THE IMPACT OF TECHNOLOGICAL INNOVATIONS IN THE FIELD OF INFORMATION AND COMMUNICATION TECHNOLOGIES ON THE ENVIRONMENT

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Abstract

The social and economic evolution of the last decades has led to the general use of information and communication technologies (ICT) with direct and indirect impact on environment. The current trend is to focus on the development of less invasive hardware for environment and software that should support the monitoring and protection activities of the human ecosystem. Beyond the amazing facilities provided by the technological innovations, the users' behaviour should be rational and by means of individual and collective measures, it should result in positive medium- and long-term actions, so that the following generations might benefit from life standards at least decent from this perspective. The technological "explosion" in the ICT field should be used both for the improvement of life standards and for favourable actions on the environment, the more so as the specific achievements may be the key to solve these problems. This paper aims to identify the main influences of the innovations in the field of information and communication technologies upon environment, the way in which they could be used in pro-environment measures and to state recommendations in view of mitigating the negative effects of these technologies on the human ecosystem.

Key words: information and communication technologies, technological innovation, environment

The information and communication technologies (ICT) have evolved very much in the last decades, influencing directly and indirectly all fields of the activity. In less than half of a century, mankind has become addicted to them. Their omnipresence under various forms, mobile phones, PDAs, notebooks, traffic and electricity control systems, media communication, etc, all connected to the Internet, have changed the way people live and work and have led to the creation of new products and services, such as employment opportunities, hard to be imagined before the ICT development. Nowadays, it is difficult to imagine for a large part of the population life without various equipment and specific applications. This spectacular evolution and the major influence they have at economic and social level have made ICT to be considered *our collective nervous system— a platform for helping to solve some of our greatest economic, social and environmental challenges*. (World Economic Forum, 2009). Their contribution to the economic growth has been the topic of numerous studies and the general conclusion has been that ICT determined the acceleration of economic development in all fields and countries, with larger influences in the developed ones and smaller in the developing countries.

From the perspective of the economic theory, there are three factors causing the productivity growth, through the use of ICT: (1) the use of more performing equipment, (2) the increase in work quality considerably influenced by the easy access to information and knowledge and (3) the technological innovation manifested in the creation, distribution and use of new knowledge (Kozma, B., R., 2008) Currently, the world is hyper connected by means of the Internet and other ICT. This phenomenon triggers chain reaction of progress or downturn, leading to the disappearance of certain areas and activities and to the creation of others as a result of technological innovation. One of the most significant merits of technological innovation is represented by the disappearance of geographical barriers, enabling globalization and the almost unlimited access to information and knowledge. These represent premises and consequences of the technological innovation which, directly or indirectly, contributes to the economic and social progress. As far as environment is concerned, the ICT influence is complex and bidirectional. The dramatic evolution of the computational power offers

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exceptional facilities for collecting and processing of information that strongly exceed the individuals' ability, in time intervals much superior to the human life and being able to comprise the entire earth system from the bottom of the oceans to the highest atmosphere layers (ITU, 2008). The estimation of human activity effects and climate changes they determine can be performed nowadays with an acceptable precision, by means of interconnected computational platforms and by the access to the information stored in high capacity data warehouses. On the other hand, the production and use of ICT imply the use of non-reusable resources, causing pollution, while the decommissioning of equipment generates large quantities of non-biodegradable waste. The efforts made in the last decades focus on finding and applying solutions in this field in order to maximize the advantages of ICT use and to minimize the negative effects on the human ecosystem.

MATERIALS AND METHODS

The research was conducted by observing and analysing the main contributions of technological innovation within the ICT to the economic and social evolution with direct and indirect influences on the human ecosystem. The ICT study on environment is a relatively new preoccupation, their negative effects being much outstripped by the favourable results of their use in economy and social life. In comparison with other fields of activity, where the amount of waste, energy generated and non-reusable resources used or air pollution are at very high peaks, the outcomes of ICT production and use are, apparently, rather small. The spectacular evolution in the field, bringing about considerable decrease in prices and easy access to technology, has determined a substantial growth of negative, direct or indirect effects and has drawn the attention of authorities and public towards environment-friendly ICT. The developers have also reached a degree of evolution which allowed them the allocation of considerable human, financial and material resources for the analysis of side effects of ICT development and use and the search for alternative solutions. In this respect, the developers are interested in finding the least invasive production methods, inclusively in terms of used raw materials and stimulation of product development which should support the environmental protection activities.

RESULTS AND DISCUSSION

The ICT interfere in the environment by means of their two forms of existence: *hardware* and *software*. While the negative influence of hardware components is direct and obvious (energy consumption, resources used for their production, waste, pollution), in terms of applications the negative effects are indirect and the positive ones are multiple and direct.

In our opinion, the ICT negative effects which are fairly conclusive are translated in the following results:

- The global information and communications technology (ICT) industry accounts for approximately 2 percent of global carbon dioxide (CO2) emissions, a figure equivalent to aviation. (Gartner, 2007);
- 18% of office workers never switch off their PC at night or weekends, and a further 13% leave it on some nights each week, producing about 700,000 tons of CO2 emissions (equivalent to the annual emissions of a typical gas-fired power station) (World Economic Forum, 2009);
- With the fast growth of ICT application in business operation and people's daily life, that energy use by these devices will double by 2022 and increase threefold by 2030 (International Energy Agency, 2009);
- A photocopier left on overnight uses enough energy to produce over 1500 copies. (NCB, 2011);
- The total footprint of the ICT sector – including personal computers (PCs) and peripherals, telecoms networks and devices and data centres – was estimated at 830 MtCO2e, about 2% of the estimated total emissions from human activity in 2007. Even if the efficient technology developments are implemented, this figure seems to grow at 6% each year until 2020. The carbon generated from materials and manufacture is about one quarter of the overall ICT footprint, the rest coming from its use. It was also estimated that ICT has the potential to reduce global emissions by 15% by 2020. (SMART 2020 Report, 2008);
- The cost of running data centre facilities is rising by as much as 20% a year, far outpacing overall IT spending, which is increasing at a rate of 6% (World Economic Forum Green Technology 2009 Report);
- A data centre with 1000 servers uses enough electricity in a single month to power 16,800 homes for a year. (Forrester Research, 2009);
- At least 240 kilograms of fossil fuels, 22 kilograms of chemicals and 1,500 kilograms of water are required to produce one desktop computer. (The ITAM Review, 2012);
- Only 20 percent of total energy use goes into running a computer; the rest is in its manufacture. (Williams, E., 2003).

As it can be noticed, the negative incidence on environment is mainly determined by the hardware components, while the favourable results are generated by the use of software whose

functioning is impossible without the adequate devices. In its turn, this last one may be used either directly for environment matters, either for the economic and social activity from various fields, thus generating economic growth with favourable or unfavourable impact on environment (Figure 1).

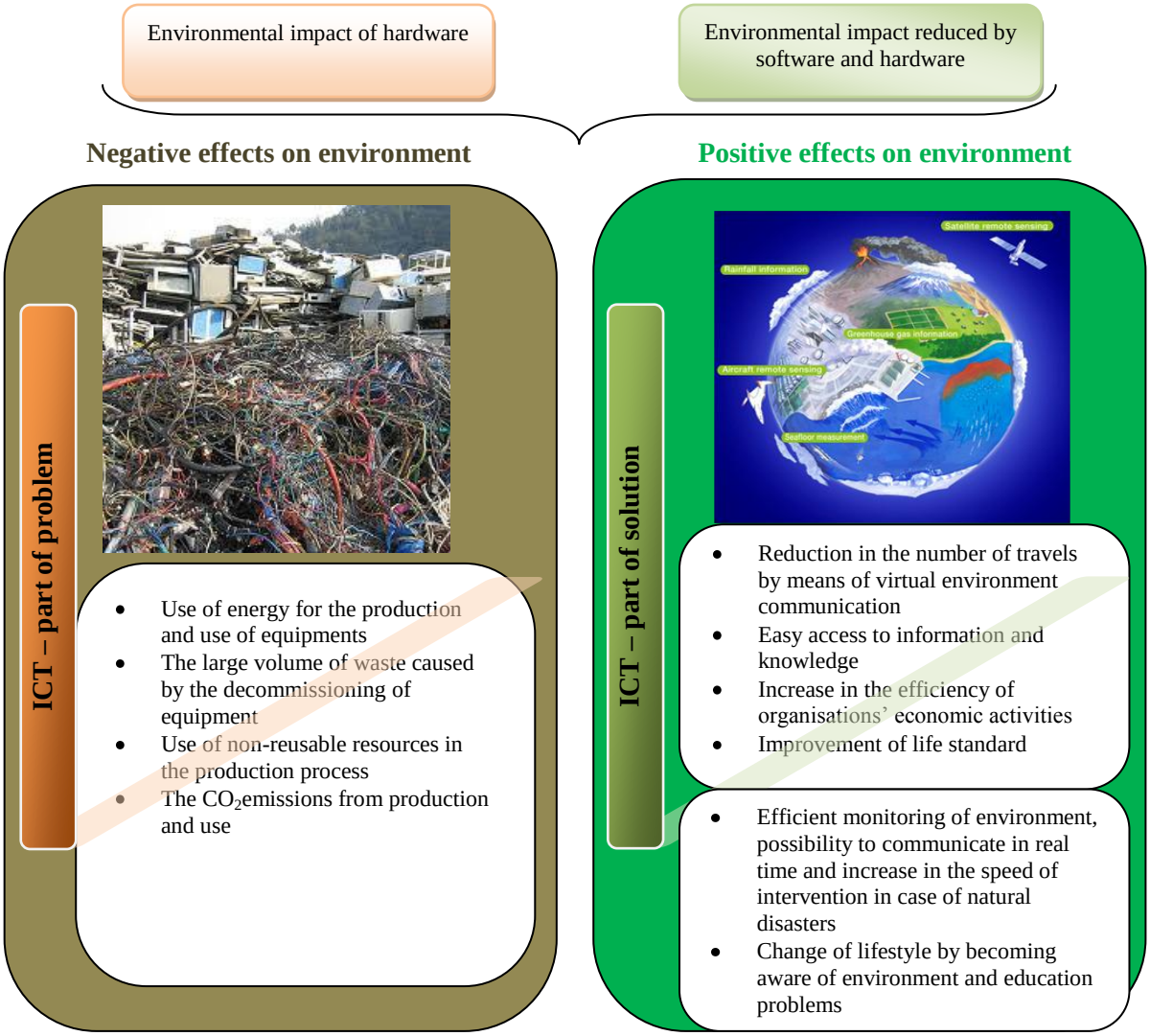

Figure 1 **The ICT effects on environment - by means of equipments and services provided**

Nowadays, the economic growth allows the allocation of resources and interest in the development of products and production methods able to generate as little damage as possible to the human ecosystem. The companies are interested in the reduced consumption of raw materials, in the reduction of expenses by means of virtual activities, or replacement of some tangible goods with some intangible ones. The innovations in the ICT field have an important role in this respect since they allow the development and implementation of some alternative production methods and products, the performance of simulations in order to determine the effects on environment, the easier and quicker dissemination towards partners and other interested users.

The technological innovation in the ICT field is strongly oriented towards the development of devices and applications enabling the environment monitoring and finding solutions for the existing problems, generated either by man or by natural phenomena. In table 1 we present some of the ways in which the ICT devices and applications are used for the efficient management of the relationship between man and environment.

The degree of ICT use is different, mainly according to the economic level of each region and country. The interest in their use is also various in terms of environmental protection measures. In the present, after an explosive evolution period in the production and entrance in the economic and social life of specific ICT equipment and applications, after the buzz specific to the pioneering period, a

rational and balanced approach is needed where the attention should move from the super-demonstrated beneficial economic effects, to the social effects also reflected in environment.

Table 1

ICT for the efficient management of the relationship with the environment (adaptation after ITU, 2008)

The use of hardware and software components for environmental matters can be performed as follows:	
Hardware:	Software:

• Satellite and direct sensor technology that provide the ability to record and store massive amounts of geographical and historical information with increasing resolution and geographic coverage.
• Increasingly faster and available microprocessors which have provided computational power as well as increasingly intelligent algorithms that have allowed modeling of environmental systems and thus a better understanding of the complexity of the physical and biological systems that are part of the environment.
• Geographic information systems (GIS) that allow the visualization and interpretation of the datasets made available through these observation systems.
• Increasing bandwidth and very rapid distributed communications, processing and storage capabilities that facilitate data sharing and undertaking computationally-intensive tasks through the use of Grid and Cloud computing;
• Rapid, inexpensive and increasingly high capacity storage devices networked directly to one another and to users who may want to exploit these data sets. Currently, "…storage density doubles every 12 months".
• Wireless technologies that allow broadband rates of data exchange and the linking of devices to form networks or clouds of sensors for monitoring and recording environmental phenomena of various sorts.
• Increasingly rapid and sophisticated chip sets and processors containing an increasing number and density of transistors operating at an increasingly rapid number of transactions per second using increasingly rapid data buses and working collaboratively and in parallel to manipulate the data in concurrent streams and power software.
• An increasing number of intelligent physical and embedded devices that are connected through the Internet — sometimes known as the "Internet of Things". These devices will be "…integrated into larger systems, where they will perform control functions and communicate with one another over the Internet". These include:
  ○ Smart tags using radio frequency identification (RFID) technology;
  ○ Smart devices: including devices embedded in sensors for telemetric data collection and remote sensing, in appliances of all sorts, in testing and medical equipment, etc.;
  ○ Smart offices where "roomware in the workplace will ensure greater efficiency and better working conditions".
	• Software such as database management systems (DBMSs) that can manipulate digital data. This includes geographic information systems (GIS); specialized database management systems that use textual, numeric, alphanumeric and imagery data including especially maps. Of particular use are spatial imagery and data and the possibility of linking data sets and images to map coordinates.
	• Web-based services: a new class of Internet-based services based on open standards and resource sharing which have a "service orientation".
	• Software development:
	  ○ Environmental observation : terrestrial (earth, land, soil, water), ocean, climate and atmospheric monitoring and data recording technologies and systems (remote sensing, data collection and storage tools, telemetric systems, meteorological and climate related recording and monitoring system), as well as geographic information systems (GIS) as it applies to data recording and georeferenced data formats.
	  ○ Environmental analysis: once environmental data has been collected and stored, various computational and processing tools are required to perform the analysis and comparison of data available.
	  ○ Environmental management and protection: environmental policy and strategic direction set during planning must reach the implementation phase in order to have a direct impact on the environment. In the area of climate change, management and protection deals with issues related to mitigating the impacts of climate change as well as adaptation to climate change.
	  ○ Environmental capacity building: the end results of any efforts to improve environmental conditions rely on the actions of individuals and organizations in order to be fully effective.
	  ○ Impact and mitigating effects of ICT utilization: ICT use can mitigate environmental impact directly by increasing process efficiency and as a result of dematerialization also and indirectly by virtue of the secondary and tertiary effects resulting from ICT use on human activities which in turn reduce the impact of humans on the environment.

The national and international policies must support such attitudes and measures and discourage the sometimes less responsible actions of producers and users. The organisational,

national and international strategies, applied to ICT, should mitigate the impact on environment by encouraging the following actions and behaviours (ITU, 2008):

- Travel replacement using technologies such as videoconferencing and audio-conferencing, tele-education, tele-medicine, tele-care/remote assistance services, flexi-work, intelligent living: flexible car ownership, e-Commerce, e-Government and e-Business in general;
- Reducing energy and material consumption:
  - Intelligent building design;
  - Intelligent building management including controlling the internal environment (heating and air or climate conditioning) of buildings through the use of intelligent building system (IBS);
  - e-Commerce, e-Government and e-Business in general which enhance process efficiency;
- De-materialization: virtual answering machines, online billing, web-taxation, video on demand, music on demand;
- Virtual meetings that could reduce CO2 emissions by around 24 million tonnes / year. This would include audio and visual conferencing applications in lieu of travel.

CONCLUSIONS

The interest in the environment-friendly ICT and in those serving the studies in this field is increasing. In the last years, the concept of *green ICT has become popular, aiming to reduce the energy consumption and CO_2 emissions by using ICT and mitigating the impact generated by the waste resulted from the products specific to this field.* In spite of this, we are still in an expansion period, and the attempts to reduce the negative effects are considerable, but still in the process of being identified and implemented. The advantage of the current period is that the measures to counterbalance the negative effects spread with the same speed as the performances in this area. The disadvantage is that they have a more reduced economic and social impact, because they are less spectacular in comparison with the technological progress and the facilities offered by the new technologies to the end user.

In the present context, the position of national and international organisations as well as the social awareness is very important. The first ones may interfere by setting measures that should stop the development of products harmful for the environment or offer incentives, under various forms, while the population, through common or individual attitudes and actions, may regulate the offer through demand. The development level of each country and region is also decisive in this field.

Taking into consideration the aspects presented in the paper, we find useful to set some recommendations in order to mitigate the direct negative effects on the environment, applicable for ICT producers and/or users:

- The efficient management of equipment and the integration, whether it is possible, of recyclable or biodegradable components;
- The promotion of recycling by the establishment of specialised collection centres and the education of population in this direction;
- Offering less invasive alternatives for environment, such as the online communication instead of travels, the e-commerce and e-business, the promotion of experiences and training in the virtual environment;
- The promotion of introduction of environmental protection measures towards the equipment producers which should stimulate the reduction in the use of non-reusable resources, the pollution reduction generated by the use of devices and energy consumption;
- The reuse of equipment by distributing them to the interested persons and companies, the stimulation and encouragement of transactions from this category in the electronic environment, leading to the increase in product lifespan.

ACKNOWLEDGMENTS

This work was supported by the project "Post-Doctoral Studies in Economics: training program for elite researchers - SPODE" co-funded from the European Social Fund through the Development of Human Resources Operational Programme 2007-2013, contract no. POSDRU/89/1.5/S/61755.

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