.

2.2 Economic growth

Economic growth is the increase in the amount of the goods and services produced by an economy over time. It is conventionally measured as the percent rate of increase in real Gross domestic product (GDP).

GDP refers to the market value of all officially recognized final goods and services produced within a country in a given period. It can be expressed in current prices or in current purchasing power parity (PPP). The input data of GDP in this analysis was used in current prices (Knoema, 2012).

GDP growth in USA and Czech Republic, Germany, Japan, China, India and Brazil in period 1999-2012 is plotted at Figure 1. It is visible the highest GDP growth in China and Japan with low impact of financial crises in 2009 in the comparison to USA, Germany, CR and India. Medium impact is obvious in Brazil.

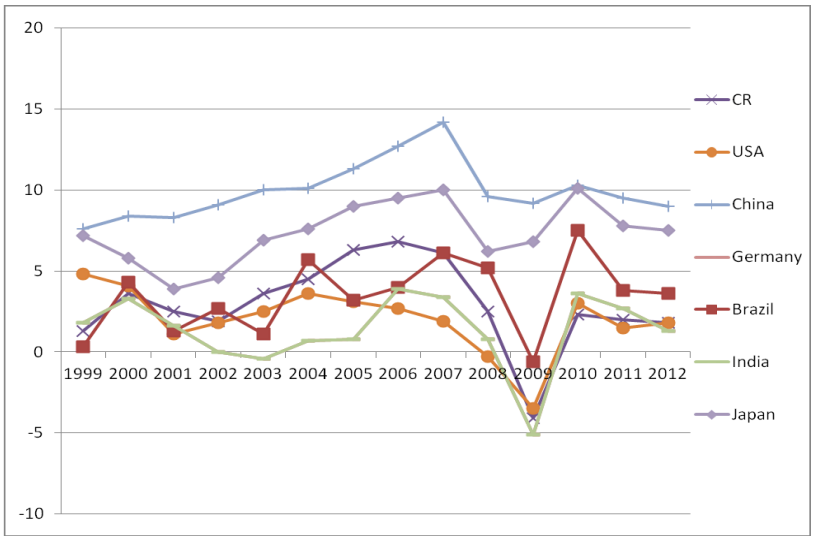

Figure 1: Annual GDP change in CR, Germany, China, India, Japan, Brazil and USA

2.3 Technological progress

Technological progress has been generalized in Moore's law (Kurzweil, 2001). In case of computer technology, it can be quantified as a double exponential dependence of the growth of computing power (calculations per second / cost) see (1).

$$V = Ca * (Cb^{(Cc * t)})^{(Cd * t)} \quad (1)$$

where the following characters are

- V: computing power (speed) (measured in calculations per second/ cost)

- T: time

- Ca, Cb, Cc, Cd are constants

The above model assumes an exponential increase in costs for development and production of computer technology. Graphical representation of the model is shown in Figure 2. This graph is consistent with the available data for the 20th century, all 5-mediated paradigms (Kuhn, 1997) and provides projections for the 21st century. There are also illustrated predicted achievement's levels of different creatures' species' intelligence. Achieving the computational capacity of a human brain (8 * 10^{16} instructions/ sec) per 1 000 USD is expected around the year 2023.

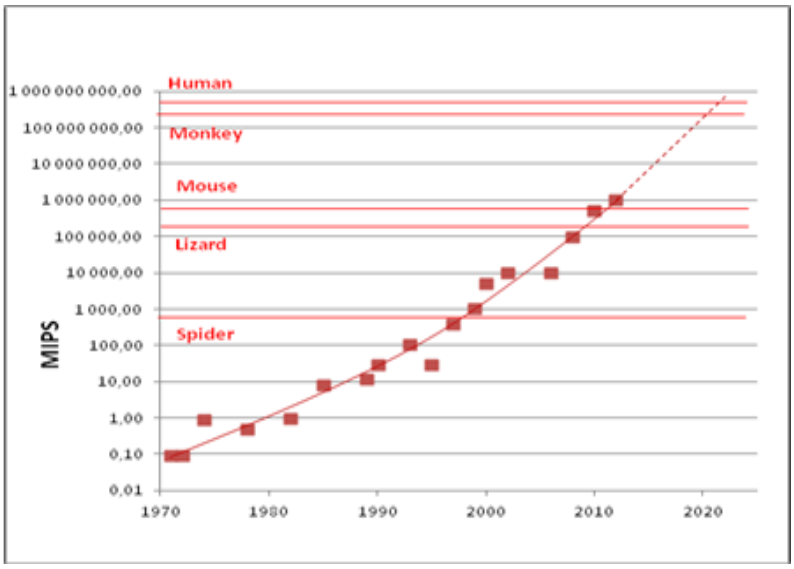

Figure 2: Development of computing power (Kurzweil, 2001)

The economic development of ICT can be characterized according to the time evolution yields of the relevant period, see Figure 3. In this graph (IDC, 2009) are evident business cycles, highlighted by the annual percentage growth curve. These innovation cycles reflect the emergence of new paradigms of new technologies. This is the so-called Schumpeter's growth, based on the growth of knowledge, technological progress and institutional changes.

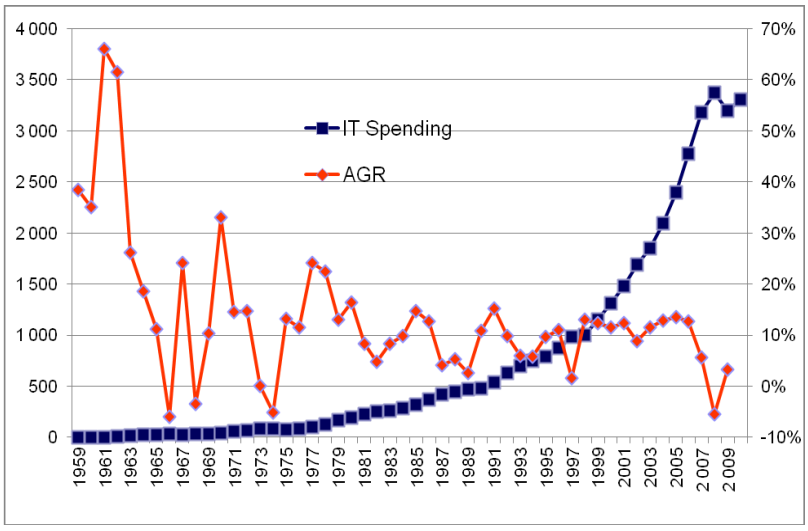

Figure 3: Worldwide ICT development (spending in billions USD) (IDC, 2009)

2.4 ICT Market analysis

Business ICT market cycles are used by companies to analyze and forecast the ICT market, particularly IDC (IDC, 2009), Gartner (Gartner, 2010) and OVUM (OVUM, 2010).

The most extensive historical data for analysis of development of the ICT market can be obtained from the U.S. market. They are substrates for a period of 53 years in properly structured form. There was created a graph of ICT investment to GDP ratio time trends, see Figure 4. There were summarized the following conclusions for the behavior of the ICT market in the USA.

ICT market in the USA graduated in 1950 from four waves of technological innovation and growth. Three times since 1950 in the U.S. technology market went from 16 to 20-year cycle of the fast and then slow growth. In any case, the introduction of new technology is undergoing a period of eight to 10-year growth when technology investments are growing twice faster than the economy, followed by a similarly long period when technology investments are growing at the same pace as the economy (Loesch, 2006), (Loesch, 2012). The last wave of growth in technological innovation began in 1992 and ended in 2008. Based on historical patterns in the U.S. should be the next wave of technological innovation and growth, beginning around 2008.

Technology purchases began to grow much faster in 2008, did not intervene until the financial crisis. The data on business investment in the U.S. technology shows that technological investments were (starting in Q4 2007 and the first two quarters of 2008) an average of 8.4%, almost double the average growth rate of nominal GDP by 4.6%. While the financial crisis and resulting recession stopped this growth, relatively strong growth in IT investment in late 2007 and early 2008 indicated that there was plenty of pent-up demand for technology goods, which reappear when the recession is over.

There is created a new generation of technology. History repeats itself, if the conditions are repeated. Conditions are repeated again in technological innovation. The convergence of innovations in software architectures, backup operations, data centers, wireless and broadband communications and a lot of smaller, efficient, client devices connected to the network. It provides the technology together in a clever solution to complex business problems that previous generations of computing technology could not solve. The seeds of this new technology are based on technological innovation in industry-focused products of new suppliers that combine elements of hardware, software and communications for solving business problems. For example, distribution companies encourage energy conversation and avoid investments in new production facilities, and hospitals are using electronic patient records to provide better treatment o more efficient use of resources.

This new generation of technology has been called "smart Computing" (Bartels, 2009). It adds new possibilities to existing technologies for real-time situational awareness and automated analysis. The technology is thus shifting from the mere task of proposing solutions (such as starting a sales order) to the perception (what is happening in the world around her), analysis (new information on risks and opportunities, presenting alternatives) and taking action. It can help people to make more intelligent decisions about alternatives and implement activities that will streamline business processes and business balance sheets.

If we look more closely at the development of the ICT market in the USA in the period since 1959, according to historical data (Bartels, 2009), see Figure 4, there are three clear business cycles and experiencing growth, corresponding to the introduction of new technologies and their adaptation.

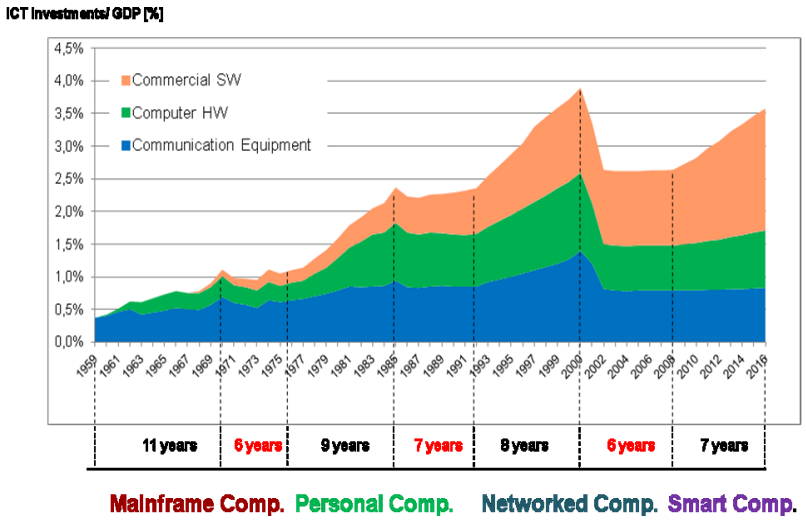

Figure 4: Three cycles of ICT development in USA (Bartels, 2009)

2.5 ICT trends evaluation

To evaluate trends in ICT investment data was analyzed from selected countries of the European market (the Czech Republic, Germany), the Asian markets (China, India, Japan) and Latin America (Brazil) and the results were compared with the market in the U.S. for the period since 1999. Comparison of the ratio of ICT investment to GDP (the equivalent in USD according to PPP) is shown at Figure 5. It was evaluated by a chart (technical) method of change (growth / stagnation / decline) (Fialova, 1999) in individual states and their mutual consistency or time shift was quantified.

This method is mainly used for tracking stock exchange commodities, stock markets and foreign exchange markets. The basis is a study of the development and shape of the curves characterizing the analyzed indicators of value or quantity. The interpretation of charts includes many specialized names for each configuration value from which they were used mainly these basic patterns:

- The trend line component of development curve,
- Cyclical component of the development curve,
- Top, gap,
- Growth, stagnation, decline.

The deployment of chart (technical) analysis has been done because of it is relatively effective tool, which enabled suitable highlight the trend and cyclical components and subsequent examination of waveforms monitored curves and time shifts of partial cycles in evaluated countries.

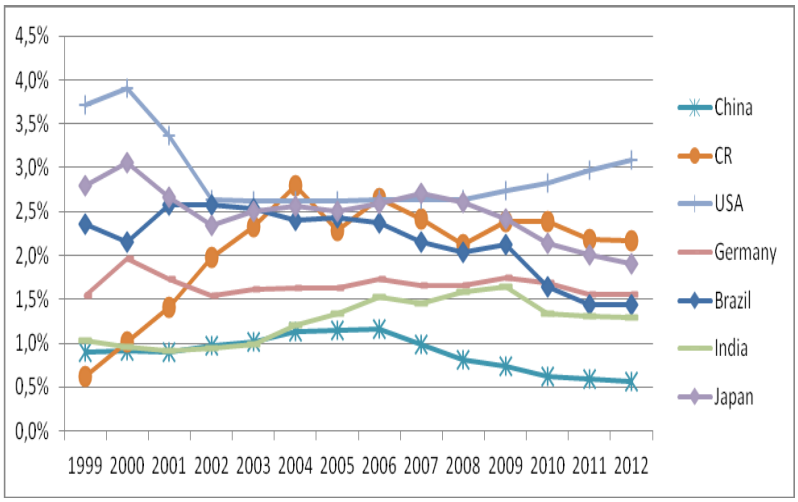

Figure 5: ICT Investment/ GDP in CR, Germany, China, India, Japan, Brazil and USA

We can see that the digestion period, mentioned at U.S. market from year 2000 is 4 years postponed in Czech Republic, which probably reflects innovations' delay. Nevertheless innovation growth period starts in both markets in the same year 2008 with more pessimistic prediction in Czech Republic for 2012.

The same start of digestion period as in USA in 2000 is obvious in Germany and Japan. Nevertheless the predictions in 2012 are similarly pessimistic as in Czech Republic with decline after 2009.

The digestion period in Brazil is only 1 year delayed in comparison to USA with the same start of innovation's growth in 2008, but followed with decline, which is predicted also till 2012. This situation is affected by fluctuating rate of Brazilian currency and represents Latin America market.

Asian market is represented with India and China, which has relatively high GDP growth. It can explain lower level of ICT investments/ GDP and its less cycling feature. ICT investments had similar ratio to GDP in both countries till 2005 then followed by slight ICT digestion in China and slight growth in India till 2009 and pessimistic prediction till 2012.

Mentioned low impact of financial crisis on GDP growth in China and Japan at Figure 1 is reflected with the digestion and its higher impact (in USA, Germany, Czech Republic, Brazil) is reflected with the innovation growth at Figure 5.

The comparison of ICT services revenue/ GDP indicator in Czech Republic, Germany, China, India, Japan, Brazil and USA is at Figure 6. We can see continuous growth at all markets except Brazil, where is the indicator's curve affected by fluctuating rate of Brazilian currency and the usage of GDP in current prices.

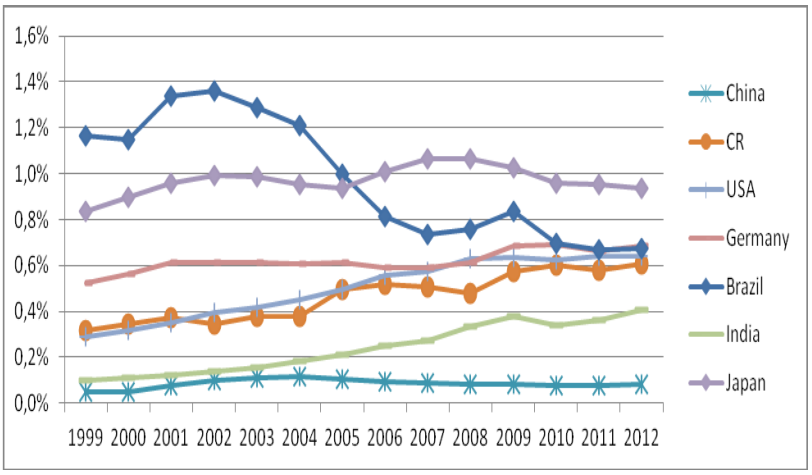

Figure 6: ICT Services revenue/ GDP in CR, Germany, China, India, Japan, Brazil and USA

Model of ICT cycle

The mathematical model of the ICT cycle was proposed which consists of a trend component T (x) and the cyclical component of Y (x) for 6 time periods according to following Table 1.

Table 1: Model of ICT cycle in period 1959-2025.

From	To	Trend component	Cycling component
1959	1970	$T(x) = 0{,}0022 * (x)^{0{,}6697}$ $R^2 = 0{,}914$	$Y_1(x) = 0{,}001 \sin(x * \pi/12 + 3\pi/2)$
1971	1975		$Y_2(x) = 0{,}001 \sin(x * \pi/10 + 3\pi/2)$
1976	1985		$Y_3(x) = 0{,}05 \sin(x * \pi/9 + 3\pi/2)$
1986	1991		$Y_4(x) = 0{,}05 \sin(x * \pi/8{,}3 + 3\pi/2)$
2001	2004		$Y_5(x) = 0{,}01 \sin(x * \pi/8 + 3\pi/2)$
2005	2025		$Y_6(x) = 0{,}05 \sin(x * \pi/8 + 3\pi/2)$

Initial identification of the two components was based on graphical analysis of time series of ICT cycle of the U.S. market. The trend component T (x) has been done by power regression functions with

coefficient of determination R^2, according to which 91,4 % percent of the time series of ICT cycle's variance has been done due to the time dependence, and the remaining 8,6% of the variance is caused by other factors.

The cyclical component is formed by sinusoidal function with varying values of amplitude and cycle length in investigated period which has been measured with chart (technical) analysis.

Graphical representation of the proposed model is shown in Fig.7. of the mean square deviation has been used. Proposed model is considered more convenient when the variance, respectively standard deviation is less.

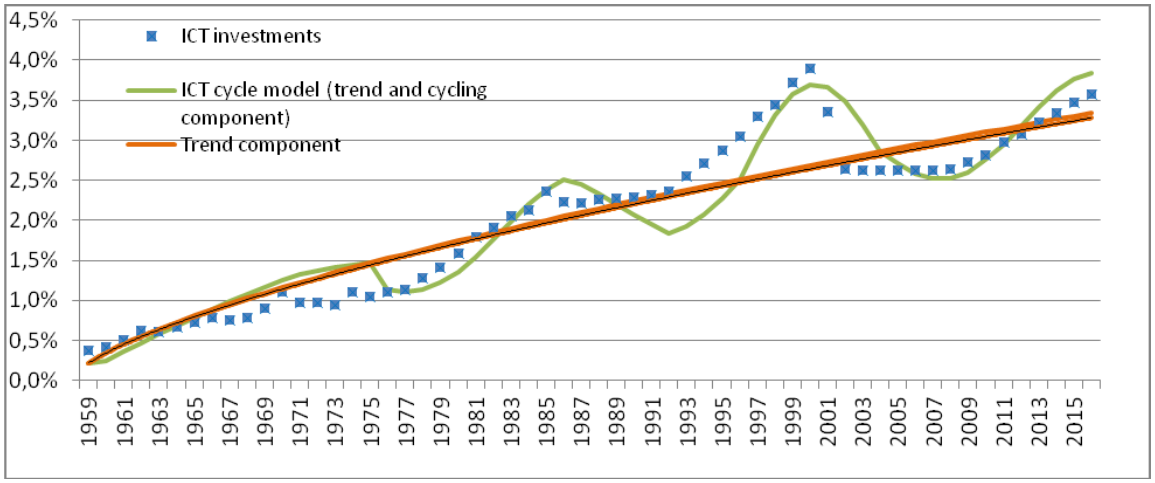

Fig. 7: Model of ICT cycle for period 1959- 2016 and its experimental values

Analysis of the variance and standard deviation according to their minimum value was made for the ratio of investment in ICT / GDP in all 7 investigated countries. The analysis resulted in lower values of the standard deviation in order of percent units in Germany, Japan and the Czech Republic. Proposed model was thus confirmed as satisfactory for these countries.

Nevertheless it is not suitable for China, India and Brazil, where standard deviation reaches one order higher values. There is no clearly obvious cyclical component for China and India from chart analysis. And there is not a regular cycle period shift from the proposed model in Brazil.

Reasons of ICT trends' differences

The reasons of ICT trends' differences in selected countries have been evaluated with reference to countries' development stage and consequent factors: market size, macroeconomic environment, institutions/ economic openness (WEF, 2012).

The development stage of USA, Germany, Japan and Czech Republic has been assessed at highest stage (innovation driven). The reason of postponed digestion period of ICT cycle in Czech Republic has been mainly caused by its lower market size.

The development stage of Brazil has been assessed at upper medium stage (transition between efficiency and innovation driven). The reason of ICT cycle difference has been done by reported macroeconomic instability.

The development stage of China has been assessed at medium stage (efficiency driven) and the development stage of India has been assessed in lower stage (factor driven). The reason of these both countries' ICT trend difference (no cycling) is their strong government institutions' influence and lower economic openness.

3. Conclusion

Historical data of ICT development for last 13 years were analyzed in selected countries (Czech Republic, Germany, China, India, Japan and Brazil) to confirm general validity of ICT business cycles in USA for 53 years period with three generations of computing: mainframes, personal and networked computing. New ICT generation (called smart computing according to (Bartels, 2009)) is predicted for new business opportunity and the deployment of cumulated ICT innovations. Realized analyses used the indicator of ICT investment (or IT services revenue)/ GDP ratio, which reflects realized investments

of government and private sector to ICT technology. The results confirm innovation theory of ICT development and describe rules of examined country's business cycle synchronization to US one in the dependence of country's development stage, market size and economy openness. It can be summarized:

- Countries with higher development stage and higher market size (Germany, Japan) have the same business cycle dynamics as US market.
- Countries with higher development stage and lower market size (CR) have postponed digestion period, accompanied with synchronized innovation growth period with US market.
- Asian countries (China and India) have medium or lower development stage, relatively high GDP growth and lower level of ICT investments/ GDP and its less cycling feature because of low economy openness.
- Latin America countries (Brazil) have medium development stage but higher macroeconomic instability. They were excluded from general conclusion because of fluctuating currency rate and its distortion of analyzed trend.

ICT development can be described with innovation theory (Schumpeter, 1982). Its trends with conjunctions can be explained with the exchange of computing's generations (Valenta, 2001). Its validity was confirmed with these findings:

a) There is different dynamics of ICT development in their provision of services compared to the form of product (investments). Innovations' Juglar's cycles are obvious in case of ICT investments with period about 14-18 years. Its stages have character of 8-10 years innovation growth and 6-8 years digestion decline. While no cycle encounters in case of ICT services. Continuous growth of the development of ICT services reflects to their more continuous consumption, without digestion then in case of the investments to products.

b) Global ICT development has dominant dependence over local economies' influence because new products' information sharing in Internet environment and their accelerated delivery in globalized world.

c) The validity of above mentioned finding is limited only for countries with higher development stage (innovation driven).

The work has allowed ICT development trends' justification and contributes to its further prediction.

This paper was realized in frame of the grant: GACR P403-10-0092

References

Bartels, A.H., 2009: *Smart Computing Drives The New Era of IT Growth*, Forrester analysis, [on-line], citováno: 2012-08-10, zdroj: <http://www07.ibm.com/ph/ssmeconference/pdf/smart_computing_drives_the_new_era_of_it_growth_forrester.pdf>

ČSÚ, 2012: *ICT sektor v zemích OECD 1988-2009*, [on-line], citováno: 2012-09-25, zdroj:<http://www.czso.cz/csu/redakce.nsf/i/tabulky_oecd_ict_sektor /$File/ict_sektor_oecd.xls>

ČSÚ , 2012: *ICT sektor v České republice ; 1995-2010*, [on-line], citováno: 2012-09-25 zdroj:<http://www.czso.cz/csu/redakce.nsf/i/tabulky_cze_ict_sektor/$File/ICT_sektor_Tabulky_CZE_2010.xls>

Fialová H., Jaroš M., 1999: *Konjunkturní analýza v mezinárodním obchodu*, VŠE Praha, 142 s. ISBN 80-7079-671-5

Gartner Analysis, 2010: *IT Spending*

IDC Analysis, 2009: *Czech Republic ICT Services*

IDC Analysis, 2010: *The IT Services Market in the USA*

KNOEMA: *GDP Statistics by Country*, [on-line], citováno: 2012-08-10, zdroj: <http://knoema.com/tbocwag/gdp-statistics-by-country>

Kuhn, T.S. ,1997: *Struktura vědeckých revolucí*, Praha: OIKOYMENH, 206 s. ISBN 80-86005-54-2

Kurzweil, R. 2001: *The Law of Accelerating Returns*, [on-line], citováno: 2012-08-10, zdroj: <http://www.adpoems.com/products/wireless/files/law-of-accelerating-returns.pdf.gz>

Loesch Ch. W., 2006: *Do We Need A New Information Technology?, Scenarios in Microelectronics and their Impact*, 20 Years of IDIMT Conferences Looking Back proceedings, SEA Publications, 2012, 253 s. ISBN 978-3-902457-35-6

Loesch Ch. W., 2012: *ICT Trends and Scenarios Reflected in IDIMT Conferences 2012,* 20 Years of IDIMT Conferences Looking Back proceedings, SEA Publications, 253 s. ISBN 978-3-902457-35-6

Moore, G.E., 1965: Cramming more components onto integrated circuits, *Electronics Magazine*

OVUM, 2010: *Worldwide IT Spending*

Schumpeter, J. A., 1982: *Business cycles: a theoretical, historical, and statistical analysis of the capitalist process*. 2. přeprac. a dopl. vyd. Philadelphia: Porcupine Press, 2 v. Harvard economic studies, v. 46. ISBN 08-799-1807-1

Vacek, J., Skalický, J., Vostracký, Z., Potměšil, J. 1998: *Společnost, věda a technologie*, ZČU, ISBN 80-7082-463-8

Valenta, F., 2001: *Inovace v manažerské praxi*. Praha, Velryba, 151 s. ISBN 80-85860-11-2

Vobecký J., 2005: *Nové trendy polovodičových součástek -pohledem začátku roku 2005*, FEL, [on-line], citováno: 2012-08-10, zdroj: <http://www.roznovskastredni.cz/dwnl/pel2005/01/vobecky.pdf>

Global Competitiveness Report 2012-2013, World Economic Forum [on-line], citováno: 2012-11-24, zdroj: <www.weforum.org>

Zlatuška, J., 2000: *Informacni spolecnost a nova ekonomika*. Vyd. 1. Ostrava : Ostravská univerzita, 11-23 s. ISBN 80-7042-795-7

JEL: O10