THE OCCURRENCE OF POWER LAW FOR COMPOSITE INDICATOR OF ICT ADOPTION IN SERBIANS ORGANIZATIONS

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Abstract. *This paper presents analysis of power law occurrence in the Serbian organizations. Its occurrence in physics, economics and finance, computer science, biology, earth and planetary sciences, demography, and the social sciences has been covered by research, but this study researches its occurrence in business application of ICT, where published research is still scarce. Parameter used in measurement is composite indicator of ICT adoption, already successfully used as a tool to measure ICT adoption in organizations in three studies of different context. It is described in detail in first part of the article, and compared with other approaches in measurement of ICT adoption in organizations. We analyzed the occurrence of power law in three cases: distribution of values of ICT adoption indicator in 67 selected enterprises, distribution between values of ICT adoption and size of the enterprises measured by number of employees, and distribution between values of ICT adoption and profit per employee. Thus, we found that ICT adoption in the Serbian organization is distributed according to Pareto's power law distribution, in all cases, with the tail exponent (or parameter* α *) smaller than 1, which means that ICT adoption in the Serbian organizations is undeveloped. This is the first paper that shows the distribution of ICT adoption possesses properties of Pareto's law in the Serbian organizations.*

Keywords: *Power law, ICT adoption, organization size, profit per employee*

1.INTRODUCTION

Power-law states that appearance of small values is quite common, while large values appearances are rear. This law is literately regarded as Zipf or Pareto's law[1]. When the probability of measuring a particular value of some quantity varies inversely as a power of that value, the quantity is said to follow a power law, also known the Pareto's distribution [2].

Atkinson, Piketty, and Saez wrote that the Pareto's law for top ICT index is given by the following (cumulative) distribution function for ICT indicator *z* [3]:

$$1 - F(z) = \left(\frac{k}{z}\right)^{\alpha}, \left(k > 0, \alpha > 1\right), \qquad (1)$$

where *k* and α are given parameters, α is called the Pareto parameter. The corresponding density function is given by

$$f(z) = \alpha k^{\alpha} z^{-1-\alpha} \qquad (2)$$

The value of the exponent depends on the value of the lower ICT indicator bound. Indeed, empirical studies show that the value of changes across different countries, and is typically in the range [4].

Further details on the mathematics of power laws can be found in Newman research [2]. Power laws are common in the systems that are constituted out of pieces that have no specific size and in the systems that are constituted out of self-catalyzing elements. They represent the link between simple microscopic basic laws on individual level and macroscopic phenomena that occur collectively [5].

2. LITERATURE REVIEW

Power laws appear widely in physics, economics and finance, computer science, biology, earth and planetary sciences, demography, and the social sciences [2]. Pareto's law has also been proposed as a model of word frequency [6], fluctuation in finance [7], firm sizes [8,9], citations of scientific papers [10,11], web hits [12,13], the cumulative distribution of the number of telephone calls received on a single day [14,15], frequencies of family names [16], turnover [17], income [18,19,20]), wealth [4,21] [22,23] ,), and so on. Clauset, Shalizi, and Newman [24] present power law distributions in empirical data from a range of different disciplines. Gabaix [25] surveys empirical power laws regarding income and wealth, the size of cities and firms, stock market returns, trading volume, international trade, and executive pay. He surveyed power laws in finance and economics, and he showed that Pareto laws have also been applied in several areas outside of income and wealth distribution. Atkinson, Piketty, and Saez [3] surveyed some of these theoretical models.

3. COMPOSITE INDICATOR OF ICT ADOPTION

In order to analyze power law occurrence we first need to present objective measurement of ICT adoption in the company, which can also be useful for comparison with other characteristics of the organization, as a guideline for changing processes in organization, measuring infrastructure requirements high technology projects or organizational changes that include information and communication technologies, or as a benchmarking tool among different companies. A tool for objective assessment of ICT adoption has long been needed by the consulting and scientific community in order to enable comparison with other characteristics in organizations[26], benchmarking [27,28] or measurement of existing state of infrastructure before implementation of Enterprise information system [29]. Presenting objective measurement of ICT adoption level can ease problems of managing ICT in organization. It could lead to certain level of formalization and as all control systems could be misrepresented and distorted to fit subjective, illegitimate goals, but would nevertheless present benefits of ordered measurement system in organization. In mentioned and other studies in the field problems of defining adoption emerge, and different approaches are applied in different studies. For the purpose of this study, we will use term "adoption" as establishing prerequisite ICT infrastructure in organization, both software and hardware. In such definition, adoption is different from actual usage by employees of the organization, which has other, behavioural dimensions, and introduces humanware requirements. It describes potential for usage, and is necessary, but not sufficient condition for actual usage of ICT by employees, that depends on other, less tangible factors.

Formula of composite indicator used for the purpose of this research was the result of several years of experimentation during consulting experience in companies, where authors searched for different tools to objectively quantify adoption of ICT in the organization. It was developed as a tool, basically for the purpose of scientific research, to the point subjective assessment of business consultants was that it describes adoption of ICT accordingly to the qualitative assessment observed in organizations that were included in the research. In practice, organizations with low level of index were estimated with low level of adoption of ICT and organizations with good or excellent adoption of ICT had higher levels of this indicator. For example, if indicator was low in value, computers were rarely or even not at all used, core processes in organization were driven without ICT and at best ICT was used below its potential – e.g. computers were used as typewriters and calculators. In contrast, companies with advanced practices of ICT usage, like ERP systems application, active internet presence, TEL programs or electronic office collaboration had high levels of this indicator. In this form, formula has been applied successfully used in studies that compared levels of ICT adoption in organizations with autocratic, democratic and liberal management styles [30], organization size [31] and dominant management orientation [32]. Currently, efforts are given into further improvement of the formula, which is in its original formula given below.

For the purpose of calculation of this formula data from wider research of 71 organizations in transitional countries in Southern and Eastern Europe was used. During mentioned wider research each organization was analyzed, resulting in reports covering wide range of data extracted into more than 40 indicators that served as a basis for several different research papers. Problems with difference of estimated values by different personnel or misunderstanding of questions by interviewed personnel were solved by asking for clarification and second estimation, common to simplified application of Delphi method used in articles of De Icaza et al. [33] and Radauceanu et al. [34]. Written reports from companies were used to detect inconsistencies in data, comparing qualitative with quantitative descriptions.

There are other approaches in measuring ICT adoption, besides by development of composite indicator as used in this paper:

- Subjective assessment by users on a questionnaire scale, e.g. "yes/no" or "1-10" scale (Thong and Yap [35]; Thong et al. [36]; Yang et al. [37])
- Subjective categorization by users or external party into defined qualitative categories, usually by intensity of adoption and usage (Howard [37]; Redoli et al. [38])
- Calculation of ICT adoption by single factor, like number of computers per employee, (Moore and Benbasat [39]; Golubeva and Merkuryeva [40]; El-Mashaleh [41])
- Quantitative assessment of ICT adoption, similar to composite indicator of ICT adoption is more usual in studies that measure trends in national economies, like Kauffman and Kumar [42] and Hanafizadeh et al. [43], who mainly utilize statistics on population usage of ICT to develop quantitative assessment of ICT adoption. However, there has not been much research with measuring similar indicator on national level.

$$CIICT = \frac{NoC}{NoE} + \frac{NoCC}{NoE} + \sum_{i=1}^{i=8} Cfi + \prod_{i=1}^{i=8}\left(\sqrt{\frac{NoCC}{NoE}} + Cf_i\right) + CDB + DBA \quad (3)$$

Where mentioned factors represent: CIICT = composite indicator of ICT adoption in company in its original form; NoC = Number of computers in the company; NoE = Number of employees in the company; NoCC = Number of computers connected to internal network in the company; Cf_i = Coverage of enterprise function by ICT, where for different values of i functions are: 1 – human resources, 2 – accountancy, 3 – financial, , 4 – technical, 5 commercial, 6 – administrative, 7 – legal, 8 – protection; Coverage of business function was estimated by IT staff, functional staff and top manage-ments as percentage of usual job in that function supported by ICT existing in the organization; DB = Existence of integrated company database (0=no, 1=yes); DBA = Database administrator present (0=no, 1=yes).

First addend in the formula was given as ratio between number of computers and number of employees. By using the ratio this factor becomes relative to organization's size. Second addend was introduced as extension of the first to emphasize importance of computer networks in a company. This factor will probably make first factor of the formula obsolete in several years, and replace it completely. First factor will not be as fit to measure ICT adoption in future companies as the second, because only computers that have ultimate security demands or otherwise special status will not be in network, even in small enterprises. Today, however, especially in small and medium enterprises we have a large number of unconnected computers so both addends were used. Third addend is a simple sum of coverage of business functions by information system. It has more impact on the final value, because practice and literature review like in Scheer and Habermann [44] or Scheer and Schneider [45] connects coverage of business functions by ICT and ICT adoption in organization. Fourth addend emphasizes importance of synergetic effect of ICT appliance in the company. Since business can be seen as chain with several interconnected functions, its strength is determined by the weakest link, and when all major business functions are fully covered, ICT adoption is much better than when one function is omitted, leaving weak link that will slow down other functions. In other words, adoption increase does not follow coverage of business function linearly, company with half of main business function covered by ICT compared to company with all main functions covered by ICT should be valued as much less than half successful as the second example in ICT adoption, because of the lack of synergy. Coverage of all functions in the organization by ICT, usually realized by implementation of all or most necessary ERP modules gives synergetic benefits. Fifth addend was treated as binary in original formula, representing existence of integrated database (0 if it does exist and 1 if it exists). The problem of integrating separate databases in organization is important in business adoption of ICT, and this factor values contribution to its solution. Sixth factor in used formula represented employment of worker with database administrator duties, again as binary value, 0 if none exists, and 1 if there are one or more employees. Tarafdar and Vaidya [46] compared companies with "Pioneer", "Advanced", "Late" and "Laggard" roles of ICT adoption, and indicative is that in Laggard case roles of database administrators were performed by staff from other functions, subsequently trained for those tasks. Importance of database administrator role for ICT adoption was also observed by Vogel et al. [47] and Van den Hoven [48].

Main goal of this indicator is to satisfy following requirements:

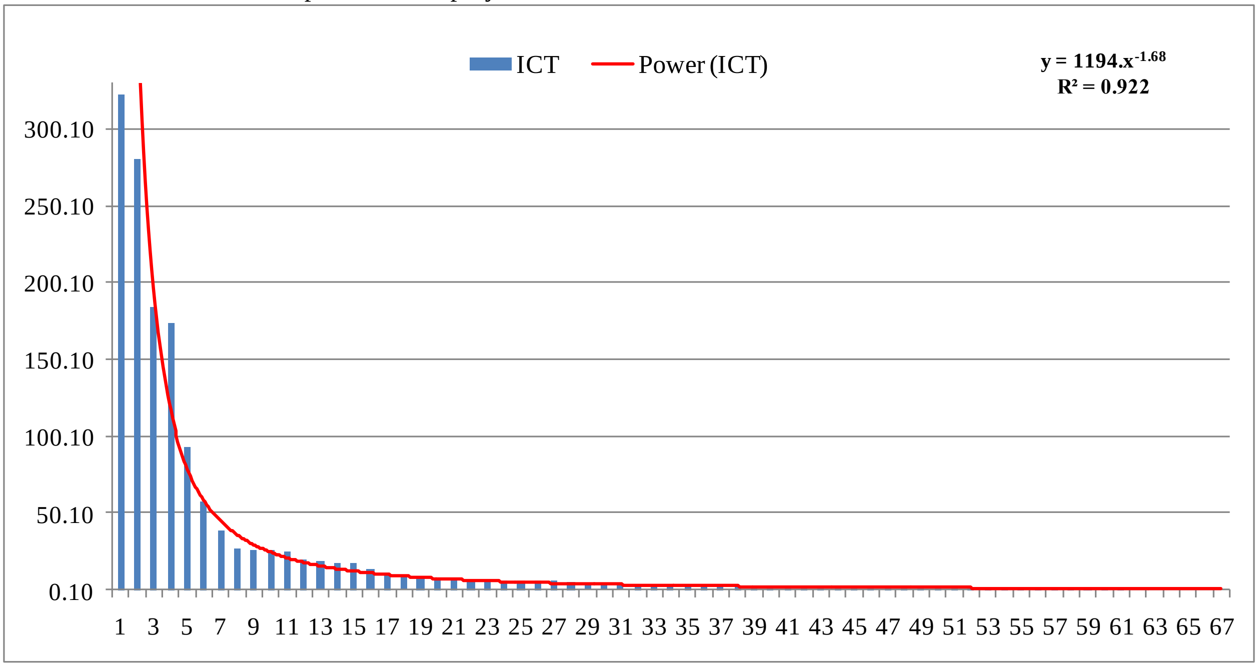
a) To take into consideration various different factors of ICT adoption in organization described in literature and observed during our consulting experience.

b) To maximize practical usability of the formula for other consultants and researchers, it should consist of data which can usually be easily collected during interview in a company, and be as simple as possible, but not simpler, according to famous Einstein recommendation – still retaining power to accurately describe level of ICT adoption;

c) To be as objective as possible, because of perceived tendency that in different organizations individuals have different criteria of subjective assessment of ICT adoption.

4. RESULTS

The occurrence of power law was measured in comparison with size of enterprises measured by number of employees, and profit per employee.



Source: Data from primary source, Authors' estimation of Pareto's parameters.

Fig.1. Power law distribution of values of ICT adoption indicator in 67 selected enterprises.

The corresponding density function, from Figure 1, for ICT indicator is:

$$f(z) = 1194 \cdot z^{-1-0.68}. \quad (4)$$

An estimate of the expected statistical error on the exponent α is given by http://www-personal.umich.edu/~mejn/courses/2006/cmplxsys899/

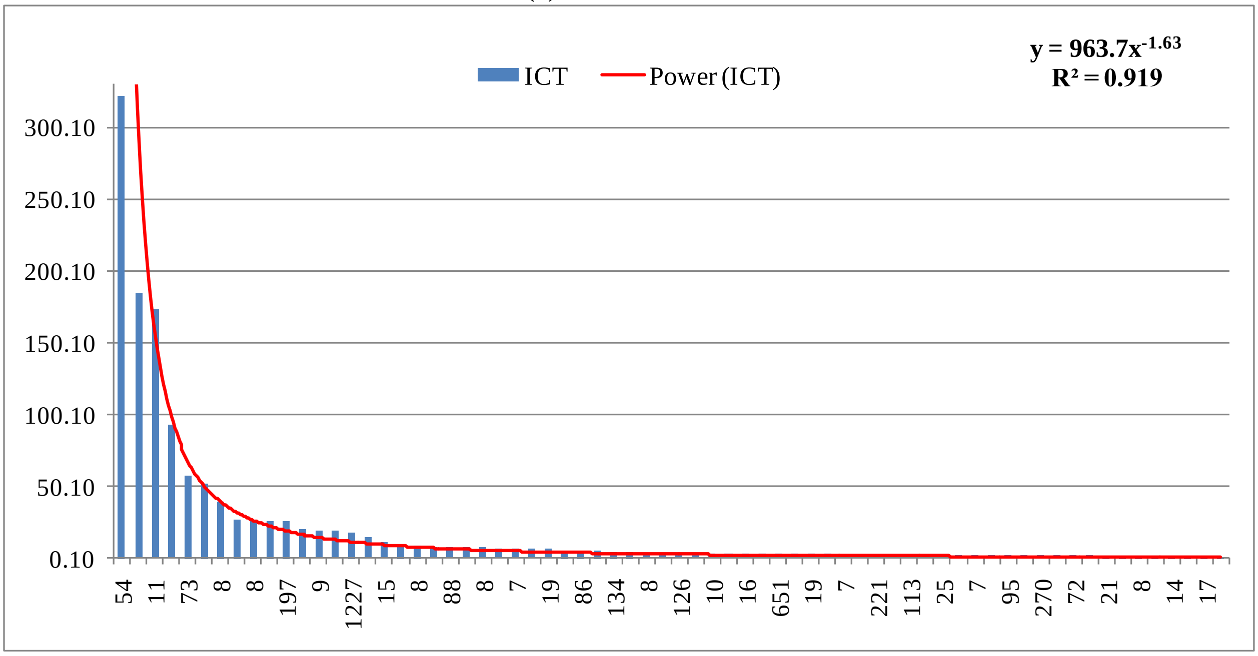
$$\sigma = \frac{\alpha}{\sqrt{n}} = 0.08 \qquad (5)$$

where n is number of observation.

The Pareto parameter is:

$$\alpha = 0.68 \pm 0.08. \qquad (6)$$

Power law has been checked between ICT adoption and size of the enterprises measured by the number of the employees.



Source: Data from primary source, Authors' estimation of Pareto's parameters.

Fig. 2. Power law distribution between ICT adoption indicator and the size of enterprises measured by number of employees.

The corresponding density function, from Figure 2, for ICT indicator is:

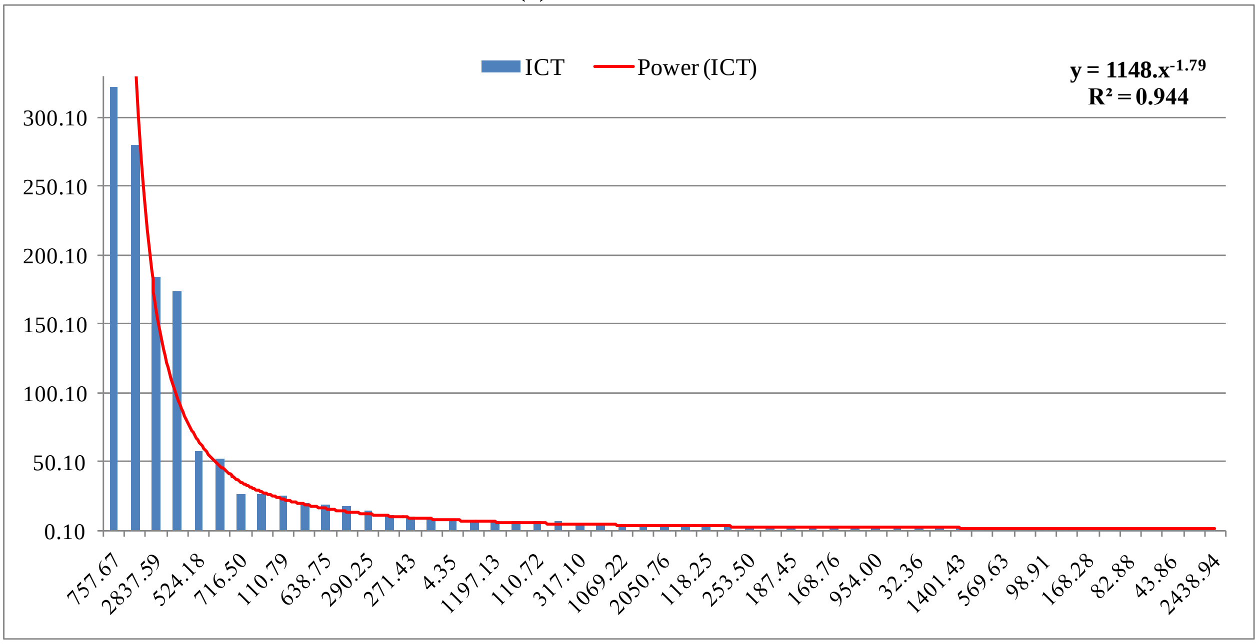
$$f(z) = 963.7 \cdot z^{-1-0.63} \qquad (7)$$

The Pareto parameter with the expected statistical error is:

$$\alpha = 0.63 \pm 0.07 \qquad (8)$$

where the expected statistical error on the exponent α is calculated by equation (5).

Power law between ICT adoption measured by composite indicator and profit per employee has also been analyzed. Results are given in Figure 3.



Source: Data from primary source, Authors' estimation of Pareto's parameters.

Fig.3. Power law distribution between ICT adoption indicator and the size of enterprises measured by profit per employee.

The corresponding density function, from Figure 3, for ICT indicator is:

$$f\left(z\right) = 1148 \cdot z^{-1-0.79} \tag{9}$$

The Pareto parameter is:

$$\alpha = 0.79 \pm 0.10. \tag{10}$$

From equations (6), (8), and (10), we can observe that the tail exponents of Pareto's distributions are smaller than 1, in all cases. Generally, empirical studies show that the value of α changes across different countries, and is typically in the range $1 < \alpha < 2$. In our three cases $\alpha < 1$, which means that ICT adoption in the Serbian organizations is undeveloped. In all cases the coefficient of determination (R^2) is pretty high (92% and 94%). These values indicate that the interpolation line very well fits the real ICT data.

5. CONCLUSIONS

This paper has two distinctive parts. After introduction remarks and explanation of power law and its occurrences outside physics, mostly in economy, sociology and business sciences, indicator which properties are tested is described. Formula proposed as composite indicator of ICT adoption is proposed as advancement over usual, mostly subjective methods of measuring ICT adoption in organization. It has already been successfully used in three studies, and in this study power law properties have been tested. The paper presents the occurrence of power law distribution of values of ICT adoption indicator in 67 selected enterprises. Described ICT indicator has been compared with firm size measured in number of employees, and profit per employee. In both cases, we found that the distribution of ICT adoption possesses properties of Pareto's law in the Serbian organization. Therefore, in all cases, ICT adoption is distributed according to Pareto's distributions with the tail exponent smaller than 1, which means that ICT adoption in the Serbian organizations is undeveloped. In all cases the coefficient of determination (R^2) is pretty high (above 90%), which indicates that the interpolation line very well fits the real ICT data. This is the first paper that shows the distribution of ICT adoption possesses properties of Pareto's law in the Serbian organizations.

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7. REFERENCES

[1] Adamic, L. A. (2007), *Zipf, Power-laws, and Pareto-a ranking tutorial*, Xerox Palo Alto Researches Center, Palo Alto, CA 94304, http://www.hpl.hp.com /research/idl/papers/ranking/ranking.html

[2] Newman, M.E.J. (2005), *Power laws, Pareto distributions and Zipf's law*. *Contemporary Physics*, Vol. 46, No. 5, pp. 323 – 351.

[3] Atkinson, A. B, Piketty T., Saez E. (2009), *Top incomes in the long run of history*, Working Paper 15408, National Bureau of Economic Research.

[4] Klass, O. S., Biham O., Levy M., Malcai O., Solomon S. (2004), *The Forbes 400, the Pareto Wealth Distribution and Efficient Markets*, The European Physical Journal B, 55, pp. 143-147.

[5] Solomon, S. (1999), *Generalized Lotka-Volterra Models, in "Aplications of Simulations to Social Sciences"*, eds. G. Balot and G. Weisbuch; Hemes Science Publications. http://xxx.lanl.gov/PS_cache/cond- mat/pdf/ 9901/9901250v1.pdf

[6] Zipf, G. K. (1932), *Selected studies of the principle of relative frequency in language*. Harvard University Pree. Cambridge. MA

[7] Mandelbrot, B. B. (1997), *Fractals and Scaling* in Finance in France, Springer, Berlin.

[8] Axtell, R. L. (2001), *Zipf distribution of U.S. firm sizes*. Science, 293 (5536), pp. 1818-1820.

[9] Stanley, M. H. R. Amaral L. A. N., Buldyrev S. V., Havlin S., Leschhron H., Maass P., Salinger M. A., and Stanley H. E. (1996), *Scaling behavior in the growth of companies*, Nature, 379, pp. 804-806.

[10] Price, D.J. de S. (1965), *Networks of Scientific Papers*, Science,149 (3683), pp. 510-515.

[11] Redner, S. 1998. *How popular is your paper? An empirical study of the citation distribution*. European Physical Journal B, 4, pp. 131-134.

[12] Adamic, L. A., Huberman B. A. (2000), *Power-Law Distribution of the World Wide Web*, Science, Vol. 287, no. 5461, p. 2115.

[13] Barabási A. L., Albert R. (1999), *Emergence of scaling in random networks*. Science, 286, pp. 509-512.

[14] Abello, J., Buchsbaum A., and Westbrook J. (1998), *A Functional Approach to External Graph Algorithms*, in Proceedings of the 6th European Symposium on Algorithms (Springer, Berlin), pp. 332-343.

[15] Aiello, W., Chung F., and Lu L. (2000), *A random graph model for massive graphs*, in Proceedings of the 32nd Annual ACM Symposium on Theory of Computing (Association for Computing Machinery, New York), pp. 171–180.

[16] Miyazima, S. L. Y, Nagamine T., Miyajima H. (2000), *Power-law distribution of family names in Japanese societies*, Physica A, 278, pp. 282-288.

[17] Bentley, A., Ormerod P., and Batty M. (2008), *Evolution and turnover in scaling systems, Working paper series*, paper 135, UCL Centre for Advanced Spatial Analysis University College London.

[18] Atkinson, A.B, Piketty,T. (2007), *Top Incomes over the Twentieth Century*. Oxford, UK: Oxford Univ. Press

[19] Yamamoto, K., Miyazima S., Koshal K. R., Yamada Y. (2002), *A model for distribution of high-tax payers*, Physica A, 314, pp. 743-748.

[20] Aoyama, H., Souma W., Nagahara Y., Okazaki M. P., Takayasu H., Takayasu M. (2000), *Pareto's law for income of individuals and debt of bankrupt companies*. Fractals, 8, pp. 293-300.

[21] Minović, J., Minović M., Milovanović M. (2009), *Modeling wealth distribution for 100 reachest people in South-Eastern Europe,* Proceedings of the 10th International Symposium on Operational Research SOR' 09, Slovenian Society Informatika, Nova Gorica, Slovenija, pp. 545-552.

[22] Nirei M., Souma W. (2007), *A two factor model of income distribution dynamics*. Rev. Income Wealth 53, pp. 440–59.

[23] Kleiber, C., Kotz S. (2003), *Statistical Size Distributions in Economics and Actuarial Sciences*. New York: Wiley.

[24] Clauset, A., Shalizi C. R., and Newman M. E. J. (2007), *Power-law distributions in empirical data.* http:// arxiv.org/abs/0706.1062v1.

[25] Gabaix, X. (2009), *Power Laws in Economics and Finance,* The Annual Review of Economics, 1, pp. 255–93.

[26] Gagnon, M.P., Legare, F., Labrecque, M., Fremont, P., Pluye, P., Gagnon, J., Car, J., Pagliari, C., Desmartis, M., Turcot, L. & Gravel, K., (2009), *Interventions for Promoting Information and Communication technologies Adoption in Healthcare Professionals,* The Cochrane Collaboration,Vol 2, pp.1-31.

[27] Cragg, P.B., (2002), *Benchmarking information technology practices in small firms*, European Journal of Information Systems, Vol. 11, pp. 267-282.

[28] Caldeira, M.M. and Ward, J.M., (2003), *Using resource-based theory to interpret the successful adoption and use of information systems and technology in manufacturing small and medium sized enterprises*, European Journal of Information Systems,Vol.12, pp.127-141.

[29] Ma, X., Lombardo, S., Sciaba, E.S., (2008), *Learning mechanisms in a technology based organizational change programme: an exploratory study between Chinese and Norwegian corporations*, International Journal of Technology Management, Vol.41 No. 1/2, pp.75-95.

[30] Čudanov,M., Jaško,O., Jevtic,M., (2009), *Influence of Information and Communication Technologies on Decentralization of Organizational Structure.* Computer Science and Information Systems Journal, 6, pp. 93-108.

[31] Čudanov, M, Jaško, O, Savoiu, G, (2010), *Interrelationships of Organization Size, Information and Communication Technology Adoption*. Journal of Applied Quantitative Methods, 5/1, pp 29-40

[32] Čudanov M, Jaško O, (2010), *Adoption of information and communication technologies and dominant management orientation in organizations*. Behaviour and Information Technologies, online first available on: http://www.informaworld.com/smpp/content ~db=all~content=a923093688~frm=titlelink

[33] De Icaza, Alfonso and Pick, J., (1998), *Quantitative Model of Size and Complexity of Prospective Geographic Information Systems for Regional Governments in Mexico*. Proceedings of Americas Conference on Information Systems (AMCIS) Paper No. 134. pp. 396-398, Available from: http://aisel.aisnet.org/cgi/viewcontent.cgi?article=1561&context=amcis1998 [last accessed on 12.10.2011.]

[34] Radauceanu, A., Chouanière, D., Wild, P., Héry M., and. Créau Y., (2008), *Assessment of asbestos exposure in asbestos removal operations: Proposal of a task exposure matrix.* Archives des Maladies Professionnelles et de l'Environnement, Vol. 69, Iss. 4, pp. 586-592

[35] Thong, J.Y.L., and Yap, C.S., (1995), *CEO characteristics, organizational characteristics and information technology adoption in small businesses. Omega* – The International Journal of Management Science. 23, pp. 429-442.

[36] Thong, J.Y.L., Yap, C.S. and Ramen, K., (1996), *Top management support, external expertise and information systems implementations in small businesses*, Information Systems Research, 7, pp. 248-267.

[37] Howard, K., (1997), *IT Means Business? A survey of attitudes in smaller businesses to information and technology*, London, UK: Institute of Management.

[38] Redoli, J., Mompó, R., García-Díez, R.J., López-Coronado, M., (2008), *A model for the assessment and development of Internet-based information and communication services in small and medium enterprises*, Technovation, Vol. 28 No. 7, pp. 424-435.

[39] Moore, G.C., and Benbasat, I., (1991), *Development of an Instrument to Measure the Perceptions of Adopting an Information Technology Innovation*. Information Systems Research, 2, pp. 192-222.

[40] Golubeva, A., Merkuryeva I., (2006), *Demand for Online Government Services: Case Studies from St. Petersburg.* Information Polity Vol.11,No.3–4, pp.241–54.

[41] El-Mashaleh, M.S., (2007), *Benchmarking information technology utilization in the construction industry in Jordan*. Journal of Information Technology in Construction, Vol. 12, No. 19, pp. 279-291.

[42] Kauffman, R. J., and Kumar, A., (2005). *A critical assessment of the capabilities of five measures for ICT development*. MIS Research paper, available from: http:// citeseerx.ist.psu.edu/viewdoc/download [last accessed 04 October 2011]

[43] Hanafizadeh, P., Hanafizadeh, M.R., Khodabakhshi, M., (2009), *Extracting Core ICT Indicators Using Entropy Method.* The Information Society, Vol. 25, pp. 236–247.

[44] Scheer, A.W., and Habermann, F., (2000), *Making ERP a Success*. Communications of the ACM,43,pp.57-61.

[45] Scheer, A.W, and Schneider, K., (2006), *ARIS — Architecture of Integrated Information Systems*, in Bernus, P., Mertins, K., and Schmidt, G., International Handbooks on Information Systems, 2006, Part Three - Handbook on Architectures of Information Systems, pp. 605-623.

[46] Tarafdar, M. and Vaidya S.D., (2006), *Challenges in the Adoption of E-Commerce Technologies in India: The Role of Organizational Factors*. International Journal of Information Management, vol. 26, pp. 428-441.

[47] Vogel, D.R., Orwig, R., Dean, D., Lee, J. and Arthur, C., (1993), *Reegineering with Enterprise Analyzer.* Proceedings of the 26th Annual Hawaiian International Conference on System Science (HICSS), Los Alamitos, California, USA, Vol 3, pp. 127 – 136.

[48] Van den Hoven, J., (1999), *Information resource management: Stewards of data.* Information Systems Management, Vol. 16 No. 188-91.