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Completed Research Paper

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Abstract

The ICT sector is one of the most important industries in the world, thanks to the high added value of its production. The competitive advantage of such a sector depends (among other things) on the ability to acquire knowledge from various available resources. ICT firms need to be able to adapt and react flexibly due to the high dynamics of development in the field of information and communication technologies. These firms are trying to use different knowledge resources, engaging in knowledge cooperative networks in a globalized innovation environment. Determinants of this environment are also largely influencing their production function. Due to the importance of the field and the level of public funding, it is necessary to study the impact of different innovation sources on the ability of ICT firms to produce innovations. Our study is a macroeconomic study of the ICT sector in the EU using data from Eurostat (Community Innovation Survey). With three own regression models, we demonstrate that firms in the ICT sector often use resources from the group of cooperating companies, acquire the existing know-how, licenses and patents on the market, and pay great attention to their own employees as a source of potential knowledge. Results of the research so far confirm the negative impact of public organizations on innovation (or R&D) performance of the ICT firms. In the context of public funding of support for R&D activities in the ICT industry, it is possible to talk about significant allocation inefficiencies or possibly too long-term investments with uncertain results.

Keywords: information sources, knowledge, industrial, ICT sector, EU

Introduction

Innovative processes are currently embedded in every firm. At the end of these processes, a commercially-available product or service is expected. This is a change of the original solution or concept, or the realization of a completely new idea in practice (Boschma, 2005). Therefore, it is clear that the essence of the innovation creation is knowledge and the ability of the economic entity to transform them. Already Polanyi (1966) has revealed that these knowledge are not more codified but tacit. Thus, those knowledge that are non-transferable (or very difficult to transfer), are very specific and non-trivial. It is a mixture of codified knowledge, many years of experience in repeating and meeting different practices (Jasimuddin, Klein & Connell, 2005). Sharing of this knowledge is possible only through co-existence, co-operation, and it is subject to a very high codification. Fischer & Varga (2002) stated that this kind of knowledge has to be carefully distinguished from information in the usual sense that it is factual, while knowledge is characteristically complex and aims to discover the why (procedural knowledge) and how (skills and competences)."

In this context, the knowledge spill-over effect must be mentioned (Acs, Braunerhjelm, Audretsch & Carlsson, 2009). This kind of effects (they often have the form of knowledge or competences) become a significant determinant of innovation activities. There are some specifics: uniqueness and randomness of the occurrence essentially zero direct and high indirect cost of their occurrence and an extremely long time to transfer. The knowledge spill-over effects are beneficial to both the corporate sphere and the public; they occur frequently as the product of university-industry (-government) cooperative activities (Howells, 2002). The very nature of this knowledge is the subject of very numerous discussions. There are studies that perceive this knowledge as a public good (Kogut & Zander, 1993; Stiglitz, 1999; Fischer & Varga, 2002; Kezar, Chambers & Burkhardt, 2015). The knowledge spillover effects are disseminated to society through various channels, particularly from the research and development area (very often funded from national or supranational budgets). They are disseminated specifically with conference papers and scientific journals. Their bearers are graduates of universities, especially technical engineers, who can apply the knowledge gained through their study into new commercialized products of their companies or their employers. This leads to a geographical diffusion of knowledge. But their creation is purely local (Paci, Marrocu & Usai, 2014).

The effectiveness of the knowledge transfer, both codified and tacit, always depends on the recipient – on the potential and the capacity of the human capital bearer. The success of the knowledge transfer therefore depends on the ability to transform knowledge into outputs that are applied to the market and thus meet the company's goals. Therefore, it is logical, that the company itself significantly influences this success (especially the corporate environment, investment in science and research, new technologies, but also the composition of workers, the degree of cooperativity, openness and trust, etc.). Given that the newly applied knowledge requires the use of a large number of manufacturing assets, it can be argued that firm´s absorption capacity affects the success of the knowledge transfer (Aghion & Jaravel, 2015).

The research of the knowledge influence on the innovation capabilities of firms, or on their productivity or the achievement of strategic goals was carried out and the results are described in a number of studies (Camisón & Villar-López, 2014; Martín-de Castro, 2015). Many of them focus on different kinds of knowledge or information sources where it is possible to obtain incentives for further production development. All studies document that analysed production factor has a greater or lesser impact on the outcome of innovation or business processes. All of them therefore deal with variables of the production function, which may be useful when studying industrial sectors on a large geographic sample of economies (Ponds, Oort & Frenken, 2009).

The studies show that innovation approaches differ across sectors in terms of various dimensions (Corrocher, Malerba & Montobbio, 2007). Malerba & Orsenigo (1997) describe the different patterns of innovation in various industrial branches (so called Schumpeterian patterns of innovation). With the help of different models, the conditions determining the innovation capacity of the firms can be characterized. With this taxonomy, it is possible to assess the absorption capacity of the firms or the knowledge base of innovative activities in various firms. Scholars agree that the ICT industry is very specific based on the Schumpeterian patterns of innovation. Firms in the ICT sector have high opportunity applications and diversified knowledge base with high variability over time. short product life cycles and rapidly changing technologies. This corresponds to the fact that ICT firms face rapid technological change and, therefore, are heavily involved in R&D and innovation activities. Other specific features of ICT industry include a more frequent employment of engineers and scientists and the extremely short product life cycles (Lu & Yang, 2004). In response to this dynamic environment, they continuously offer products that correspond to the degree of technological advancement and high end-user requirements. The variability and dynamism of ICT markets also determines a high degree of specialization and the need to have a new knowledge and technology (inherent in cooperation with the knowledge industry, e.g. through spin-off firms or university start-ups). Guo et al. (2015) showed that the degree of innovation in ICT industry can be attributed organizational factors, such as service technological capability, strategic orientation or organization design. Another important determinant of successful new product development in this industry was the integration of the R&D and marketing (Shim et al., 2016). Responsible research and innovation in ICT industry has also received considerable attention recently (Chatfield et al., 2017).

It is clear that the results of different studies differ in certain aspects and therefore greater attention should be paid to studying the conditions of the innovation environment and examining the impact of various information sources, ICT and knowledge management influence on innovation outcomes (Grillitsch, Tödtling and Höglinger, 2015). The results of the studies show that the ICT sector is an important sector that influences input variables in all possible forms. Bonanno (2016) examined whether ICT and R&D are productive inputs or efficiency determinants in Italian firms. The results of two similarity models confirm that ICT and R&D should be perceived as input to a production function that affects the output variable. The JRC Prospective Insights in ICT R&D reports that the ICT sector has tripled over the past 20 years and brings a tremendous added value (73.1% of the global added value globally globally). As regards employment, in 2014, the EU's ICT sector employed 5.7 million workers. Also big R&D investments have also been invested in this sector. In 2014, one quarter of global R&D expenditure was spent on ICT, 16% in the EU. Significant public investments in the form of subsidies also go to this sector. It was 6.7% of the total public spending of the EU budget that was spent on ICT science and research. Public support is continuous, stable, but low when compared to other countries in the world (8.3% in the US or 10.2 in Japan).

The situation ICT sector in different countries must be investigated. It will help to define a favourable business environment (innovation), the role of ICT and the need to integrate knowledge management into firms´ strategies. In such a high-quality and knowledge-based environment, it will be possible to implement an effective public policy, target it more meaningfully, and create a financial scheme of grant or incentive support. There is a lack of studies that would analyse how R&D, knowledge or market determinants affect the knowledge production function of ICT firms. Therefore, the aim this paper is to analyze influence of different knowledge sources on firms´ product innovations in ICT industries within selected European countries.

This paper is organized as follows. First, theoretical background is provided on knowledge production function in ICT firms and its determinants. Second, research methodology and underlying data are described. The next section provides the results of logistic regression models. Final section concludes this paper and discusses the results and political implications.

Theoretical Background

The theory of production functions is known from many textbooks and scientific publications. However, the knowledge production function was defined by Griliches in 1979 (Griliches, 1979; Fritsch, 2002) in a framework of the Cobb-Douglas production function. This function identifies the determinants that affect the productivity of the company, especially the knowledge determinants (knowledge, knowledge spill-over effects and others knowledge-based), investments invested in production of innovations. It is clear from previous studies that the output of the knowledge production function is "innovation" (in any measurable form – e.g. in the volume of sales or turnover from innovated production or the value of innovated production, usually in relative terms or most often patent numbers). Fritsch (2002) describes the knowledge production function (based on Griliches´s production function) as follows

$$\text{R\&D output} = a \text{ R\&D input}^{b}, \tag{1}$$

where a is a constant production factor,

b represents elasticity (the relationship between R&D output and input).

Frisch defined the slope of the knowledge production function as an output elasticity of R&D input that describes the productivity of innovation process inputs. It then logically follows that elasticity should grow at the same time when the quality of inputs into the production process is also increasing. It should be remembered that the quality of the innovation environment and influences from other market players must also be included among the inputs. These players are private companies (competitors or members of the supply chains or global production chains), private consulting organizations, public organizations (including national and regional governments), government agencies and knowledge-based research organizations (universities, R&D organizations). Variable *a* expresses how many innovations were created without R&D input. Such an output, which does not require any formalized inputs, can only be achieved by the use of latent input factors, i.e. spill-over effects, knowledge stock, or the effects of cooperatives. In both cases, *a* variable represents a problematic input into this equation, and it is up to scientists to accurately consider whether or not it can be included in their analyses.

Griliches' production function was extended by Jaffe (1989). In this function, the number of corporate patents is the dependent variable, R&D industry and university research are the input (independent) variables. Jaffe added to his function the variable *C*, which measures the geographic coincidence of university and industrial research activities within the state. Most scholars agree that the impact of human capital (usually students in certain fields and levels of study) should be mentioned in the equation too. We also need to remember that the Fischer-Varga's knowledge function (Fischer & Varga, 2003), is based on the same principle but also takes into account the geographical (regional) rather the mezzo-economic context. These are the representatives of scholars who are exploring the regional impact of the knowledge production functions.

In the literature, the knowledge production function is associated with knowledge growth models by Romer (1990) and Jones (1995). Romer determines his knowledge function, "where knowledge is linear in the existing stock of knowledge, holding the amount of research work constant." It follows that the growth of knowledge stock is directly proportional to the production of knowledge in the R&D field. Public policies supporting science, research and technology therefore logically increase the growth rate of knowledge. In his 1995 work, Jones discussed Romer's knowledge production function. In his research, he examined total factor productivity growth and involvement of the volume of human potential in the production of R&D outputs. He did not demonstrate the relationship between the variables and that´s why he argues that “a smaller magnitude of knowledge spillovers needs to be imposed.“ Jones concluded that long-term growth depends on exogenous factors, and public policy (public supporting systems) does not affect it at all (Abdih & Joutz, 2006).

Followers in their studies prove that there are other variables that affect the knowledge production function (Ó hUallacháin & Leslie, 2007). It is necessary to analyse the individual variables of the knowledge production function and determine the influence to which the output is affected, or proper weight. Buesa, Heijs & Baumert (2010) analysed the determinants of the knowledge function in Europe (using the combination of factorial analysis and regression). They analysed the number of patents as the dependent variable, and 21 independent variables. They showed that the variables belonging to the groups: national environment, innovating firms, universities and R&D done by the Public Administration have an impact on the number of patents. Porter & Stern (2000) conducted an international study analysing data from the U.S. patent office. They investigated the influence of full-time equivalent scientists and engineers in all sectors in countries and years, patent stocks and spillover effects. A closer focus on knowledge was made in Schartinger, Rammer, Fischer & Fröhlich (2002). They analysed the role of the R&D exchange between firms and knowledge-based organizations in Austria. The results of their empirical study show the intensity of knowledge interactions does not follow a simple sectoral pattern (assuming intense interactions between high-tech industries and firm-orientated technical sciences and low interactions in humanities and low-tech industries). They are rather influenced by a large set of different factors producing a complex pattern of interactions. Hülsbeck & Pickavé (2014) investigated industrial and university characteristics as determinants of technologically oriented entrepreneurship. Their results show that high-technology entrepreneurship is highly dependent on regional knowledge production by industry and university, while technology entrepreneurship does not largely dependent on these factors.

There are a number of other factors influencing innovation processes in ICT. Those that were evaluated in this study are described in detail in the following chapter and table 1.

Data and Methodology

We analyzed the influences of different knowledge sources (inputs – Fig. 1) on the firms´ product innovations (output) in ICT industries within selected European countries by using own regression models. In general, different kinds of regression models are commonly used to express the influences of independent variables (determinants) on dependent variable (e.g. Nieto & Quevedo, 2005; Chen & Huang, 2009; Bishop, D'Este & Neely, 2011 – logistic regression; Schneider & Spieth, 2013; Prokop & Stejskal, 2017 - multiple linear regression).

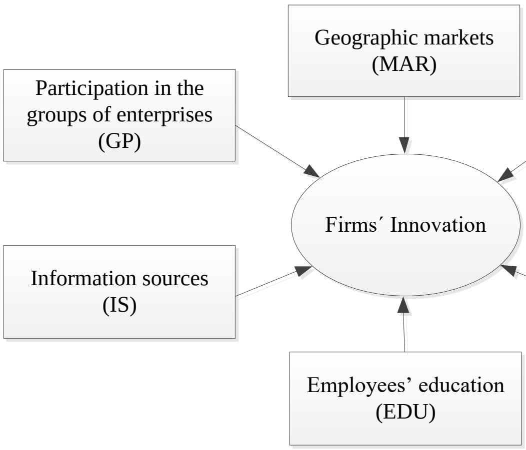

Figure 1 Proposal of Research Model

For the purpose of our study, we used logistic regression models that explain the relationship between binary dependent variable (e.g. innovation and non-innovation) and number of different categorical and continuous independent variables (different knowledge sources). As a data source, in accordance with previous studies analyzing influence of knowledge sources on innovation activities across industries (e.g. Grillitsch & Nilsson, 2015; Raymond et al., 2015; Estrada et al., 2016; Turnbull & Richmond, 2017), we used the Community Innovation Survey (CIS) 2010-2012. CIS uses harmonized questionnaire created for all EU Member States by Eurostat and combines stratified random sampling with exhaustive surveys. This is the latest data currently available at the Eurostat. Details on the sampling methodology can be found here http://ec.europa.eu/eurostat/web/microdata/community-innovation-survey. The survey is limited to firms with at least 10 employees. In total, we analyzed 6,819 firms from the following European countries: Bulgaria, Czech Republic, Estonia, Croatia, Cyprus, Latvia, Hungary, Germany, Norway, Portugal, Romania, Slovakia, Slovenia, and Spain. These analyses were performed within the ICT industries, specifically ICT manufacturing and ICT services. A harmonized questionnaire was used for all these countries. The CIS 2012 Survey Questionnaire can be downloaded at the Eurostat web pages, http://ec.europa.eu/eurostat/documents/. Note that not all firms in the sample answered all questions. Therefore, missing data had to be treated. We used a common procedure for this task, replacing the missing values with median values of the respective country and industry.

Own logistic model were specified as follows:

$$ln[P(INN_i)/ (1 - P(INN_i)] = \beta_0 + \beta_1 \times GP_{1i} + \beta_2 \times MAR_{2i} + \beta_3 \times RD_{3i} + \beta_4 \times IS_{4i}, + \beta_5 \times FS_{5i} + \beta_6 \times EDU_{6i} \quad (1)$$

where subscript i denotes the i-th observation in the sample, P is the probability of the outcome, β_0 is the intercept term, and $\beta_1, \beta_2, \dots \beta_n$ are the coefficients associated with each explanatory variables (see below in Table 1). A positive coefficient means that the log of odds increases as the corresponding independent variable increases. However, it is possible to interpret the coefficients in terms of odds $[P / (1 - P)]$ or probability (P) of the outcome by observing the relationship between P, $[P / (1 - P)]$ and $ln[P / (1 - P)]$. It can be shown that $[P / (1 - P)]$ is a monotonically increasing function of P and $ln[P /$

(1 – *P*)] is a monotonically increasing function of [*P* / (1 – *P*)]. Consequently, if the log of odds *ln*[*P* / (1 – *P*)] is positively (negatively) related to an independent variable, both odds [*P* / (1 – *P*)] and probability (*P*) of the outcome are also positively (negatively) related to that variable. The only difference is that this relationship is linear for the log of odds and nonlinear for odds and probability of the outcome. The coefficients in the logistic regression are estimated using the maximum likelihood estimation method (for further explanation see Neupane et al., 2002 or Retherford & Choe, 2011). We tested the collinearity among the independent variables by Variance Inflation Factor (VIF) for each regression model. Multicollinearity was rejected in the models (VIF<5).

Table 1 Selected Knowledge Sources

Participation in the groups of enterprises (GP)	Firms that belong to wider company groups are able to draw on (i) knowledge and resources from within their wider groups and (ii) the power, security and prestige of their wider groups in seeking partners for innovation (Tether, 2002).
Geographic markets where enterprises sell goods and/or services (MAR)	With growing rate of change, there is a greater need for increasing knowledge inflows and launching innovations in different markets. Therefore, exploring of local and foreign network connections for the development of an innovation are able to bring new product innovations into the international marketplace more rapidly (Patel et al., 2014).
Firms´ R&D activities (RD)	The presence of R&D activities creates an organizational climate that is propitious to questioning, thus favoring the flexibility of firms, their capacity to integrate new concepts and their adaptability to market changes. Therefore, the knowledge and experience gained from past R&D activities, as well as their existence on a permanent rather than sporadic basis, are deemed to favor innovation (Raymond & St-Pierre, 2010).
Information sources (IS)	Firms´ innovation draws on number of various information and knowledge sources and, therefore, firms may improve their odds of successful innovation by accessing many different knowledge (information) sources. By accessing a greater number of knowledge and information sources, the firm improves the probability of obtaining knowledge that will lead to a valuable innovation outcome (Leiponen & Helfat, 2010).
Firms´ size (FS)	Damanpour (2010) proved significant positive relationship between size and innovation, when small organizations are more likely to be innovative because they have a more responsive climate for making quicker decisions to go ahead with new and ambitious projects (e.g. less bureaucratic inertia, flexible structure). On the other hand, large organizations are more likely to be innovative because they have more financial and technical capabilities.
Employees' education (EDU)	Knowledge sources and its sharing are fundamental building blocks in facilitating innovation in organizations. Employees' education, experience and sharing of knowledge bring new ideas and are such organizational resources for innovation (Hu & Zhao, 2016).

As output variable in our analyses, we used firms´ product (goods and services) innovation (INN). As input variables, the following inputs were selected:

- Group of Enterprises: Enterprise as part of an enterprise group (GP);
- Markets (MAR): National (MARNAT), Other European Union or associated countries (MAREUR) and all other countries (MAROTH);
- Firms´ R&D activities (RD): In-house R&D (RRDIN), External R&D (RRDEX), Acquisition of knowledge (ROEK), Training for innovative activities (RTR);

- Information sources (IS): Within enterprise or enterprise group (SENTG), Universities or other higher education institutions (SUNI), Suppliers of equipment, materials, components, or software (SSUP), Government, public or private research institutes (SGMT), Clients or customers from the private sector (SCLPR), Conferences, trade fairs, exhibitions (SCON), Clients or customers from the public sector (SCLPU), Scientific journals and trade/technical publications (SJOU), Competitors or other enterprises in industry (SCOM), Professional and industry associations (SPRO) and Consultants and commercial labs (SINS);
- Firms Size (FS): Enterprise's total turnover for 2012 (TURN);
- Education (EDU): Percentage of employees with tertiary education (EMPUD).

In the next part, the results of logistic regression models are shown.

Empirical Results

Following previous parts, we created three logistic regression models (Model 1-3) to analyse the influences of different knowledge sources on firms´ product innovations in ICT industries in European countries. The first model involves all selected variables. To analyse the sensitivity and accuracy of variables, we created Model 2 (without the influences of R&D activities) and Model 3 (without the influences of information sources). Seven independent variables show strong significant positive effects across the models, one independent variable shows strong significant negative effects across the models.

Results of our models in Table 2 show that selection of proper markets represent significant factor influencing firms´ product innovation in ICT industries in the EU. In general, market orientation allows firms to obtain better economic and commercial results and has positive effect on businesses' degree of innovation (Lado & Maydeu-Olivares, 2001). Geographical proximity of countries within Europe shows to be important because only European markets influenced firms´ product innovation significantly. This kind of proximity seems to facilitate a more complex knowledge exchange, interactive learning and provide various kinds of knowledge sources. It affects firms´ absorption capacity, knowledge stocks and supports the generation of innovations, especially radically (Grillitsch et al., 2015). On the other hand, national and Non-European markets were insignificant. Moreover, non-European markets had negative effects in some cases (insignificant).

Innovation activities of European firms in ICT industries were influenced by various R&D determinants:

- Research and development activities undertaken by enterprises to create new knowledge or to solve scientific or technical problems (RRDIN);
- Acquisition of existing know-how, copyrighted works, patented and non-patented inventions (ROEK);
- Training (In-house or contracted out) for innovation activities (RTR).

These results show that European ICT industries prefer internal research and development (external R&D was completely insignificant) and do not tend to share their unique knowledge (e.g. via research cooperation). On the other hand (in many cases), in-house R&D can be more expensive and less effective for firms than acquiring external knowledge resources within the framework of R&D cooperation (Becker & Dietz, 2004). For these reasons, European ICT firms also gained external knowledge through acquisition of existing knowledge (know-how) or through innovation training. Beneito (2006) show that significant innovations are mainly gestated in-house, whereas contracted R&D seems more orientated towards innovations of incremental nature. Chen et al. (2016) showed that internal R&D activities and external knowledge sourcing together have a positive effect on firms' innovation performance. Internal knowledge and R&D enhances firms´ ability to identify and use external knowledge sources that complements firms´ own internal innovation activities. Therefore, both attitudes to R&D activities represent key determinants of European ICT firms´ innovations and there is a need to combine different knowledge sources in proper way.

Table 2 Results of research models

	Model 1		Model 2		Model 3	
	p-value	β(expβ)	*p*-value	β(expβ)	*p*-value	β(expβ)
GP	.477	-.090	.821	-.028	.125	.131
MARNAT	.449	.109	.446	.107	.061*	.206
MAREUR	.000***	.623	.000***	.677	.004***	.302
MAROTH	.240	-.186	.299	-.161	.091*	.181
RRDIN	.027**	.302	-	-	.000***	1.148
RRDEX	.267	.167	-	-	.164	.147
ROEK	.002***	.473	-	-	.000***	.990
RTR	.014**	.311	-	-	.000***	1.020
SENTG	.000***	.286	.000***	.373	-	-
SSUP	.134	.097	.088*	.108	-	-
SCLPR	.000***	.247	.000***	.263	-	-
SCLPU	.311	.068	.434	.051	-	-
SCOM	.271	.074	.207	.083	-	-
SINS	.008***	-.187	.042**	-.139	-	-
SUNI	.612	.042	.265	.087	-	-
SGMT	.189	-.117	.198	-.112	-	-
SCON	.183	.106	.139	.115	-	-
SJOU	.557	.049	.296	.085	-	-
SPRO	.706	-.028	.452	-.055	-	-
TURN12	.207	.000	.056*	.000	.205	.000
EMPUD	.009***	.091	.002***	.104	.000***	.104
r^2 - Nagelkerke	.258		.235		.321	
r^2 - Cox & Snell	.187		.170		.241	
-2 Log likelihood	1787.480		1846.658		3596.774	
Correctly predicted (%)	74.0		72.8		71.9	

Legend: * statistically significant at p=.10, ** at p=.05 and *** at p=.01.
Source: own processing

In accordance with the results above, European ICT firms were able to significantly influence their innovation activities by using only two out of eleven information sources. Namely, information sources within the enterprise or enterprise group and information sources from clients or customers from the private sector. It is clear that firms using internal R&D tend to use internal information sources for the same reasons mentioned above. However, to support firms´ absorptive capacity, knowledge base, R&D, innovation activities and, finally, performance, there is the necessity to find other external sources of information. Varis & Littunen (2010) state that firms must possess adequate internal knowledge and capabilities, often but not necessarily always attained through in-house R&D, to get access to and gain from externally generated knowledge. Therefore, in-house R&D and external information cannot be substitutes but complements. For these reasons, European ICT firms also used market (external) sources of information, namely clients or customers from the private sector. Laursen & Salter (2006) pointed out that modern innovation processes require firms to master highly specific knowledge about different technologies, markets and users, while users (customers) represent a key source of information for innovation. On the other hand, using consultants and commercial labs led to significant but negative effects. The use of specialist knowledge providers tends to complement firms' own internal innovation activities and to complement other external sources of knowledge, however, there are significant differences in the types of specialist knowledge providers and their impact on firms´ innovation activities (Tether & Tajar, 2008). Therefore, firms´ should find proper information sources and monitor whether knowledge and information inflows are not higher than their outflows and whether negative externalities (spillovers) do not occur.

Education of firms´ employees within ICT industries in EU played a strong significant role in the process of product innovation. There is no doubt about the link between firms´ innovation and employees´ education level. Østergaard et al. (2011) analysed that skills and education of employees are an important part of the firms' human capital and that firms employing workers with a high education are more likely to be innovative. The educational background is an important part of the employee's knowledge base and it influences the working methods. The employee has a professional identity (rooted in education) that affects the employees' decision making and views on how to identify and solve problems (Joshi & Jackson, 2003). On the other hand, knowledge and information sourcing from educational institutions was insignificant and from research institutes and government were insignificant and negative. This kind of university-industry or university-industry-government cooperation, knowledge and information sourcing could be insignificant and ineffective because each actor have different targets and there are number of barriers, such as bureaucratic inflexibility and ineffective management of university (Siegel et al., 2003). Therefore, firms should focus on these sources of knowledge and its efficiency because knowledge, technology and information transfer between academia and industry is expected to spur innovation and firms´ performance (Rajalo & Vadi, 2017).

Conclusion

According to the previous studies we can claim that the ICT sector is an important creator of R&D performance in the EU. ICT firms (pressed by the market situation on international markets) must be flexible and pay great attention to innovation. Due to the high speed of development in this area, they focus on internal knowledge and innovation processes. Especially Eastern European countries, results are a consequence of a large gap between research and practice. For Western countries, these results are determined by financial or cost conditions, or by the dichotomous goals of market entities (the objectives of the knowledge organization differ significantly from business objectives of the ICT firms). However, based on the results, it can be argued that the ICT firms would cooperate and gain knowledge of science and research collaboration. ICT firms are often members of collaborative knowledge networks, but they see this form of cooperation as a long-term investment. In addition, it can be argued that firms with in-house R&D have a greater chance of benefiting from spill-over effects or synergy effects, thus they can significantly improve their internal knowledge-based processes.

It was found that European ICT firms only use a limited amount of information resources. Here we can see the corresponding behaviour two Schumpeterian innovation patterns. The second pattern (Schumpeter Mark II) is used by more dominant firms and stable leading innovators from a group of companies. These firms are more likely to use in-house research and acquire information from entities that are linked to a group of companies (usually part of a business network). On the other hand, firms that apply the first innovation pattern (Schumpeter Mark I) are independent firms that perceive the market as a place where additional external knowledge can be gained. This corresponds to their market strategy, specific focus and high technological dynamics. Therefore, we can conclude that European ICT companies are influencing their R&D processes by a suitable combination of knowledge resources. Likewise, training of own employees is perceived by ICT firms as an important determinant of a knowledge and innovation environment.

A separate conclusion can be learned about the role of public (government) organizations in the process of creating knowledge or innovation outputs. The government should consider the appropriateness of interventions into the industry within the framework of its own public policies. It is important to target the intervention that focuses on clearly measurable outcomes affecting the production of ICT firms. The results of the research so far confirm the negative impact of public organizations on innovation (or R&D) performance of the ICT firms. In the context of public funding of support for R&D activities in the ICT industry, it is possible to talk about significant allocation inefficiencies or possibly too long-term investments with uncertain results. These conclusions should be an inspiration for public policy makers.

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