MUNI
ECON

# XXII. MEZINÁRODNÍ KOLOKVIUM O REGIONÁLNÍCH VĚDÁCH. SBORNÍK PŘÍSPĚVKŮ

# 22ND INTERNATIONAL COLLOQUIUM ON REGIONAL SCIENCES. CONFERENCE PROCEEDINGS

Place: Velké Bílovice (Czech Republic)
June 12-16, 2019

Publisher: Masarykova univerzita (Masaryk University Press), Brno

**Edited by:**
Viktorie KLÍMOVÁ
Vladimír ŽÍTEK
*(Masarykova univerzita / Masaryk University, Czech Republic)*

**Vzor citace / Citation example:**

AUTOR, A. Název článku. In Klímová, V., Žítek, V. (eds.) *XXII. mezinárodní kolokvium o regionálních vědách. Sborník příspěvků.* Brno: Masarykova univerzita, 2019. s. 1–5. ISBN 978-80-210-9268-6. DOI.

AUTHOR, A. Title of paper. In Klímová, V., Žítek, V. (eds.) 22nd *International Colloquium on Regional Sciences. Conference Proceedings.* Brno: Masaryk University Press, 2019. pp. 1–5. ISBN 978-80-210-9268-6. DOI.


ISBN 978-80-210-9268-6 (online : pdf)

DOI: 10.5817/CZ.MUNI.P210-9268-2019-22

# EFFICIENCY OF INTELLECTUAL CAPITAL GENERATION: A DEA ANALYSIS OF SELECTED EU REGIONS

## Efektivnost tvorby intelektuálního kapitálu: DEA analýza vybraných regionů EU

**HENRY JUNIOR ANDERSON**

**SOLOMON GYAMFI**

**JAN STEJSKAL**

*Ústav ekonomických věd* | *Institute of Economic Sciences*
*Fakulta ekonomicko-správní* | *Faculty of Economics and Administration*
*Univerzita Pardubice* | *University of Pardubice*
✉ *Studentská 95, 532 10 Pardubice, Czech Republic*
*E-mail: henry.anderson@upce.cz, solomon.gyamfi@upce.cz, jan.stejskal@upce.cz*

***Annotation***
*Intellectual capital generation has gradually been entrenched as a measure of firm and regional competitive advantage in this era of knowledge economy. Firms, regions and countries and even international organisations around the world have rigorously engaged in the creation of property rights for control and usage. However, as regional innovative performance has been directly connected with intellectual capital creation, we question whether regions with high innovation prowess efficiently employ the scarce financial and cognitive resources that are harnessed for the manifestation of intellectual capital and property rights. Hence, using a multi-stage DEA approach and data of ten countries from European Innovation Scoreboard, we aim to comparatively compute the efficiency scores of innovation leaders and strong innovators to reveal the efficiency of resource inputs. Results at the first-stage revealed a mixed efficiency performance amongst countries whilst second-stage analysis with intermediate inputs revealed a dominance of innovation leaders on the efficiency ranking but eventually innovative leaders were found to be generally efficient in financial and cognitive resources employed in intellectual capital generation. We further gave recommendations on way of bolstering efficiency scores of countries.*

***Key words***
*efficiency, intellectual capital, DEA analysis*

***Anotace***
*Tvorba duševního kapitálu se v období vzrůstu zájmu o znalostní ekonomiku postupně etablovala jako měřítko regionální konkurenční výhody. Firmy, regiony, země a dokonce i mezinárodní organizace po celém světě se důsledně zabývají tvorbou vlastnických práv k jejich komerčnímu využití. Vzhledem k tomu, že tvorba inovací v regionech je přímo spojena s tvorbou intelektuálního kapitálu, je nezbytné diskutovat, zda regiony s vysokou inovační schopností efektivně využívají vzácných finančních a znalostních zdrojů, které jsou využívány k tvorbě duševního kapitálu a následnému komerčnímu využití vlastnických práv. Studie využívá vícestupňovou DEA analýzu a na datech European Innovation Scoreboard z desíti vybraných zemí EU analyzuje efektivnosti znalostních procesů v jednotlivých regionech. Výsledky v první fázi ukázaly proměnlivou efektivnost inovačních výkonů mezi zeměmi. Výsledky druhé fáze ukazují, že inovativní vůdci jsou obecně efektivní ve využívání finančních a kognitivních zdrojů k tvorbě intelektuálního kapitálu. Součástí řešení jsou i doporučení na zvýšení efektivnosti v dalších regionech EU.*

***Klíčová slova***
*efektivnost, znalostní kapitál, DEA analýza*

***JEL classification:*** *O34, P35*

## 1. Introduction

Innovation in the knowledge-based economy is dependent on the quality knowledge generation capacity within the economic ecosystem of countries in contemporary times. Intellectual capital comprises of diverse forms of intellectual material that facilitates growth and value creation for nations and firms. Intellectual Capital can be likened to knowledge capital and other intangible resources which put together constitute the intellectual assets of a nation or an organization (Guthrie, 2001). Kianto et al. (2014) defined Intellectual Capital as putting together all intangible and knowledge-related resources needed and used by an organization's productive processes to create value for consumers. Pulic (2008) concurs with Kianto et al. (2014) and mainly attributed IC to those individuals or employees with the abilities to combine and transform knowledge into product and services which create value for the nation or company.

In the era of the industrial economy, a nation's or company's wealth was determined by its ability to ensure mass production of goods and services. However, in the contemporary epoch, the production of knowledge has become predominant in what most scholars refer to as the knowledge economy. Economic value is created not just through the quality of production rather, by the knowledge of the human resource (Kai Wah Chu et al, 2011) hence, knowledge production is imperative for competitive advantage Pulic, (2008). Likewise, continuous improvement in all business aspect is dependent on the knowledge, talent, and creativity of people. A growing number of researches has found a strong correlation between IC and economic (business) performance (Firer, Williams, 2003; Shiu, 2006; Ze´ghal, Maaloul, 2010; Komnenic, Pokrajčić, 2012; Vishnu Kumar Gupta, 2014; Kai Wah Chu, Hang Chan, Wu, 2011) which ultimately determines the regional innovation performance.

We are of the view that strong innovative performance of any country can be attributed to the efficient generation of intellectual capital and also by the support from the government geared towards innovation and research through research and development expenditure of government research institutes and public institute of higher learning. Carayannis, Grigoroudis, and Goletsis (2015) using a multi stage and multi-level analysis found large differences regarding the efficiency scores of the different stages and levels of 23 selected EU member states revealing the presence of significant divergences from the expected norm concerning. Afzal (2014) also investigated national innovation systems' input–output components of 20 developing countries with both DEA analysis and TOBIT regression. He eventually suggested that secondary school enrolment ratio; the labour force (ages 15–65), as a percentage of the total population; and domestic credit expansion by the business sector, as a percentage of GDP should be focused on if innovation is to be improved. However, our research adds to the this collection by using a multi-stage DEA analysis to assess the efficiency of intellectual capital generation of innovation leaders and strong innovators revealing their core and intermediate process (in)efficiency.

Thus, the main purpose of the research is to comparatively compute the intellectual capital generation efficiency of innovative leaders and strong innovators and also reveal the driver of such efficiency or inefficiency. These groups, consisting of 10 countries, were focused on as they occupied the highest ranks on the innovation scores on the European Commission (2018) as we are of the view that efficient scores of intellectual capital generation is a antecedent of higher innovation. The remaining sections are organized as follows; the review of relevant literature on intellectual capital which outlines the various aspect of the IC concept follows right after the introductory part. Necessary questions are raised and gaps in the literature stock identified which our empirical analysis will seek to answer and fill the void.

## 2. Literature review

The European Innovation Scoreboard classifies human resources, excellent and open research systems as well as finance and support as enablers for innovation performance. This means that human resource, the custodians and repository of knowledge of the firm intellectual assets is key if high innovation results must be achieved. Intellectual Capital is defined as the ownership of the knowledge, experience, technology, skills as well as better customer relation that enable a company to gain a competitive notch in its business sector. Zeghal and Maaloul (2010) state that Intellectual Capital consists of all the company knowledge employed in the firm's businesses to generate value. Alipour (2012) on the concept of Intellectual Capital, defines it as the intangible knowledge assets rooted in the company, He further classifies Intellectual capital as comprising of the intellectual competences, resources, and property of the organization. In most Intellectual capital literature, the acceptable classification of IC consists of three main elements, which include; human capital (HC), structural capital (SC) and relational capital (Bhuyan, 2015 and Alipour, 2012, Ornek & Ayas, 2015). Moreso, Schiuma et al. (2008), in addition to the world-wide accepted classification, included organizational capital and social capital to the list whilst naming the relational capital as stakeholder capital to encapsulate the broader perspective of the stakeholder view of the firm ownership. In contrast, the OECD classifies IC as comprising of two main aspects that are; Human Capital and Structural Capital (OECD, 2000). Slarter and Narver (2000) suggest that knowledge (intellectual capital) is

generated through four main generic strategies. Amongst them is the collaborative knowledge generation strategy which involves the creation of intelligence mainly with and from other organizations. Through research expenditure in the business and public sector as well as investment by venture capitalist, the innovation environment is created to enable firms to collaborate for generating intellectual capital. Intellectual capital creation is as necessary for a firm's financial performance and growth as the nation's competitiveness in the global economy. This notion is enshrined in the Europe 2020 agenda for smart growth based on knowledge and innovation. It is based on this idea that the nations of the European Union are ranked on the innovation scoreboard. Firms generate new knowledge through various activities and interactions which result in knowledge co-generation (Carayannis, Grigoroudis, 2016).

Most empirical studies have found that intellectual capital has a positive relationship with innovative performance. Xu and Wang (2018) in their paper assessing IC, financial performance and sustainable growth of Korean companies found that Intellectual Capital improves firm financial performance aiding in wealth creation in South Korea at the same time affecting sustainable growth of businesses. In the Chinese context, Yuqian and Dayuan, (2015) assess the effect of intellectual capital on innovative performance and found that the former influences the latter positively mediated by knowledge-based dynamic capabilities. In a case study of Italian SMEs, Mazro & Scarpino (2016) find a rather interesting result of the collaboration for an intellectual capital generation where the SMEs' external stakeholders constitute the main source for intellectual capital improvement. Jordao & Almeida (2017) analysed the influence of Intellectual capital on long term corporate performance of Brazilian companies and find that intellectual capital systematically increases financial performance in the long round. Bontis warned that despite the massive proliferation of the intellectual capital concept which has spurred more intellectual capital creation, its usability, and frequent usability is paramount else, the knowledge created may fade out (Bontis, 1999).

As shown by the numerous empirical works of literature reviewed, most researches focus on the effects of intellectual capital on innovation performance and firm profitability. We refer to these studies as focusing mainly on the output and effects with the exception of the European Innovation scoreboard which has created comprehensive indicators to measure yet the output performance of EU countries, it does gives us the motivation to explore the efficacy of the enabler indicators that contribute to the overall innovation performance of the EU strong innovators and innovative leaders using a Data Envelopment Analysis to compare these groups. The research seeks to answer this research question:

- How efficient do strong and innovative leaders generate intellectual capital for innovation performance?
- Do innovative leaders have generally higher efficiency scores? If yes, why?

## 3. Data and Methodology

The research resorted to the use of data from the European Commission (2018). This data represents a yearly comprehensive analysis of the innovation performance of European Union countries revealing their strengths and weaknesses in intellectual capital creation. The survey ranks countries according to their relative scores with the EU average of innovation thereby classifying them as innovation leaders, strong innovators, moderate and modest innovators. The data focused on countries that had featured among the innovation leaders and strong innovators summing up to ten (10) countries. They were selected because the research wanted to focus on highly innovative countries and how efficient they perform in generating intellectual capital and whether their essentially high innovation scores are connotes with their efficiency. The variables were also selected in line with A collection of inputs and countries selected is thereof presented in Table 1.

***Table 1: Selected country and variables for the research.***

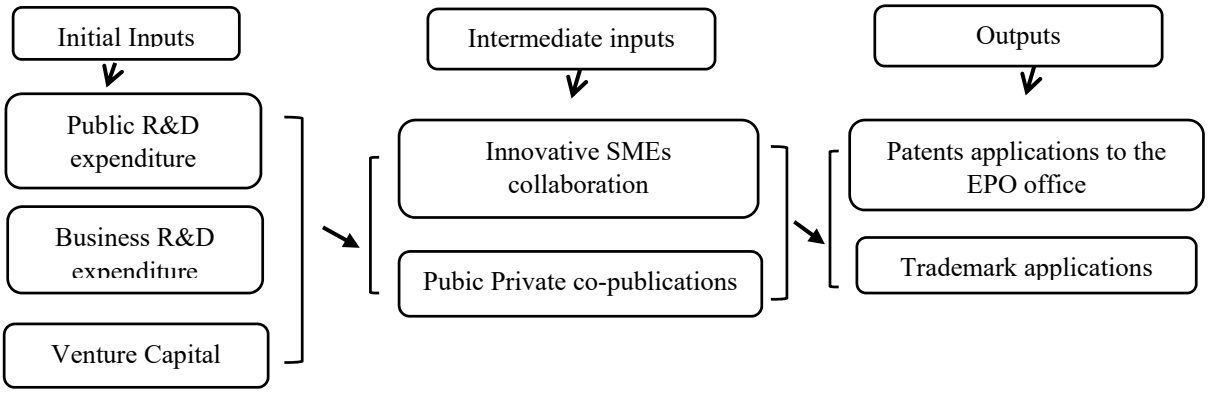
| Innovation leaders | Strong Innovators | Inputs Variables | Intermediate variables | Output variables |
|---|---|---|---|---|
| Finland (FI) | Germany (DE) | Public R&D expenditure (PR&D) | SMEs collaboration with others. (SMEColl) | Patent applications to the EPO office (PAT) |
| Sweden (SW) | France (FR) | Business R&D expenditure (BR&D) | Public private publications (PPP) | Trademark applications. (TRD) |
| United Kingdom (UK) | Luxembourg (LU) | Venture Capital (VCI) | | |
| Denmark (DK) | Netherlands (NL) | | | |
| | Austria (AT) | | | |
| | Belgium (BE) | | | |

*Source: European Commission (2018)*

Regarding the analytical tool assessed the used of parametric and non-parametric test of efficiency and we opted for a non-parametric test of efficiency Among several parametric and non-parametric techniques, Data Envelopment Analysis (DEA) has been widely applied to measure the relative efficiency of multiple decision making units (DMUs) that transform multiple inputs to multiple outputs in a similar context. The fact that, unlike parametric models, DEA does not require an explicit function that relates inputs to outputs is considered to be one of the main advantages of DEA. Data envelopment analysis was used as the tool of analysis of the efficiency at which intellectual capital is generated by countries. Thus, DEA models focus exactly on input-output efficiency of innovation systems, where each country or region is considered as an independent DMU (Cao 2011).

To capture the various stages of intellectual capital generation as used by (Carrayannis et al. 2015, Kao 2014) and not to assume a linear production function for patent and trademark generation, the research employed the multi stage innovation process that captures the introductions of variation of capital, the cooperation tendencies or output required and the eventual output to be measured. Based on the elements of European Commission (2018) and the work of Carrayanis et al (2015), Afzal (2014) and other literature on intellectual capital, we created a model for the research as shown in Figure 1 below. The research follows the structure below as shown in Figure 1 below. To acquire the efficiency scores, we opted for the multiplicative instead of the additive method since this more accurately reflects the scores of the Decision making Units (DMU's). In applying the DEA model, we opted for the CCR (Charnes, Cooper and Rhodes) model. The BCC model is based on the CCR (Charnes, Cooper and Rhodes) model. The CCR model assumes constant returns to scale and produces efficiency scores of up to one (1). A DMU with a score of less than is regarded as inefficient where as a score of up to one (1) is regarded as efficient.

***Fig. 1: Theoretical Model of DEA analysis of***




*Source: Based on the literature Carrayanis et al. 2015; Afzal 2014; European Commission (2018)*

### 3.1 Data Envelopment Analysis (DEA): Multi-stage process

As noted by several scholars, the two stage modelling is a rather simplified approach which could potentially help draw a line between innovation and invention and also enable the comprehension of complexity of intellectual capital generation process (Kai 2014, Carrayannis et al. 2015). Many authors pre suppose that the study of innovation in isolation can give misleading results (Carayannis, Provance, 2008; Cruz-Cázares, Bayona-Sáez, García-Marco, 2013, Chilingerian, Sherman, 2011; Ebrahimnejad, Tavana, Lotfi, Shahverdi, Yousefpour, 2014; Kao, Hwang, 2008; Matthews, 2013) because costs regarding some inputs now may have already been incurred. Furthermore, the European Union document on diffusion of innovation in 2009 duly recognizes cooperation as the very significant catalyst in the creation of intellectual capital. Hence, the existence of a complex knowledge production function in the intellectual capital generation process, captures the level of raw capital input, the catalytic process and expected output generated similar to Mode 3 function by Carayannis, Campbell, (2009). Even more, given the existence of several involved actors, (universities, research institutions, business enterprises, governmental organizations, etc.), we consider intellectual capital generation as an interactive, networking and collaboration process rather than a linear generation. Efficiency scores calculated at the first stage are multiplied with the efficiency scores at the second stage.

## 4. Results and Analysis

Below is the descriptive statistics of the innovation scores of the countries selected for the efficiency analysis.

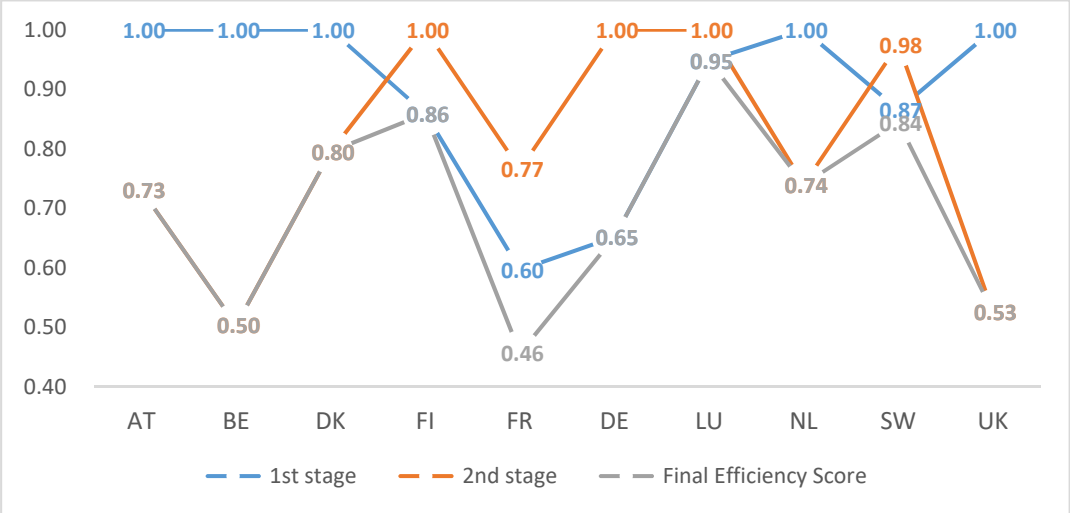
***Tab. 2: Descriptive statistics of countries selected.***

| | PR&D | VCI | BR&D | SMECOLL | PPPUB | PAT | TRD |
|---|---|---|---|---|---|---|---|
| Valid | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| Missing | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mean | 117.350 | 125.190 | 138.020 | 148.140 | 140.370 | 136.430 | 149.400 |
| Std. deviation | 27.794 | 57.158 | 45.678 | 49.611 | 35.161 | 55.927 | 52.421 |
| Minimum | 64.600 | 63.300 | 51.900 | 80.000 | 79.500 | 47.500 | 90.300 |
| Maximum | 146.000 | 205.500 | 193.500 | 217.400 | 201.300 | 223.700 | 278.700 |

*Source: Authors' analysis of European Commission (2018)*

Using data from the European Commission (2018), at constant returns to scale, we run a multi-stage DEA analysis of innovation leaders and strong innovators in their efforts to generate intellectual capital measured as patent applications and trademark applications submitted to the European Patent Office. In the diagram below, we provided a relative efficiency scores at both stages and the eventual efficiency score of the countries considered using DEA technique.

***Fig. 2: DEA analysis of Innovation leaders and Strong***




*Source: Author's own Computation.*

From Figure 2, it could be seen that in the first stage of innovation analysis produced mixed results as the innovation leaders together with the innovation followers recorded higher than one another. France, Germany, Finland and Sweden were revealed to be the countries that were relatively inefficient in the production of intellectual capital. This implies that when we consider the inputs of venture capital, public and business expenditure invested in public and private institutions, in relative terms, these countries have less efficient processes of utilization of these input resources. This could be interpreted in the context of causality such that invested may not be entirely oriented to research or outright misapplication or inefficiency of resource utilization even though firm investments may be the weakest strength of France and Sweden unlike Germany. These findings of especially Austria, Belgium, Denmark and Finland are contrary to the findings Pan, Hung and Lu (2010) who researched on Asian and European countries to measure magnitude of performance difference; however, it concurred the results of Cullman, Schmidt-Ehmcke, Zlocyzsti (2009) who researched on the relative efficiency of knowledge production in OECD countries.

Results of second analysis reveals only 3 relatively efficient countries, two of which are innovation leaders, making up 75% of the pie. Although Sweden and Denmark were the next closely related countries, largely the rest of the inefficient countries were composed of the strong innovators. This goes to imply that countries with higher innovation performance equivalently exhibits an efficient usage of the inputs, that is firm- to- firm cooperation as well as public private sectors collaboration in publications of research results. This also largely shows that firms that firms-to-firm cooperation is not adequately harnessed among the less efficient countries, namely, Belgium, Austria, Netherland, France, Denmark and Sweden even as cooperation has been largely publicized as a strong mediator and antecedent in creation of intellectual capital. These findings are concurred by the work of Broekel, Buerger, Brenner (2015), Broekel (2012) and the ideas Cai (2011) who studied innovative efficiency of 22

countries; he recommended that market environment, governance, education system and even ICT infrastructure affects regional capacity to be innovative.

Final efficiency scores of the countries assessed at constant returns to scale using the multiplicative model revealed that even though none of the countries assessed was found to be efficient, the countries that obtained the highest portion of efficiency scores were largely from innovation leaders namely, Luxembourg, Finland, Sweden and Denmark as the top four member states bar United Kingdom which was next to the two lowest efficient countries, Belgium and France chronologically. This implies that despite the strengths and weakness of countries innovation poles, they may always find means of notching up their innovation targets but cannot underestimate the need for cooperation intensity as proved by results and other studies mentioned above. Eventual efficiency score reveals 80% of the innovation leaders formed the top 5% of the efficient countries at constant returns to scale in the generation of intellectual capital. Inadvertently revealing innovation leaders is largely more efficient in intellectual capital generation than strong innovators at a constant return to scale. Results of research also further concurs the work of Cai (2011).

## 5. Conclusion

The research set out to assess the efficiency scores and performance of innovative leaders- Finland, Sweden, United Kingdom, Denmark and strong innovators- Germany France, Luxembourg, Netherlands, Austria, and Belgium. Using the multi-stage DEA approach commercialized by various authors with the objective of capturing all levels of knowledge production processes we conducted the research in this mold. Initial stage analysis conducted portrayed public research and expenditure, venture capital and business research and expenditure as the initial inputs whilst intermediate inputs, SMEs collaboration and public and private sector publication were held as the output variables; intermediate inputs were thereon used as inputs in the second analysis and the scores for both stages were multiplied to acquire the total efficiency score.

The first stage analysis that postulated financial investments as basic inputs revealed mixed efficiency scores between both the innovative leaders and strong innovators as their efficiency scores such that out of the four, only Denmark and United Kingdom had efficient scores making up 50% of their rank whilst Austria, Belgium and Netherland also had efficient scores for the strong innovators. Second stage of the analysis focused on primarily on cooperation of SMEs and the public and private sector. In that Innovative leaders formed 75 % of the efficient member states making up three (3) out of the four (4) efficient countries. Eventual efficiency scores also revealed innovative leaders with the highest efficiency even though no country was found efficient. Luxembourg , Finland, Sweden and Denmark all innovative leaders occupied the top 4 most efficient countries effectively revealing innovative leaders as more efficient as intellectual capital generation than strong innovators. The question of what makes them more efficient can be drawn from the second analysis which revealed the innovative leaders operating with more efficiency when we measured basically SMEs collaboration and public private co-publications, essentially cooperation. Cooperation seems to be the strongest factor that cuts across all innovative leaders even though countries may have different regional strength; it has even further been buttressed by the most researchers and the European Commission as well.

We recommend that not a drastic shift but a focus on not just firm-to-firm cooperation and firm-to-academia but a more concerted effort to hinge and organize efforts to create patents and trademarks on openness of private, public, Universities and NGOs as well. We also recommend healthy benchmarking practices among countries and a more active interactions at all levels of public organizations and private ventures despite the need to also compete for the good of the countries concerned and European Union eventually.

## Literature

[1] AFZAL, M. N. I., (2014). An empirical investigation of the National Innovation System (NIS) using Data Envelopment Analysis (DEA) and the TOBIT model. *International Review of Applied Economics*, vol. 28, no. 4, pp.507-523. DOI 10.1080/02692171.2014.896880.

[2] BONTIS, N., (2001). Managing organizational knowledge by diagnosing intellectual capital: framing and advancing the state of the field. In: *Knowledge management and business model innovation*. IGI Global, pp. 267-297. DOI 10.4018/978-1-878289-98-8.ch016.

[3] BROEKEL, T., (2012). Collaboration intensity and regional innovation efficiency in Germany—a conditional efficiency approach. *Industry and Innovation*, vol. 19, no. 2, pp. 155 - 179. DOI 10.1080/ 13662716.2012.650884.

[4] BROEKEL, T., BRENNER, T., BUERGER, M., (2015). An investigation of the relation between cooperation intensity and the innovative success of German regions. *Spatial Economic Analysis*, vol. 10, no. 1, pp. 52-78. DOI 10.1080/17421772.2014.992359.

[5] CAI, Y., (2011). Factors affecting the efficiency of the BRICSs' national innovation systems: A comparative study based on DEA and Panel Data Analysis. *Economics Discussion Paper*, no. 2011-52. DOI 10.2139/ssrn.1974368
[6] CARAYANNIS, E., GRIGOROUDIS, E., (2016). Quadruple innovation helix and smart specialization: knowledge production and national competitiveness. *Foresight and STI governance*, vol. 10, no. 1, pp. 31–42. ISSN 2500-2597. DOI 10.17323 / 1995-459X.2016.1.31.42.
[7] CARAYANNIS, E. G., CAMPBELL, D. F., (2012). Mode 3 knowledge production in quadruple helix innovation systems. In *Mode 3 knowledge production in quadruple helix innovation systems* (pp. 1-63). New York, NY: Springer. DOI 10.1007/978-1-4614-2062-0_1.
[8] CARAYANNIS, E. G., PROVANCE, M., (2008). Measuring firm innovativeness: towards a composite innovation index built on firm innovative posture, propensity and performance attributes. *International Journal of Innovation and Regional Development*, vol. 1, no. 1, pp. 90-107.
[9] CARAYANNIS, E. G., GOLETSIS, Y., GRIGOROUDIS, E., (2015). Multi-level multi-stage efficiency measurement: the case of innovation systems. *Operational Research*, vol. 15, no. 2, pp. 253 -274. DOI 10.1007/s12351-015-0176-y.
[10] CHILINGERIAN, J. A., SHERMAN, H. D., COOPER, W., SEIFORD, L. M., ZHU, J., (2011). *Handbook of Data Envelopment Analysis*. 2nd ed. New York, NY: Springer. ISBN: 978-1-4419-6150-1. DOI 10.1007/978-1-4419-6151-8.
[11] CULLMANN, A., SCHMIDT-EHMCKE, J., ZLOCZYSTI, P., (2009). Innovation, R&D efficiency and the impact of the regulatory environment: A two-stage semi-parametric DEA approach. DIW Berlin Discussion Paper No. 883. Available from: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1460709. DOI 10.2139/ssrn.1460709.
[12] EUROPEAN COMISSION (2018). European Innovation Scoreboard 2018. Available from: https://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en
[13] EBRAHIMNEJAD, A., TAVANA, M., LOTFI, F. H., SHAHVERDI, R., YOUSEFPOUR, M., (2014). A three-stage data envelopment analysis model with application to banking industry. *Measurement*, vol. 49, pp. 308 -319. DOI 10.1016/j.measurement.2013.11.043.
[14] FIRER, S., MITCHELL WILLIAMS, S., (2003). Intellectual capital and traditional measures of corporate performance. *Journal of intellectual capital*, vol. 4, no. 3, pp. 348-360. ISSN 1469-1930. DOI 10.1108/14691930310487806.
[15] GUTHRIE, J., (2001). The Management, Measurement and the Reporting of Intellectual Capital. *Journal of Intellectual Capital*, vol. 2, no. 1, pp. 27-41. ISSN 1469-1930. DOI 10.1108/14691930110380473.
[16] HAN, Y., LI, D., (2015). Effects of intellectual capital on innovative performance: the role of knowledge-based dynamic capability. *Management decision*, vol. 53, no. 1, pp. 40-56. ISSN 0025-1747. DOI 10.1108/MD-08-2013-0411.
[17] JORDÃO, R. V. D., ALMEIDA, V. R. D., (2017). Performance measurement, intellectual capital and financial sustainability. *Journal of intellectual capital*, vol. 18, no. 3, pp. 643-666. DOI 10.1108 / JIC-11-2016-0115.
[18] KAI WAH CHU, S., HANG CHAN, K., WU, W. W., (2011). Charting intellectual capital performance of the gateway to china. *Journal of intellectual capital*, vol. 12, no. 2, pp. 249-276. ISSN1469-1930. DOI 10.1108/14691931111123412.
[19] KAO, C., HWANG, S. N., (2008). Efficiency decomposition in two-stage data envelopment analysis: An application to non-life insurance companies in Taiwan. *European journal of operational research*, vol. 185, no. 1, pp.418-429. DOI 10.1016/j.ejor.2006.11.041.
[20] KIANTO, A., RITALA, P., SPENDER, J. C., VANHALA, M., (2014). The interaction of intellectual capital assets and knowledge management practices in organizational value creation, *Journal of intellectual capital*, vol. 15, no. 3, pp. 362–375. ISSN 1469-1930. DOI 10.1108/JIC-05-2014-0059.
[21] KOMNENIC, B., POKRAJČIĆ, D., (2012). Intellectual capital and corporate performance of MNCS in Serbia. *Journal of intellectual capital*, vol. 13, no. 1, pp. 106-119. ISSN 1469-1930. DOI 10.1108/14691931211196231.
[22] MARZO, G., SCARPINO, E., (2016). Exploring intellectual capital management in smes: an in-depth Italian case study. *Journal of intellectual capital*, vol. 17, no. 1, pp. 27-51. ISSN 1469-1930. DOI 10.1108/JIC-09-2015-0075.
[23] MATTHEWS, K., (2013). Risk management and managerial efficiency in Chinese banks: A network DEA framework. *Omega*, vol. 41, no. 2, pp.207-215. DOI 10.1016/j.omega.2012.06.003.
[24] ÖRNEK, A. Ş., AYAS, S., (2015). The relationship between intellectual capital, innovative work behavior and business performance reflection. *Procedia-social and behavioral sciences*, no. 195, pp. 1387-1395. ISSN 1877-0428. DOI 10.1016/J.SBSPRO.2015.06.433.
[25] PAN, T. W., HUNG, S. W., LU, W. M., (2010). DEA performance measurement of the national innovation system in Asia and Europe. *Asia-Pacific Journal of operational research*, vol. 27, no. 3, pp. 369-392. DOI 10.1142/S0217595910002752.

[26] PULIC, A., (2008). *The principles of intellectual capital efficiency-a brief description*. 1st ed. Zagreb: Croatian intellectual capital centre.
[27] SHIU, H. J., (2006). The application of the value added intellectual coefficient to measure corporate performance: evidence from technological firms. *International journal of management*, vol. 23, no. 2, pp. 356-365. ISSN 0813-0183
[28] SLATER, S. F., NARVER, J. C., (2000). Intelligence generation and superior customer value. *Journal of the academy of marketing science*, vol. 28, no. 1, pp. 120-130. ISSN 1552-7824. DOI 10.1177/0092070300281011.
[29] VISHNU, S., KUMAR GUPTA, V., (2014). Intellectual capital and performance of pharmaceutical firms in india. *Journal of intellectual capital*, vol. 15, no. 1, pp. 83-99. ISSN 1469-1930. DOI 10.1108/JIC-04-2013-0049.
[30] XU, J., WANG, B., (2018). Intellectual capital, financial performance and companies' sustainable growth: evidence from the Korean manufacturing industry. *Sustainability*, vol. 10, no. 12, art no. 4651. DOI 10.3390/SU10124651.
[31] ZEGHAL, D., MAALOUL, A., (2010). Analysing value added as an indicator of intellectual capital and its consequences on company performance. *Journal of intellectual capital*, vol. 11, no. 1, pp. 39-60. ISSN 1469-1930. DOI 10.1108/14691931011013325.

***This work was supported by grant provided by the scientific research project of the Czech Sciences Foundation Grant No: 17-11795S.***