UNIVERSITY OF TARTU
Faculty of Social Sciences
School of Economics and Business Administration

Iryna Olshanska

University-Industry Collaboration in terms of Smart Specialisation concept

Master's Thesis

Supervisor: Urmas Varblane
Co-supervisor: Kärt Rõigas

Tartu 2016

Allowed for defence on ……………………………..
(date)

……………………………………………
(Urmas Varblane)

……………………………………………
(Kärt Rõigas)

I have written this master's thesis independently. All viewpoints of other authors, literary sources and data from elsewhere used for writing this paper have been referenced.

....
(*signature of author*)

University-Industry Collaboration in terms of Smart Specialisation concept

Iryna Olshanska

Abstract

The aim of the thesis is to examine the relation between university-industry collaboration and firms' performance using Community Innovation Survey (CIS) data for 14 European countries. Cooperation variables are incorporated as well as size indicator and control variables that are related to firms' performance. The analysis includes two priority sectors, which are defined in terms of Smart Specialisation innovation concept: Information and Communications Technology (ICT) and Enhancement of Resources. Standard ordinary least squares (OLS) and tobit models are the utilized statistical techniques used on the firm level data, with a dependent variables indicating total turnover and turnover from innovative sales. Main findings reveal that the cooperation with foreign universities is positively related to firms' performance; at the same time collaboration with national universities does not have such relation. Results differ across countries among analyzed types of cooperation in considered priority sectors.

Keywords: university-industry cooperation, Smart Specialisation concept, priority sectors, Europe, comparative view, Information and Communications Technology (ICT), Enhancement of Resources

TABLE OF CONTENTS

1. INTRODUCTION

With respect to EU's growth strategy for coming decade, European Commission has announced the setting up of the S^3Platform in a 2010 in order to push forward Smart Specialisation concept (EC, 2010). Over the last several years the importance of Smart Specialisation concept has become central to economic development and growth policies in Europe (McCann and Ortega-Argilé, 2011).

According to the Regulation (EU) 1301/2013 of the European Parliament, Smart Specialisation strategy is defined as innovation strategy on national or regional level which is designed to build competitive advantage by developing and matching research and innovation own strengths to business needs and set priorities according to it in order to recognize emerging opportunities and market development.

Smart Specialisation is a new innovation concept designed to promote the efficient and effective use of public investment in research and is a central focus of Europe 2020 Strategy. Its goal is to stimulate regional innovation by enabling regions to indentify sectors of competitive advantage and then focus their regional policies on promoting innovation in these fields in order to achieve economic growth (EC, 2010).

In Estonia there were indicated three main growth areas on the basis of qualitative analysis carried out by Estonian Development Fund (Estonian Development Fund, 2013):

- Information and Communication technology (ICT)
- Enhancement of resources
- Health technologies and services

In order to reach the efficient and effective use of public investment in research, the high collaboration between universities, government and public or private research institutes is required to retain EU’s competitiveness, which was also highlighted in EU’s Europe 2020 Strategy for smart, sustainable and inclusive growth (EC, 2010). Also in order to commercialize research outcomes, which is carried out in European countries mostly by universities and public research institutes, an efficient interaction between research and its exploitation is required (Polt at al., 2001). The main idea is that knowledge that is related to different types of innovations, could be transferred using the linkages between universities, government, public or private research institutes and private enterprises. Hence, both parties involved in this process, private enterprises from one side and universities, government, public or private research institutes from another side should be interested and have clear motivation to collaborate with each other. From university side, the collaboration with private enterprises brings substantial stream of external funding, possibility for professors and graduates to work on innovative research, creating knowledge on the cutting edge of the disciplines and delivering solutions for global challenges (Edmondson et al., 2012). From industry side, the universities should provide relevant valuable innovation and at the same time in order to use universities as cooperation partners on innovation, it should be more beneficial for firms than using their own internal research capacity. Successful university-industry collaboration implies meeting the interests of both parties involved (NCURA, 2006). There are different types of cooperation on innovation activities; in this research following types of collaboration are distinguished: cooperation with national and foreign universities; cooperation with national and foreign government, public or private research institutes. In order to promote university-industry collaboration, it is important to understand what is driving firms to collaborate with universities and research institutes[1] and what kind of cooperation is more valuable for them. The aim of the thesis is to estimate the relation between university-industry collaboration and firms' performance.

The main contribution of this work is to provide some new empirical insights into understanding of firms' motivation to collaborate with research institutes, by answering the questions: what is the relation between university-industry collaboration and firms' performance? Whether different types of collaboration have positive relation to firms' performance measured by total turnover and turnover from innovative sales or there is no clear linkage between firms' performance and collaboration with research institutes? In addition, the relation between collaboration with universities, research institutes and firms' performance is analyzed by country groups and in priority sectors determined in terms of Smart Specialisation concept.

The research questions are tested on the firm level data from Community Innovation Survey (CIS) 2012 for 14 European countries. Standard ordinary least squares (OLS) model and tobit model are used as statistical tools. The models incorporate the cooperation variables as well as size indicator and control variables that could be related to firms' performance.

The rest of the thesis is organized as follows. The next section reviews the theoretical concept and existing literature on this topic. Section 3 provides the research questions, presents the applied dataset and the model. Section 4 introduces and discusses the empirical results. The final section draws the conclusions and suggests some ideas for future implication.

---

[1] The term "research institutes" is used for government, public or private research institutes.

2. LITERATURE REVIEW

The fundamental idea behind university-industry collaboration is the creation of effective linkages between universities, government, public or private research institutes and private enterprises in order to maintain the transmission of knowledge related to different types of innovation. Technological and innovation development of economies depends heavily on the capability of private enterprises to combine their own knowledge capacity with external sources of innovation. The generation and use of this scientific knowledge for innovative activities forms one of the key important measurements of the "National Innovation System" performance, what brings the focus of science and technology policies to encourage university-industry collaboration (Polt et al., 2001). The ability of enterprises to implement scientific knowledge on innovation activities has increasing relevance recent years in terms of "knowledge-based" economies (Etzkowitz et al., 2000). The term "knowledge-based economy" has been originated in 1969 in the book "The Age of Discontinuity" by Peter Drucker (Drucker, 1969). "Knowledge-based" economy can be defined as products and services generated on the base of knowledge-intensive activities and its key concept is based on greater reliance on intellectual capacities rather than on physical ones or natural resources (Powell and Snellman, 2004). With growing of "knowledge intensification" and "science-based technologies" such as biotechnology, information technology and new materials, the industrial enterprises in these fields require more scientific knowledge (Polt et al., 2001).

There are different approaches towards necessity of university-industry collaboration. These approaches are based on the fundamental theories about the role of university itself. In general there are two views on the role of university: The Triple Helix thesis and the New Economics of Science. The Triple Helix thesis was introduced by Etzkowitz and Leydesdorff (1997) and described the relations between industry, university and government. This model assumes that the interactions between these three sides promote innovation and states that the university has to be directly linked to the industry in order the industrialization of knowledge would be maximized. Hence, according to this model, university is delegated "third mission" besides teaching and research (Etzkowitz and Leydesdorff, 2000). In contrast, the New Economics of Science considers education as a main function of university (Dasgupta and David, 1994).

Considering the approach of universities' involvement into university-industry collaboration, it is worth to note that university-industry collaboration may take different modes depending on demand. The research on the state of university-industry cooperation in Europe, distinguishes eight types of university-industry cooperation: curriculum development and delivery, lifelong learning, student mobility, academic mobility, commercialization of R&D results, collaboration in R&D, entrepreneurship, and governance (Davey, Baaken, Galan and Meerman, 2011). Some of these channels are used as sources of contribution to industry's innovation by universities and research institutes (see Figure 1). Universities and research institutes provide high educated employees and this is in fact considered as one of the most important benefits for industry (Varblane et al, 2008); also generated by universities and research institutes knowledge such as publications, conferences and patents is widely used by private enterprises; at the same time private enterprises cooperate on R&D projects with universities and research institutes; besides above, recently there is an emerging of technology-based enterprises which are mainly created by researches or graduates (Polt et al., 2001). What is more, firms also value the positive effect on reputation, which they get as a result of cooperation with high-ranked universities (Santoro and Chakrabarti, 2002). There is also difference between firms that choose to cooperate with national universities or foreign universities (Rõigas, Varblane and Mohnen, 2016).

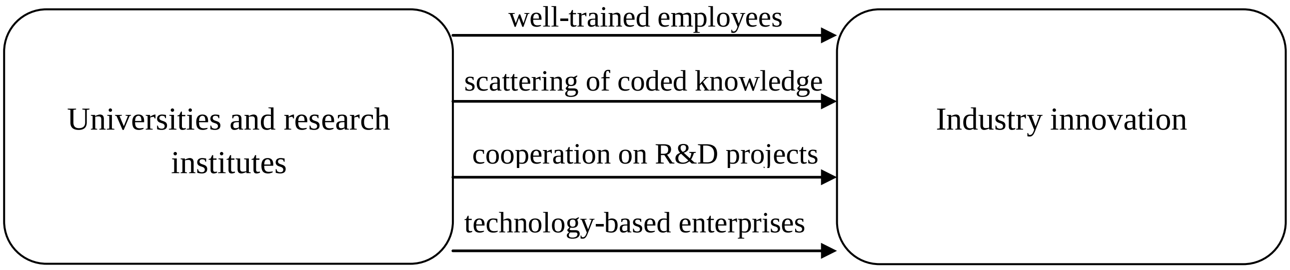


Figure 1. Major channels of university-industry collaboration (Polt et al., 2001).

On the other side, universities and research institutes benefit from university-industry collaboration by access of additional funding, improvement in teaching methods, reputation acceleration and opportunity to work with empirical data from industry (Guimón, 2013). However, for successful university-industry collaboration the universities also should be distinguished as those which focus on university-industry cooperation and implement necessary structure modifications according to it and those for which the university-industry collaboration is not a priority (Roy, 1972). The other side of the coin is, however, that in case of strong university-industry collaboration, the universities might be somewhat limited in their academic freedom and have to focus on topics which would contribute to commercial gain for the industry; this aspect might slow down the university-industry collaboration development (Lee, 1996). Geisler (1995) estimated that more independent in terms of resources universities and firms tend to collaborate. But in contrast, Santoro (2000) and Freel and Harrison (2006) have found that firms don't tend to establish partnership with universities because of mismatch of research interests. At the same time technological regimes of sectors affect the patterns of innovation activities as noted by Breschi et al. (2000) and Park and Lee (2006).

Trying to measure the university-industry collaboration, there are researches using patent data as a measure of university-industry cooperation as it can reflect the cooperation situation. For example, Margherita and Andrea (2006) used patent data in combination with data collected through interviews to measure the extent and intensity of cooperation of academic and industrial researches. On behalf of research based on patent data in China, Motohashi (2008) found that the ties between enterprises and universities become stronger, while the ties between enterprises and scientific institutes have weakened. Chen (2007) investigated outputs of Chinese patents and found that university-industry cooperation plays an important role in technological innovation. Hong (2008) also using Chinese patent data from 1985 to 2004 showed a decentralizing/localizing trend in knowledge transfer from university to industry. Hui (2010) on behalf of more recent research similar to Hong (2008), focused on cooperation in regions using data on patents in China from 2001 to 2008 to measure regional university-industry cooperation.

However, patent data has particular limitations, such as not all inventions are patentable and not all inventions are patented, also patent data is more limited on firm level and differs a lot across sectors due to sectoral classification with different propensity to patent across sectors (Archibugi and Pianta, 1996). All these limitation eliminate particular share of observations. The other approach considers innovative sales as a measure of effect of university-industry collaboration on firms' performance, which eliminates the limitations that are present in case of patent data (Love, Roper and Vahter, 2014; George et al., 2002; Mowery and Sampat; 2005).

One should note that while measuring the university-industry collaboration and trying to estimate whether there is a positive or negative effect of such collaboration, the empirical results are quite contradictory. Some studies indicate positive effect, but some of them find no evidence of positive correlation between collaboration with universities and increased productivity. For example, the studies using data for Europe performed by Belderbos et al. (2004a,b) and Faems et al. (2005) show that collaboration with universities significantly increase the probability of innovation success and leads to the sales increase. In contrast, the research by Eom and Lee (2009) on industry-university and industry-government cooperation and its impact on firms' performance using Korean data from 2000 to 2001 estimated no such effect as for European countries. When controlled for possible endogeneity, they find that collaboration with universities has no significant effect on the probability of innovation success and leads only to increase in patents with no increase in sales. These results suggest that for latecomer economies government policies in promoting university-industry collaboration play crucial role in comparison with developed economies. In latecomer economies with transitional nature of national innovative systems the university-industry cooperation rather influences the direction of research projects of firms than its success in technological innovations.

George et al. (2002), Mowery and Sampat (2005) concluded that industry-university cooperation does not directly influence the success of firm innovation, but it affects the direction of research projects. Monjon and Waelbroeck (2003) using data on 1460 French firms from CIS have found that cooperation with universities (foreign rather than domestic) increase the probability of radical innovation, while spillovers from universities don not have such effect.

Love, Roper and Vahter (2014) using data in Irish manufacturing plants from 1991 to 2008 find little evidence of systematic move towards the joint use of internal and external knowledge using R&D and that external linkage promote higher innovation performance.

One of the major comprehensions of the studies on university-industry collaboration has been that it does not exist isolated and it is just one of many factors influencing firms' performance. University-industry collaboration is integrated into and depends on national innovation system, which is determined by different structural features such as supply and demand for innovative knowledge. Public infrastructure, historical development, cultural and social attitudes, political environment, economic development also form background environment in which university-industry collaboration is integrated, these conditions differ within the society and vary across countries creating different environment and propensity to university-industry cooperation on innovation (Polt et al., 2001). Eun et al. (2006) argued that university-industry relations have "contingent or context-specific" perspective and that each country has different form and role of university-industry linkages due to natural distinctions.

Besides environmental differences on national level, there are also various factors on micro level which influence firms' innovation performance, such as firms' absorptive capacity, market conditions and demand, networks within the industry, factor market, technological development, innovation policy and legal regulations (Polt et al., 2001).

Figure 2 presents the model on university-industry relations within the national system of innovation. It is based on Polt et al. 2001 and shows the integration of university-industry collaboration within national and industrial framework.

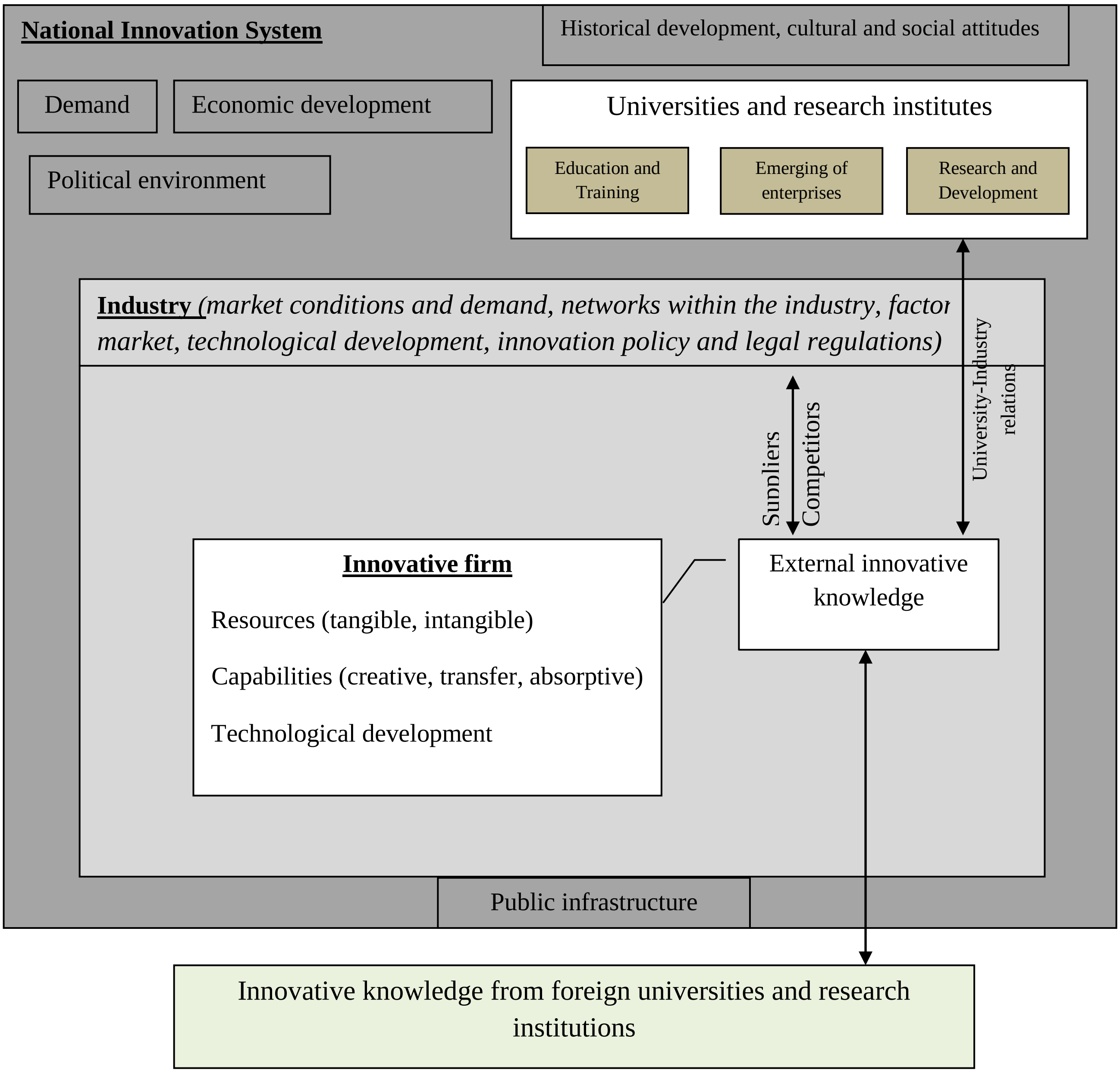


Figure 2. University-industry relations within the national system of innovation (Polt et al., 2001).

It can be seen from Figure 2 that university-industry relation is only one of the many aspects that influences firms' innovation performance and development. In order to eliminate barriers and encourage university-industry collaboration, promotion of joint research programs using bottom-up approach with direct collaboration between enterprises and universities and research institutes is required (Polt et al., 2001).

Smart Specialisation as an innovative concept focuses particularly on promotion of high university-industry collaboration using bottom-up approach in order to reach the efficient and effective use of public investment in research and captures central focus of the Europe 2020 Strategy (EC, 2010). The concept was first proposed by Dominique Foray and Bart van Ark and initially focused on explaining the productivity gap between the US and Europe (Foray et al., 2009). The main features of Smart Specialisation include the specifications of national innovation system, the ability to adapt and transform the system and strategy operating mechanisms. The original concept was designed for sectoral approach, but recently it has been applied to regional context (McCann and Ortega-Argilés, 2011).

However, Figure 2 illustrates that Smart Specialisation captures only one of the aspects that influence firms' innovation performance and it is important to bear in mind that in order to successfully increase and promote collaboration on innovation activities between private enterprises and universities and research institutes, the other components should be included as well to create favorable environment for innovation development.

This work contributes to the literature on university-industry collaboration and is of a great value in terms of extending the comparative analysis and investigation on the relation between university-industry collaboration and firms' performance using firm data for European countries.

3. RESEARCH QUESTIONS, DATA AND MODEL

Based on the previous empirical researches on university-industry collaboration and the types of firms that use universities as cooperation partners, the aim of the thesis is to estimate the relation between university-industry collaboration and firms' performance, which is measured by turnover from innovative sales and logarithmic turnover. According to the aim of the thesis, the following research questions are considered:

1. What is the relation between university-industry collaboration and firms' turnover from innovative sales?

- What is the relation of collaboration with home universities and research institutes?
- What is the relation of collaboration with foreign universities and research institutes?

2. Is there any positive or negative relation between university-industry collaboration and firms' total turnover?

3. What are the common patterns in relation between firms' performance and university-industry collaboration across European counties?

4. What are the common patterns in relation of university-industry collaboration across different priority sectors defined in terms of Smart Specialisation concept?

To provide answers to the above stated questions, I use firm level data from the Community Innovation Survey (hereafter CIS) 2012 for 14 European countries (see Appendix 1). The data sample has particular limitations in the initial survey, as in the CIS questionnaire only technologically innovative firms are required to answer questions about their cooperation partners. At the same time, due to data limitations, the Eastern and Central Europe countries are overrepresented in analyzed sample. Appendix 2 contains information about the shares of technologically innovative firms from the whole sample. It shows that among analyzed countries the share of innovative enterprises is highest in Germany, followed by Portugal, Estonia and Czech Republic, while Slovakia, Bulgaria and Romania have the lowest share. Appendix 2 also shows the shares of innovative firms which cooperate on innovation activities. Among the innovative firms in analyzed counties, the share of firms which cooperate is the highest in Slovenia, Latvia and Cyprus. The lowest share is in Bulgaria, Portugal and Romania.

I consider two priority sectors identified in terms of Smart Specialisation concept out of three due to data limitations, these are ICT and Enhancement of Resources priority sectors. It is important to note that ICT sector has also horizontal implementation besides vertical approach; it supports development of other sectors as well and nowadays application of ICT technology is widely used in other sectors as well (Estonian Development Fund, 2013).

For the descriptive statistics and countries analyzed in this work, see Table 1. It contains information about the dependent and explanatory variables and their average values among innovative firms[2] across analyzed countries. In Table 1, different types of cooperation are distinguished: cooperation with national and foreign universities and cooperation with national and foreign research institutes. It can be seen that more firms choose national universities as cooperation partners compared to foreign ones as well as national research institutes against foreign research institutes. The share of firms cooperating with home universities and research institutes remains quite high in all countries. This means that firms tend to find cooperation partners inside their country. Analyzing whether firms choose national universities or national research institutes as cooperation partners, it can be seen that there is no clear trend. In majority of the countries firms cooperate with national universities more, but at the same time in Norway, Spain, Romania and Cyprus larger share of firms choose national research institutes as cooperation partners. The share of firms using foreign universities or research institutes is quite low, but differs across countries. For example, Norway has the highest share of firms that use foreign universities and research institutes as cooperation partners, which are 15.63% and 13.91% respectively. The lowest share of cooperators with foreign universities and research institutes is in Bulgaria, 0.83% and 0.5% respectively. For the descriptive statistics in analyzed priority sectors see Appendix 4 and 5. In ICT priority sector, Estonia possesses the highest share of firms that cooperate on innovation activities; almost 60% of Estonian enterprises in ICT sector cooperate on innovation activities, the majority of firms cooperate with national universities. The lowest share of cooperators in ICT sector has Bulgaria, where 26,28% firms cooperate on innovation activities. As for sector of Enhancement of Resources, Slovenia has the highest share of cooperators (56,13%), whereas the lowest share is present in case of Bulgaria (12,94%).

In this work all the dummy variables are presented as the share of values equal maximum to 1 (see Table 1). Explanations of when these dummy variables take the value of 1 and 0 are provided below. For example, in Estonia 49.74% of all innovative enterprises in the sample cooperate on their innovation activities. This puts Estonia in the list of top four countries among analyzed countries with highest shares of cooperative firms. The share of cooperators among innovative firms is the lowest in Bulgaria (16.6%). The shares of cooperative enterprises in the sample vary across analyzed countries.

[2] In this work by “firms which have process, product, on-going or abandoned innovation activities in 2012.

Table 1. Descriptive statistics.

Variable	BG	DE	CY	CZ	EE	ES	HU	HR	LT	NO	PT	RO	SI	SK
Turnover from innovative sales (products that were new to the market or firm), %	26.88	11.28	14.73	20.77	17.59	20.72	13.87	18.19	22.17	18.54	14.57	18.55	16.88	23.32
Log(turnover)	14.08	16.8	15.29	15.95	15.18	15.71	16.02	15.4	15.2	16.54	15.19	15.51	16	16.25
Product innovation (introduced new or significantly improved product or service), %	64.14	65.46	69.85	74.69	57.01	51	64.72	66.63	63.4	58.3	67.53	61.96	74.22	69.82
Process innovation (introduced new or significantly improved method of production; logistic, delivery or distribution system; or supporting activities), %	55.09	50.56	95.1	70.04	62.47	61.42	55.64	77.33	74.27	39.81	81.17	75.58	70.67	70.36
Universities as source of information for innovation, %	31.30	59.5	14.69	38.76	32.73	42.48	49.07	39.73	41.5	64.8	47.29	45.64	63.44	38.57
Government, public or private research institutes as source of information for innovation, %	26.48	30.39	14.43	28.94	19.09	46.12	25.71	29.98	31.85	63.75	42.41	40.37	51.98	27.86
Cooperation on innovation activities, %	16.60	44.52	52.06	44.86	49.74	36.94	48.66	39.73	53.29	34.61	26.49	28.96	56.62	39.47
Cooperation with national universities, %	4.11	24.39	3.35	42.92	12.99	14.17	24.01	17.16	40.81	44.22	55.71	6.99	29.47	15.18
Cooperation with foreign universities, %	0.83	5.17	2.58	6.29	2.99	3.08	2.60	2.65	6.03	15.63	12.43	3.56	8.46	4.64
Cooperation with national government, public or private research institutes, %	2.41	16.51	3.61	16.93	5.58	15.58	8.76	12.61	28.45	46.88	35.82	11.04	20.74	7.32
Cooperation with foreign government, public or private research institutes, %	0.50	3.48	1.80	2.13	1.43	2.68	0.73	2.75	4.31	13.91	7.80	1.47	7.09	1.96
Size based on number of employees	0.41	0.6	0.42	0.61	0.48	0.45	0.69	0.63	0.64	0.49	0.44	0.71	0.61	0.64
Percentage of employees with university degree	21.79	17.24	25.77	21.07	39.87	24.01	20.36	13.56	28.63	32.88	16.58	22.82	20.87	23.57
Number of observations	2409	4130	388	2410	770	13017	1233	944	653	1849	3341	815	733	560

Note: Present values are calculated for innovative firms.
Source: calculated by the author based on CIS 2012 data.

The percentage of employees with university degree does not vary too much across countries; on average 23.5% of firms have more than 50% of employees with university degree across analyzed countries. This variable takes two values: 0 if percentage of employees with university degree is up to 50% and 1 if it is from 50% to 100%. Among analyzed countries Estonia has the largest share of innovative firms that have more than 50% of employees with university degree; around 40% of Estonian firms have more than 50% of employees with university degree.

On average there are 64.9% of innovative firms which implement product innovation and 67% implement process innovation across analyzed countries. The highest share of product innovation firms has Czech Republic (74.69%) and the lowest share has Spain (51%). As for process innovators, the highest share has Cyprus, where 95% of innovative enterprises implement process innovation and the lowest share of process innovators has Norway (39.81%).

Dependent variables

As dependent variables, the percentage of turnover from innovative sales as an innovation output measure and log of total turnover are used. The turnover from innovative sales is the proportion of enterprise's total sales derived from products that were new to the market or firm. This variable describes the firms' ability to introduce innovative products as well as their commercial success. Turnover from innovative sales is the innovation output indicator which is most widely used (Love, Roper and Vahter, 2013; Roper et al., 2008; Leiponen and Helfat, 2010; Laursen and Salter, 2006; Leiponen, 2005). As mentioned above, turnover from innovative sales has particular advantages in comparison with patent data (Archibugi and Pianta, 1996). From Table 1 it can be seen that percent of turnover from innovative sales across analyzed countries belongs to the interval from 11.28% to 26.88%. The average percent of turnover from innovative sales among innovative firms is 18.43%. Bulgaria and Latvia have the highest shares which are 26.88% and 22.17% respectively; while Germany and Hungary have the lowest shares (11.28% and 13.87% respectively).

In addition, the variable "log of total turnover" is employed in this research as a one of the measures of firm's performance. The value of this variable belongs to the interval from 14.08 to 16.8, with the Bulgaria having the lowest log of total turnover (14.08) and the highest value has Germany (16.8).

Explanatory variables

The set of independent variables measures different types of cooperation on innovation activities (Belderbos R., Carree M., Lokshin B., 2004a). All these variables are dummies, where 1 stands for conducting particular type of cooperation and 0 for not conducting. The model includes the general variable “cooperation on innovation activities” and following variables which stand for different cooperation types:

-“cooperation with national universities”

-“cooperation with foreign universities”

-“cooperation with national government, public or private research institutes”

-“cooperation with foreign government, public or private research institutes”

The variables “universities as source of information for innovation” and “government, public or private research institutes as source of information for innovation” show whether an enterprise use universities and/or government, public or private research institutes to get information for innovation (NCEE, 2005). These variables are also dummies and take value of 1 in case the firm uses universities and/or government, public or private research institutes to get information for innovation and 0 otherwise.

Control variables

Similar to the previous researches the variable indicating size is included in the model. This is “size based on number of employee”. Due to heterogeneous set of European countries I use only two size groups to define the size of the firm based on number of employees as some smaller European countries do not have more size groups in this dataset. These size groups are the following: small enterprises with less than 50 employees (the variable takes value of 0) and larger enterprises with more than 50 employees (the variable takes value of 1). The size of the firm as a factor of cooperation has been investigated on behalf of different researchers using datasets for different countries. Results by Eom and Lee (2010) indicate that the size of an enterprise measured by the log of the average number of employees has no significant effect on the university-industry cooperation. In contrast, the studies based on European countries find positive relation between size and probability to cooperate with universities (Tether, 2002; Mohnen and Hoareau, 2003; Capron and Cincera, 2003; Miotti and Sachwald, Fontana, 2003; Geuna, and Matt, 2006; Busom and Fernándes-Ribas, 2008; Eom and Lee, 2010).

"Product innovation" and "process innovation" form separate set of control variables, these are also dummy variables. "Product innovation" indicates whether an enterprise introduced new or significantly improved product or service. "Process innovation" indicates whether an enterprise introduced new or significantly improved method of production; logistic, delivery or distribution system; or supporting activities. Both variables take the values 1 and 0, where 1 indicates that the enterprise has introduced new or significantly improved product or service in case of "product innovation" dummy and has introduced new or significantly improved method of production in case of "process innovation" dummy. Product and process innovation activities are expected to have positive influence on firm's performance (Peters, 2005).

One of the control variables in the model stands for percentage of employees with university degree as mentioned before and takes values of 0 in case less than 50% of employees in firm have university degree and 1 in case more than 50% of employees have university degree. This variable reflects the potential impact of workforce quality on innovation and firms' absorptive capacity (Love, Roper and Vahter, 2013; Freel, 2005; Leiponen, 2005; Polt et al., 2001), assuming that firms that employ more university educated people tend to do more innovation activities. This assumption is based on previous researches on relation between human capital and innovation using firm level data, which found positive relation between human capital and firms' performance, such as Bugamelli et al. (2012) (based on EFIGE survey data, firms' performance is measured by the introduction of an innovation and by the number of patents filed at the European Patent Office, human capital is measured with the share of graduated workers in the firm); Ballot, Fakhfakh and Taymal (2001) (based on France and Sweden data, measuring firms' performance by the value added and human capital by training conducted at the firm level). Besides above mentioned researches, d'Amore and Iorio (2016) based on EFIGE survey data for seven European countries found positive relationship between the ratio of graduated employees and the percentage of turnover from innovative products; van Uden, Knoben and Vermeulen (2014) based on Enterprise Surveys 2013 data for Kenya, Tanzania and Uganda found positive relation between human capital and innovation, the authors measured firms' performance by innovation outcomes and human capital by the level of education of the employees, formal trainings and employee slack time.

Similar to previous researches dummy variables for countries and sectors are included as well (Love et al., 2011).

Using the above mentioned variables as determinants of turnover from innovative sales, models are set up for sample of innovative firms with a turnover from innovative sales as a dependent variable (see equations 1 for the final model). As an estimation method, standard ordinary least squares (OLS) and tobit models are used. The tobit model, also called a censored normal regression model, is used for estimating linear relationships between variables when there is either left- or right-censoring in the dependent variable and is chosen as an additional tool to provide an additional evidence and strength to the results estimated by OLS model. In case of percentage of turnover from innovative sales as a dependant variable, it has the minimum value of 0% and the maximum value of 100%, hence, for the tobit model the lower limit is set at 0 and the upper limit at 1. In such case, the dependent variable *y* (percentage of turnover from innovative sales) is fully observed value of the latent dependent variable *y**.

For total turnover as dependent variable OLS model is estimated separately; the same explanatory variables are used in all models. Following equation stands for ordinary least squares (OLS) model:

$$
\begin{aligned}
&Turnover\_from\_innovative\_sales_i=\beta_0+\beta_1 Sectors+\beta_2 Countries+\beta_3 Product\_innov_i+\\
&+\beta_4 Process\_innov_i+\beta_5 Uni\_source_i+\beta_6 Govern\_source_i+\beta_7 Cooperation_i+\\
&+\beta_8 Cooperation\_with\_nat\_uni_i+\beta_9 Cooperation\_with\_foreign\_uni_i+\\
&+\beta_{10} Cooperation\_with\_nat\_govern_i+\beta_{11} Cooperation\_with\_foreign\_govern_i+\beta_{12} Size_i+\\
&+\beta_{13} Employees\_with\_uni\_degree_i+\epsilon_i
\end{aligned}
\tag{1}
$$

The common problem of regression models is multicollinearity, when the predictor variables are correlated with each other. To test for multicollinearity in proposed models, the VIF (Variance Inflation Factor) was estimated. The coefficients of VIF for all variables were nearly equal to 0, proving that the problem of multicollinearity does not exist in estimated models[3].

In order to see how the results vary across different European countries and recognize the common patterns of relation between university-industry collaboration and firms' performance, the above models are estimated separately for country groups. In order to provide a comparative view across the European countries, they are divided into five groups based on economic development and country specific characteristics:

group 1: Bulgaria, Czech Republic, Croatia, Hungary, Romania, Slovenia, Slovakia

group 2: Spain, Cyprus and Portugal

group 3: Estonia and Lithuania

group 4: Germany

group 5: Norway

[3] In addition, F-test and Wald test were run as well. The low p-value (<0,05) indicated the good performance and suitability of estimated models.

In previous literature in case of comparative analysis across countries, they have been mostly grouped by economic development distinguished as developed and developing countries (Guimón, 2013) or the by the date of joining EU and distinguished as new or old member states of the EU (Rõigas, Varblane and Mohnen, 2016). Here analyzed European countries form five groups in order to provide more detailed analysis. For the sake of simplicity, in case of country groups, only the OLS model is estimated.

In addition, the aim of the thesis is to analyze the relation between university-industry collaboration and firm's performance in priority sectors indicated in terms of Smart Specialisation concept; for this purpose the OLS and tobit models are estimated separately for priority sectors as well. In order to identify Smart Specialization growth areas by specific economic activities, I used Statistical Classification of Economic Activities in the European Community, Rev. 2 (2008). According to this classification defined priority sectors are Information and Communications Technology (ICT) and Enhancement of Resources. See Appendix 3 for list of priority sectors indicated in terms of Smart Specialisation concept and their content.

4. RESULTS AND DISCUSSION

The specific intention of the empirical analysis is to examine the relation between cooperation with universities, government, private and public institutions and firms' performance. Therefore, the following section presents the results on relation between collaboration and turnover from innovative sales as well total turnover. At first, the models are estimated for sample of 14 European countries considering separately the ICT and Enhancement of Resources priority sectors. Secondly, the OLS model is estimated separately for defined five country groups also considering analyzed priority sectors. Tables 2-3 depict the results for turnover from innovative sales and total turnover considering the whole sample of 14 analyzed countries. In Appendixes 6-8 are presented the results for turnover from innovative sales and total turnover in defined country groups. In order to make the presentation of results easier in case of country specific analysis, the results are presented by groups of indicators.

Table 2 provides the results of relation between explanatory variables and turnover from innovative sales for the whole sample of analyzed 14 European countries. In both, OLS and tobit models, product and process innovations have positive relation with turnover from innovative sales and total turnover in both analyzed priority sectors (see Tables 2-3). The positive relation is stronger in case of product innovation as it requires more R&D and innovation activities and provides direct link between innovation activities and turnover from innovation sales. The results remain within ICT and Enhancement of Resources priority sectors for product innovation. Such relation remains for all country groups in all sectors, including priority ones, in case of turnover from innovative sales as well as for second, third group and Germany in case of total turnover when considering all the sectors together or Enhancement of Resources priority sector. As for process innovation, for most of the country groups and sectors analyzed the relation between process innovation and turnover from innovative sales or general turnover is positive and significant (see Appendix 6). The results are consistent with the literature (Peters, 2005).

Using universities as a source of information for innovation has positive relation with turnover from innovative sales in both models only when analyzing all the sectors and total turnover in case of Enhancement of Resources priority sector (see Tables 2-3). The results support general framework that usage of universities as source of information for innovation is positively related to firm's innovation activities (Costa J. and Teixeira A., 2005). There is no clear trend of the relation between using universities as a source of information for innovation and turnover from innovative sales across analyzed country groups (see Appendix 6). Second and third country groups have significant positive relation between these variables when analyzing all sectors together and Enhancement of Resources priority sector respectively. When analyzing the relation between using universities as a source of information for innovation and total turnover, first group and Norway have no significant relation between these variables, but other countries have positive relation between using universities as a source of information for innovation and total turnover in case of analyzing all the sectors and Enhancement of Resources particularly.

According to the Tables 2-3, using government, public or private research institutes as source of information for innovation has no significant relation with the turnover from innovative sales or total turnover when analyzing 14 European countries together, meaning that firms that use government, public or private research institutes as source of information for innovation activities don’t benefit from it in terms of higher turnover from innovative sales compared to those which don’t use this source of information for innovation. When specifying the country groups using government, public or private research institutes as source of information for innovation, the significant positive relation between turnover form innovative sales and getting innovation information from government, public or private research institutes is estimated only in case of Germany in ICT sector. For total turnover, there is a positive relation only for first (considering all sectors) and second (for all the sectors as well as for Enhancement of Resources priority sector) country groups (see Appendix 6).

The general cooperation on innovation activities is significant and has negative relation with turnover from innovative sales in both models in case of analyzing all the sectors (see Table 2). It also has negative relation for country group 1 for all the sectors and country group 3 for ICT priority sector. Contradictory, it has positive and significant relation in case of total turnover in all the sectors including analyzed priority sectors (see Table 3). As for the country groups, the general cooperation on innovation activities has positive relation with total turnover for all country groups in particular sectors or for all of them (see Appendix 7).

The cooperation with national universities has no significant relation with turnover from innovative sales; which means that those firms that use national universities as cooperation partners don’t have advantage in terms of higher turnover from innovative sales compared to those who don’t. The same results remain when analyzing countries by groups. Hence, in all the analyzed European countries there is significant relation between cooperation with national universities and firms’ performance measured by turnover from innovative sales (see Table 2, Appendix 7).

Table 2. The results for turnover from innovative sales.

Variables	**Turnover from innovative sales**					
	Ordinary Least Squares (OLS)			Tobit model		
	All sectors	**ICT sector**	**Enhancement of Resources**	**All sectors**	**ICT sector**	**Enhancement of Resources**
Product innovation	**0.348 (0.004)*** **	**0.396 (0.012)*** **	**0.353 (0.006)*** **	**1.412 (0.021)*** **	**1.395 (0.063)*** **	**1.415 (0.031)*** **
Process innovation	**0.025 (0.004)*** **	**0.059 (0.011)*** **	**0.016 (0.006)*** **	**0.040 (0.007)*** **	**0.079 (0.017)*** **	**0.026 (0.011)** **
Universitites as source of information for innovation	**0.008 (0.005)* **	0.008 (0.014)	-0.002 (0.008)	**0.019 (0.009)** **	0.014 (0.022)	0.001 (0.015)
Government, public or private research institutes as source of information for innovation	0.005 (0.005)	0.017 (0.014)	0.001 (0.008)	0.003 (0.009)	0.019 (0.021)	-0.006 (0.015)
Cooperation on innovation activities	**-0.008 (0.004)* **	-0.007 (0.014)	-0.009 (0.007)	**-0.018 (0.009)** **	-0.012 (0.021)	-0.018 (0.015)
Cooperation with national universities	0.003 (0.006)	0.012 (0.017)	0.005 (0.010)	0.009 (0.011)	0.013 (0.025)	0.015 (0.018)
Cooperation with foreign universities	**0.044 (0.011)*** **	0.027 (0.030)	**0.051 (0.017)*** **	**0.053 (0.019)*** **	0.018 (0.043)	**0.073 (0.030)*** **
Cooperation with national government, public or private research institutes	-0.009 (0.006)	-0.017 (0.017)	-0.014 (0.010)	**-0.020 (0.011)* **	-0.021 (0.026)	**-0.027 (0.018)* **
Cooperation with foreign government, public or private research institutes”	-0.017 (0.012)	-0.040 (0.035)	-0.006 (0.019)	-0.033 (0.021)	-0.053 (0.049)	-0.015 (0.033)
Size based on number of employees	**-0.026 (0.004)*** **	**-0.048 (0.011)*** **	**-0.035 (0.006)*** **	**-0.049 (0.007)*** **	**-0.074 (0.017)*** **	**-0.068 (0.011)*** **
Percentage of employees with university degree	**0.023 (0.005)*** **	**0.055 (0.011)*** **	**0.060 (0.009)*** **	**0.040 (0.010)*** **	**0.077 (0.017)*** **	**0.099 (0.018)*** **

Note: * significant at 10%; ** significant at 5%; *** significant at 1%. Sector and country dummies included.

Source: calculated by the author based on CIS 2012 data.

In contrast, there is a positive relation between cooperation with foreign universities and turnover from innovative sales as well as total turnover (see Tables 2-3). The same results remain for some of the country groups analyzed in this work (see Appendix 7).

The cooperation with national government, public or private research institutes has negative relation with turnover from innovative sales in case of tobit model considering all the sectors and the priority sector of resource enhancement. The same results remain across analyzed European countries with the only exception in Germany and Norway, where positive relation has been estimated in some sectors (see Appendix 7).

Table 3. The results for total turnover.

Variables	Total turnover (log)		
	Ordinary Least Squares (OLS)		
	All sectors	**ICT sector**	**Enhancement of Resources**
Product innovation	**0.057 (0.017)*****	0.061 (0.052)	**0.110 (0.027)*****
Process innovation	**0.169 (0.017)*****	**0.186 (0.046)*****	**0.203 (0.028)*****
Universitites as source of information for innovation	**0.120 (0.023)*****	0.050 (0.061)	**0.140 (0.037)*****
Government, public or private research institutes as	**0.075 (0.022)*****	0.067 (0.059)	**0.065 (0.037)***
Cooperation on innovation activities	**0.176 (0.021)*****	**0.132 (0.059)****	**0.149 (0.036)*****
Cooperation with national universities	**0.095 (0.029)*****	0.059 (0.072)	**0.120 (0.048)*****
Cooperation with foreign universities	**0.381 (0.052)*****	**0.340 (0.131)*****	**0.416 (0.082)*****
Cooperation with national government, public or private	0.020 (0.029)	0.007 (0.075)	-0.066 (0.047)
Cooperation with foreign government, public or private	**0.102 (0.059)***	**0.272 (0.151)***	-0.129 (0.092)
Size based on number of employees	**2.260 (0.017)*****	**2.430 (0.048)*****	**2.334 (0.027)*****
Percentage of employees with university degree	**0.058 (0.023)*****	**-0.381 (0.046)*****	**-0.740 (0.045)*****

Note: * significant at 10%; ** significant at 5%; *** significant at 1%.

Sector and country dummies included.

Source: calculated by the author based on CIS 2012 data.

When considering the sample of 14 European countries, the cooperation with national government, public or private research institutes has no significant relation in ICT sector, which means that firms operating in this priority sector that cooperate with national government, public or private research institutes don't benefit from it in terms of higher turnover from innovative sales compared to those which don't use this source cooperation. The same pattern is estimated for Spain, Cyprus and Portugal; these countries belong to the second country group (see Appendix 7).

As for cooperation with foreign government, public or private research institutes, the results are not significant for turnover from innovative sales, meaning that firms cooperating with foreign government, public or private research institutes don't benefit from it in terms of higher turnover from innovative sales compared to those which don't use this source for cooperation. Among analyzed European countries there is no clear trend (see Appendix 7). In some countries, the positive relation has been estimated between cooperation with foreign government or research institutes (Norway), for some countries it is not significant (Spain, Cyprus, Portugal, Estonia and Lithuania) and for some there is even negative relation between cooperation with foreign government or research institutes and turnover from innovative sales (Bulgaria, Czech Republic, Croatia, Hungary, Romania, Slovenia, Slovakia and Germany). Hence, these results go in line with previous literature on this topic and support the statement that university-industry linkages differ across the countries because of natural distinctions (Eun et al., 2006).

In this work, there has been estimated negative and significant relation between size indicator based on number of employees and turnover from innovative in both models for ICT sector, resource enhancement sector and all sectors together across all analyzed European countries (see Appendix 8). These results suggest that larger firms have lower turnover from innovative sales and can be interpreted in the way that the share of turnover from innovative sales is smaller for larger enterprises as they have higher total turnover in general compared to smaller firms. In contrast, the size of the firm based on number of employees has positive relation with total turnover for all the sectors including defined priority sectors across European countries. Hence, larger firms tend to have higher total turnover, which is quite trivial and goes in line with literature on this topic (Tether, 2002; Mohnen and Hoareau, 2003; Capron and Cincera, 2003; Miotti and Sachwald, Fontana, 2003; Geuna, and Matt, 2006; Busom and Fernándes-Ribas, 2008; Eom and Lee, 2010).

The share of employees with university degree has significant positive relation with turnover form innovative sales in both models for ICT sector, resource enhancement sector and all sectors together across analyzed European countries (see Tables 2-3, Appendix 8). Hence, firms with higher share of employees with university degree tend to have higher turnover from innovative sales. These results are in line with previous literature and support our assumption that firms that have higher share of university educated employees tend to be involved in more innovation activities and have higher absorptive capacity (Ballot, Fakhfakh and Taymal, 2001; Bugamelli et al., 2012; Love, Roper and Vahter, 2013; d'Amore and Iorio, 2016)

Based on these findings it seems that cooperation with foreign universities is especially important for firms' performance, as it has positive relation with turnover from innovative sales when analyzing all the sectors and especially for resource enhancement sector which is one of the priority sectors defined in terms of Smart Specialisation concept. This positive relation remains across analyzed European countries such as Bulgaria, Czech Republic, Croatia, Hungary, Romania, Slovenia, Slovakia, Spain, Cyprus and Portugal. It might be especially relevant for small countries, where national universities are not able to fully meet firms' needs on R&D and innovation activities. In contrast, cooperation with national universities is not as important for firms as it has no significant relation with firms' performance measured by turnover from innovative sales. Estimated results are in line with the literature and support the findings of research done by Rõigas, Varblane and Mohnen (2016), which found out that national universities are not such interesting partners for firms engaged in internationalization. It is also important to note, that other types of cooperation considered in this research have no unique pattern in relation to firms' performance and differ across analyzed countries and sectors, suggesting that it depends on national and sectoral differences and diversity (Polt et al., 2001).

According to the results presented in this work, it seems that central government, especially on behalf of Smart Specialisation concept should focus on measures to enhance the cooperation with foreign universities as well as national and foreign government, public or private research institutes in particular cases.

5. CONCLUSIONS

The thesis is focused on the relation between different types of collaboration and firm's performance measured by turnover from innovative sales and logarithmed turnover. The main contribution of this work is to provide some new empirical insights into understanding of firms' motivation to collaborate with research institutes, by answering the questions: what is the relation between university-industry collaboration and firms' performance? Whether different types of collaboration have positive relation to firms' performance measured by total turnover and turnover from innovative sales or there is no clear linkage between firms' performance and collaboration with research institutes? In addition, the relation between collaboration with universities, research institutes and firms' performance is analyzed by country groups and in priority sectors determined in terms of Smart Specialisation concept.

The research questions were investigated on the firm level data from the Community Innovation Survey 2012 for 14 European countries. There are two priority sectors considered in this work, which are defined in terms of Smart Specialisation innovation concept: Information and Communications Technology (ICT) and Enhancement of Resources. Standard ordinary least squares (OLS) and tobit models are applied as utilized statistical techniques on firm level data, these models incorporated the cooperation variables as well as size indicator and control variables that are related to firms' performance.

Following types of collaboration are distinguished here: cooperation with national and foreign universities; cooperation with national and foreign government, public or private research institutes. The results reveal that cooperation with foreign universities is the most important out of four type of cooperation considered in this research. The cooperation with foreign universities has positive relation with firm's performance measured by percentage of turnover from innovative sales in contrast to other typed of cooperation considered here. On behalf of this research there was no significant relation estimated between cooperation with national universities and firm's performance measured by percentage of turnover from innovative sales. According to descriptive statistics, across all analyzed European countries most of the firms collaborate with national universities, which might be due to focus of central government on promoting collaboration with national universities. The results of this work show that in fact it would be more efficient for private enterprises to choose foreign universities as cooperation partners. It supports the findings that national universities are not such interesting partners for cooperation on innovation for private enterprises (Rõigas, Varblane and Mohnen, 2016).

At the same time the results show that the relation of other types of cooperation on firms' performance depends a lot on the sectoral and county specifications (Polt et al., 2001). In this case the central government policy should be adjusted according to these specifications to promote particular type of cooperation that is the most efficient in specific country and sector.

According to the results presented in this master thesis, it seems that central government, especially on behalf of Smart Specialisation concept should focus on measures to enhance the cooperation with foreign universities as well as national and foreign government, public or private research institutes in particular countries and sectors. These measures should be consistent with Smart Specialisation concept and apply bottom-up approach. On the other side, national universities should strengthen and enhance cooperation with foreign universities in order to understand and meet the needs of private enterprises.

The current thesis could be further developed by applying similar methods on Estonian firm level data from Business Register to deepen the analysis and compare university-industry collaboration modes, also more detailed analysis of the framework of university-industry collaboration in defined priority sectors could be applied.

REFERENCES

Archibugi D., Pianta M. (1996). Measuring technological change through patents and innovation surveys. Technovation, 16(9), 451-468.

Ballot G., Fakhfakh F., Taymal E. (2001): Firm's Human Capital, R&D and Performance: a Study on French and Swedish firms. Labour Economics, 8: 443-462.

Belderbos R., Carree M., Lokshin B. (2004a). Cooperative R&D and firm performance. Research Policy 33, 1477-1492.

Belderbos R., Carree M., Diederen B., Lokshin B., Veugelers R. (2004b). Heterogeneity in R&D cooperation strategies. International Journal of Industrial Organization 22, 1237-1263.

Breschi S., Malerba F., Orsenigo L. (2000). Technological regime and Schumpeterian patterns of innovation. Economic Journal 110 (463), 388-410.

Busom I., Fernándes-Ribas A. (2008). The impact of firm participation in R&D programmes. Research Policy, 37, 240–257.

Capron H., Cincera M. (2003). Industry-University S&T Transfers: What can we learn from Belgian CIS-2 Data? Brussels Economic Review, 46 (3), 59–86.

Chen H. Q., Song Z. Q., Yang M. (2007). Factors analysis and primary study on the patents implementation in Chinese universities. Research and Development Management, 19(4), 102-106.

Chen Y. W., Yang Z. P., Fang S., Wen Y., Hu Z. Y., Deng Y., Wang C. (2007). Ability analysis of Chinese technological innovation based on invent patent status. Science and Technology Management Research, 6, 9-12.

Costa J. and Teixeira A. (2005). Universities as sources of knowledge for innovation. The case of technology intensive firms in Portugal. FEP Working Papers №181.

D'Amore R., Iorio R. (2016). The relation between human capital and innovation at a firm level. A study on a sample of European firms.

Dasgupta P., David P.A. (1994). Toward a new economics of science. Research Policy 23, 487-521.

Davey T., Baaken T., Galan M. V., and Meerman A. (2011). The State of European University-Business Cooperation. Part of the DG Education and Culture Study on the cooperation between higher education institutions and public and private organisations in Europe.

Drucker P. (1969). The Age of Discontinuity: Guidelines to Our Changing Society. New York: Harper and Row.

Edmondson G., Valigra L., Kenward M., Hudson R. L., Belfield H., Koekoek P. (2012). Making industry-university partnerships work. Science|Business Innovati on Board AISBL.

Eom B.-Y., Lee K. (2010). Determinants of industry-academy linkages and, their impact on firm performance: The case of Korea as a latecomer in knowledge industrialization. Research Policy 39, 625-639.

Estonian Development Fund (2013). Smart Specialisation–Qualitative analysis.

Etzkowitz H., Leydesdorff L. (2000). The dynamics of innovation: from national systems and „Mode 2“ to a triple helix of university-industry-government relations. Research Policy 29 (2), 109-123.

Etzkowitz H., Webster A., Gebhardt C., Terra B.R.C. (2000). The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm. Research Policy 29 (2), 313-330.

Etzkowitz H., Leydesdorff L. (Eds.) (1997). Universities and the Global Knowledge Economy: A Triple Helix of University-Indusrty-Government Relations. Continuum, London.

Eun J.-H., Keun L., Wu G. (2006). Explaining the „University-run Enterprises“ in China: a new theoretical framework for university-industry relationship in developing countries and ist applications to China. Research Policy 35, 1329-1346.

European Commission. (2010), EUROPE 2020. A strategy for smart, sustainable and inclusive growth, Brussels, 3.3.2010.
[http://ec.europa.eu/regional_policy/sources/docgener/informat/2014/smart_specialisation_en.pdf]
[http://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf]

Faems D., Van Looy B., Debackere K. (2005). Interorganizational collaboration and innovation: toward a portfolio approach. Journal of Production Innovation Management 22, 238-250.

Foray D., David P. and Hall B. (2009). Smart Specialisation – The Concept. Knowledge Economists Policy Brief No 9, June 2009

Freel M.S., Harrison R.T. (2006). Innovation and cooperation in the small firm sector: evidence from northern Britain. Regional Studies 40(4), 289-305.

Freel MS. 2005. Patterns of innovation and skills in small firms. Technovation 25(2): 123–134.

George G., Zahra S.A., Wood D.R. (2002). The effects of business-university alliances on innovative output and financial performance: a study of publicly traded biotechnology companies. Journal of Business Venturing 17, 577-609.

Guimón J. (2013). Promoting University-Industry Collaboration in Developing Countries. World Bank.

Hong W. (2008). Decline of the center: The decentralizing process of knowledge transfer of Chinese universities from 1985 to 2004. Research Policy, 37, 580-595.

Hui X. (2010). A Regional University-Industry Cooperation Research based on Patent Data Analysis. Asian Social Science, Vol. 6, No. 11, 88-94.

Laursen K., Salter A. 2006. Open for innovation: the role of openness in explaining innovation performance among UK manufacturing firms. Strategic Management Journal 27: 131–150.

Lee Y. S. (1996). "Technology transfer" and the research university: a search for the boundaries of university-industry collaboration. Research Policy, 25(6), 843-863.

Leiponen A. 2005. Organization of knowledge and innovation: the case of Finnish business services. Industry and Innovation 12: 185–203.

Leiponen A, Helfat CE. 2010. Innovation objectives, knowledge sources, and the benefits of breadth. Strategic Management Journal 31: 224–236.

Love J.H., Roper S., Vahter P. (2014). Dynamic complementarities in innovation strategies. Research Policy 43, 1774-1784.

Love J.H., Roper S., Vahter P. (2013). Learning from openness: the dynamics of breadth in external innovation linkages. Strategic Management Journal., 35: 1703–1716

Margherita B., Andrea L. (2006). University–industry interactions in applied research: The case of microelectronics. Research Policy, 35(10), 1616-1630.

McCann P., Ortega-Argilés R. (2011). Smart Specialisation, Regional Growth and Applications to EU Cohesion Policy. Economic geography working paper 2011: Faculty of Spatial Sciences, University of Groningen.

Miotti L., and Sachwald F. (2003). Co-operative R&D: why and with whom? An integrated framework of analysis. Research Policy, 32, 1481–1499.

Mohnen P., Hoareau C. (2003). What Type of Enterprise Forges Close Links with Universities and Government Labs? Evidence from CIS 2. Managerial and Decision Economics, 24, 133–145.

Motohashi K. (2008). Assessment of technological capability in science industry linkage in China by patent database. World Patent Information, 30(3), 225-232.

Monjon S., Waelbroeck P. (2003). Assessing spillovers form universities to firms: evidence from French firm-level data. International Journal of Industrial Organization 21, 1255-1270.

Mowery D.C., Sampat B.N. (2005). The Bayh-Dole Act of 1980 and university-industry technology transfer: a model for other OECD government. Journal of Technology Transfer 30, 115-127.

National Center on Education and the Economy (NCEE), 2005. The Sources of Innovation and Creativity.

NCURA (National Council of University Research Administrators and Industrial Research Institute). 2006. "Guiding Principles for University-Industry Endeavors: Report of a Joint Project of the National Council of University Research Administrators and the Industrial Research Institute, USA." NCURA, Washington, DC.

Park K., Lee K. (2006). Linking technological regimes and technological catch-up: analysis of Korea and Taiwan using the US patent data. Industrial and Corporate Change 15(4), 715-753.

Peters B. (2005). The Relationship between product and process innovations and firm performance: microeconometric evidence. Centre for European Economic Research (ZEW), Department of Industrial Economics and International Management.

Polt W., Rammer C., Gassler H., Schibany A., and Schartinger D. (2001). Benchmarking industry-science relations: the role of framework conditions. Science and Public Policy, 28 (4), 247–258.

Powell W. W., Snellman K. (2004). The Knowledge Economy. Annual Review of Sociology. 30:199–220.

Roper S, Du J, Love JH. 2008. Modelling the innovation value chain. Research Policy 37: 961–977.

Roy R. (1972). University - industry interaction patterns. Science, 178 (4064), 955-960.

Rõigas K., Mohnen, P., Varblane U. (2016). Which Firms use Universities as Cooperation Partners?-The Comparative View in Europe. International Journal of Technology Management [forthcoming].

Santoro M. D. (2000). Success breeds success: the linkages between relationship intensity and tangible outcomes in industry-university collaborative ventueres. Journal of High Technology Management Research 11(2), 255-273.

Santoro M., Chakrabarti A. (2002). Firm size and technology centrality in industryuniversity interactions. Research Policy, 31, 1163–1180.

Tether B.S. (2002). Who co-operates for innovation, and why: an empirical analysis. Research Policy 31, 947-967.

Van Uden A., Knoben J. and Vermeulen P. (2014). Human capital and innovation: a firm level study. Institute for Management Research, Radboud University Nijmegen.

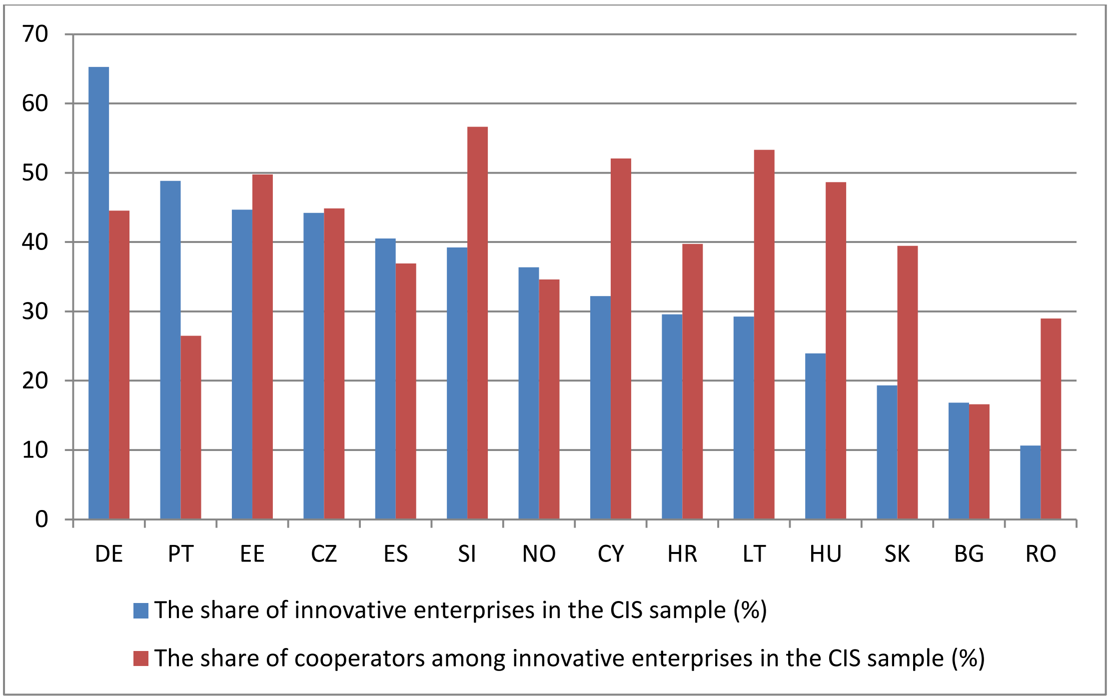
Varblane U., Mets T., and Ukrainski K. (2008). The role of the University-IndustryGovernment linkages in the innovation processes of the small catching-up economy. Industry and Higher Education, 22 (6), 373–386.

Appendix 1. List of countries.

Country code	Country Label
BG	Bulgaria
CZ	Czech Republic
DE	Germany
EE	Estonia
ES	Spain
HR	Croatia
CY	Cyprus
LT	Lithuania
HU	Hungary
PT	Portugal
RO	Romania
SI	Slovenia
SK	Slovakia
NO	Norway

Source: CIS 2012

Appendix 2. The share of innovative enterprises and the share of cooperators among them.



Source: calculated by the author based on CIS 2012 data.

Appendix 3. List of priority sectors and their content.

Sector Name	Content, NACE Rev. 2 classification number in CIS
Information and Communications Technology (ICT)	- Manufacture of computer, electronic and optical products (ICT, manufacturing); C26 - Manufacture of electrical equipment (ICT, manufacturing); C27 - Telecommunications (ICT, services); J61 - Computer programming, consultancy and related activities; information service activities (ICT, services); J62-63
Enhancement of Resources	<u>a. Material:</u> - Mining and quarrying (resources, material); B05-B09 - manufacture of textiles, wearing apparel and leather products (resources, material); C13-15 - manufacture of wood and paper products, and printing (resources, material); C16-18 - manufacture of coke and refined petroleum products (resources, material); C19 - manufacture of chemicals and chemical products (resources, material); C20 - manufacture of rubber and plastic products, and other non-metallic mineral products (resources, material); C22-23 - manufacture of basic metals and fabricated metal products, except machinery and equipment (resources, material); C25 <u>b. Construction (resources, construction); F</u> <u>c. Food:</u> - manufacture of food products, beverages and tobacco products (resources, food); C10-12 <u>d. Biotechnology:</u> - manufacture of basic pharmaceutical products and pharmaceutical preparations (resources, biotechnology); C21 - Scientific research and development (resources, biotechnology); M72

Appendix 4. Descriptive statistics for ICT priority sector.

Variable	BG	DE	CY	CZ	EE	ES	HU	HR	LT	NO	PT	RO	SI	SK
Turnover from innovative sales (products that were new to the market or firm), %	32.36	19.19	-	27.33	26.06	29.61	20.44	-	-	23.59	23.96	28.55	-	28.17
Log(turnover)	14.20	16.38	-	15.47	15.15	15.02	15.60	-	-	15.98	15.32	15.13	-	16.08
Product innovation (introduced new or significantly improved product or service), %	74.40	81.53	-	81.59	67.65	67.11	78.65	-	-	69.32	86.27	69.16	-	78.95
Process innovation (introduced new or significantly improved method of production; logistic, delivery or distribution system; or supporting activities), %	63.82	49.83	-	68.66	59.80	51.18	51.04	-	-	39.82	76.47	65.42	-	61.05
Universities as source of information for innovation, %	41.30	70.72	-	49.01	39.22	50.03	52.08	-	-	61.64	62.75	50.47	-	52.63
Government, public or private research institutes as source of information for innovation, %	31.40	33.15	-	16.36	24.51	48.40	26.04	-	-	55.03	51.37	41.12	-	32.63
Cooperation on innovation activities, %	26.28	55.73	-	43.04	59.80	42.46	55.21	-	-	29.50	42.75	36.45	-	45.26
Cooperation with national universities, %	8.19	34.78	-	42.78	16.67	18.66	26.56	-	-	38	63.30	9.35	-	20
Cooperation with foreign universities, %	2.39	6.88	-	6.94	3.92	4.12	4.17	-	-	15	13.76	4.67	-	6.32
Cooperation with national government, public or private research institutes, %	4.44	20.83	-	12.72	7.84	16.84	7.81	-	-	35	41.28	17.76	-	9.47
Cooperation with foreign government, public or private research institutes, %	1.02	4.71	-	3.47	1.96	3.21	1.04	-	-	15	11.01	4.67	-	3.16
Size based on number of employees	0.39	0.52	-	0.50	0.48	0.35	0.58	-	-	0.38	0.47	0.64	-	0.71
Percentage of employees with university degree	55.97	33.45	-	46.58	62.75	49.79	42.19	-	-	58.70	47.45	48.60	-	49.47
Number of observations	293	684	0	402	102	1651	192	0	0	339	255	107	0	95

Appendix 5. Descriptive statistics for priority sector of Enhancement of Resources.

Variable	BG	DE	CY	CZ	EE	ES	HU	HR	LT	NO	PT	RO	SI	SK
Turnover from innovative sales (products that were new to the market or firm), %	27.05	9.94	15.39	18.82	15.20	21.22	13.52	17.38	19.18	14.67	13.63	17.88	16.70	20.31
Log(turnover)	13.81	16.73	14.86	15.86	15.23	15.89	15.82	15.46	15.59	16.78	14.99	15.60	16.07	16.20
Product innovation (introduced new or significantly improved product or service), %	64.19	63.98	75	77.97	57.01	51.67	65.25	66.67	64.79	52.38	64.68	63.37	76.21	70.49
Process innovation (introduced new or significantly improved method of production; logistic, delivery or distribution system; or supporting activities), %	49.07	50.73	92.14	69.47	63.38	62.44	55.38	77.61	75.12	41.22	81.31	75.87	72.49	72.13
Universities as source of information for innovation, %	31.37	59.16	12.14	48.56	35.67	44.98	52.24	41.73	41.78	67.43	47.39	49.13	63.20	40.98
Government, public or private research institutes as source of information for innovation, %	27.16	30.61	12.86	21.89	21.66	52.06	27.35	30.79	31.93	69.38	42.02	40.70	52.05	29.51
Cooperation on innovation activities, %	12.94	45.75	51.43	47	44.59	38.17	44.40	36.13	48.83	37.77	24.28	26.45	56.13	42.62
Cooperation with national universities, %	3.72	28.12	4.29	48.72	14.65	15.12	26.68	15.78	40.39	46.09	62.12	8.14	27.51	14.75
Cooperation with foreign universities, %	0.73	6.48	2.86	7.19	4.14	3.73	3.14	2.55	4.81	18.70	13.94	2.91	11.52	7.10
Cooperation with national government, public or private research institutes, %	2.10	19.89	2.14	19.03	7.01	18.47	9.64	12.98	31.73	51.30	39.39	9.30	17.47	9.29
Cooperation with foreign government, public or private research institutes, %	0.49	3.79	1.43	2.09	2.23	3.36	0.67	4.33	6.73	18.70	7.27	0.29	8.55	3.83
Size based on number of employees	0.44	0.61	0.41	0.65	0.55	0.46	0.70	68.45	0.75	0.55	0.46	0.78	0.69	0.69
Percentage of employees with university degree	7.20	9.01	4.29	5.26	27.07	12.36	8.30	3.82	13.16	13.30	4.34	11.63	1.86	4.92
Number of observations	1237	1371	140	917	314	5154	446	393	213	609	1359	344	269	183

Appendix 6. The results on innovation and information indicators by country groups.

Country groups/ Variables	Turnover from innovative sales				Total turnover (log)			
	Ordinary Least Squares (OLS)							
	Product innovation	Process innovation	Universitites as source of information for innovation	Government, public or private research institutes as source of information for innovation	Product innovation	Process innovation	Universitites as source of information for innovation	Government, public or private research institutes as source of information for innovation
GROUP 1								
All sectors	**0,319 (0,007)*****	**0,037 (0,007)*****	0,008 (0,009)	-0,012 (0,009)	-0,005 (0,035)	**0,240 (0,034)*****	**0,182 (0,045)*****	**0,094 (0,046)****
ICT sector	**0,363 (0,025)*****	**0,066 (0,022)*****	-0,002 (0,027)	-0,002 (0,029)	0,102 (0,116)	**0,260 (0,103)*****	0,087 (0,126)	0,083 (0,133)
Enhancement of Resources	**0,324 (0,010)*****	**0,026 (0,010)*****	0,005 (0,014)	-0,011 (0,014)	-0,002 (0,055)	**0,285 (0,056)*****	**0,215 (0,075)*****	0,023 (0,077)
GROUP 2								
All sectors	**0,363 (0,004)*****	**0,017 (0,004)*****	**0,011 (0,006)***	0,004 (0,006)	**0,095 (0,019)*****	**0,089 (0,020)*****	**0,074 (0,028)*****	**0,122 (0,027)*****
ICT sector	**0,424 (0,015)*****	**0,043 (0,014)*****	0,015 (0,019)	0,011 (0,019)	0,059 (0,065)	**0,145 (0,060)*****	-0,009 (0,082)	0,109 (0,081)
Enhancement of Resources	**0,370 (0,007)*****	0,008 (0,007)	-0,006 (0,010)	0,005 (0,009)	**0,184 (0,031)*****	**0,111 (0,033)*****	**0,109 (0,044)*****	**0,121 (0,043)*****
GROUP 3								
All sectors	**0,489 (0,006)*****	**0,055 (0,032)***	0,052 (0,042)	-0,059 (0,045)	**0,079 (0,032)*****	**0,278 (0,110)*****	0,193 (0,144)	0,007 (0,152)
ICT sector	**0,258 (0,026)*****	0,039 (0,086)	0,018 (0,109)	-0,102 (0,104)	0,517 (0,022)	**0,594 (0,324)***	**1,073 (0,408)*****	-0,155 (0,391)
Enhancement of Resources	**0,174 (0,013)*****	-0,048 (0,046)	**0,100 (0,057)***	-0,031 (0,063)	**0,176 (0,085)*****	**0,527 (0,171)*****	0,215 (0,210)	-0,052 (0,231)
GERMANY								
All sectors	**0,177 (0,009)*****	**0,047 (0,008)*****	0,001 (0,010)	0,010 (0,009)	**0,117 (0,054)****	**0,213 (0,048)*****	**0,283 (0,060)*****	-0,049 (0,056)
ICT sector	**0,243 (0,030)*****	**0,091 (0,022)*****	0,023 (0,028)	**0,061 (0,025)*****	0,147 (0,144)	**0,170 (0,108)***	0,192 (0,135)	0,029 (0,119)
Enhancement of Resources	**0,165 (0,013)*****	**0,040 (0,012)*****	-0,008 (0,015)	-0,005 (0,014)	**0,181 (0,087)****	**0,226 (0,082)*****	**0,382 (0,104)*****	0,064 (0,096)
NORWAY								
All sectors	**0,320 (0,024)*****	**0,056 (0,022)*****	0,029 (0,038)	-0,005 (0,039)	-0,068 (0,129)	**0,211 (0,117)***	0,226 (0,199)	-0,088 (0,204)
ICT sector	**0,392 (0,074)*****	**0,166 (0,059)*****	0,063 (0,103)	0,011 (0,091)	-0,128 (0,290)	0,036 (0,233)	0,138 (0,407)	-0,069 (0,359)
Enhancement of Resources	**0,293 (0,032)*****	**0,066 (0,032)****	-0,030 (0,052)	-0,012 (0,057)	-0,129 (0,226)	0,187 (0,225)	-0,043 (0,371)	-0,086 (0,402)

Note: * significant at 10%; ** significant at 5%; *** significant at 1%. Sector and country dummies included.

Source: calculated by the author based on CIS 2012 data.

Appendix 7. The results on cooperation indicators by country groups.

Country groups/ Variables	Turnover from innovative sales					Total turnover (log)				
	Ordinary Least Squares (OLS)									
	Cooperation on innovation activities	Cooperation with national universities	Cooperation with foreign universities	Cooperation with national government, public or private research institutes	Cooperation with foreign government, public or private research institutes"	Cooperation on innovation activities	Cooperation with national universities	Cooperation with foreign universities	Cooperation with national government, public or private research institutes	Cooperation with foreign government, public or private research institutes"
GROUP 1										
All sectors	**-0,015**	0,005	**0,195**	-0,024	-0,068	**0,336**	-0,000	-0,355	-0,039	**0,827**
	(0,007)**	(0,033)	**(0,064)*****	(0,041)	(0,081)	**(0,037)*****	(0,169)	(0,324)	(0,212)	**(0,411)****
ICT sector	0,008	0,000	0,048	**-0,191**	-0,021	**0,300**	0,001	**-0,920**	0,170	**1,895**
	(0,025)	(0,077)	(0,121)	**(0,095)****	(0,186)	**(0,113)*****	(0,356)	**(0,557)***	(0,440)	**(0,857)****
Enhancement	-0,013	0,040	**0,188**	-0,016	**-0,199**	**0,452**	-0,092	-0,203	-0,192	**1.141**
of Resources	(0,012)	(0,051)	**(0,095)****	(0,065)	**(0,114)***	**(0,065)*****	(0,278)	(0,517)	(0,352)	**(0,618)***
GROUP 2										
All sectors	-0,001	0,005	**0,044**	**-0,014**	-0,016	**0,171**	**0,112**	**0,425**	0,001	-0,061
	(0,006)	(0,008)	**(0,015)*****	**(0,008)***	(0,017)	**(0,026)*****	**(0,036)*****	**(0,070)*****	(0,035)	(0,077)
ICT sector	0,005	-0,022	0,059	-0,014	-0,056	0,018	0,067	**0,394**	**0,185**	-0,073
	(0,018)	(0,023)	(0,046)	(0,024)	(0,051)	(0,077)	(0,096)	**(0,194)****	**(0,100)***	(0,215)
Enhancement	-0,007	0,015	0,035	**-0,024**	0,018	**0,154**	**0,144**	**0,513**	**-0,102**	**-0,590**
of Resources	(0,009)	(0,013)	(0,023)	**(0,012)****	(0,025)	**(0,043)*****	**(0,057)*****	**(0,108)*****	**(0,055)***	**(0,116)*****
GROUP 3										
All sectors	-0,043	-0,025	0,058	0,063	-0,026	**0,290**	-0,003	0,123	-0,044	-0,096
	(0,036)	(0,059)	(0,098)	(0,072)	(0,121)	**(0,123)****	(0,203)	(0,336)	(0,245)	(0,413)
ICT sector	**-0,201**	0,176	-0,376	0,069	0,344	**0,910**	**-0,950**	0,220	0,039	-0,858
	(0,096)**	(0,137)	(0,355)	(0,153)	(0,444)	**(0,360)*****	**(0,516)***	(1,333)	(0,574)	(1,669)
Enhancement	-0,004	-0,056	0,097	0,151	-0,056	**0,543**	**-0,470**	**-0,714**	-0,204	-0,064
of Resources	(0,054)	(0,084)	(0,117)	(0,098)	(0,138)	**(0,201)*****	**(0,311)***	**(0,434)***	(0,362)	(0,511)
GERMANY										
All sectors	-0,015	0,003	0,024	**0,026**	**-0,043**	0,100	0,039	**0,593**	-0,059	**1,131**
	(0,012)	(0,014)	(0,023)	**(0,013)****	**(0,027)***	(0,076)	(0,086)	**(0,145)*****	(0,080)	**(0,171)*****
ICT sector	-0,030	0,022	-0,042	**0,051**	-0,004	**0,305**	-0,169	**0,695**	**-0,315**	**1,148**
	(0,033)	(0,036)	(0,057)	**(0,032)***	(0,067)	**(0,158)***	(0,171)	**(0,274)*****	**(0,156)****	**(0,323)*****
Enhancement	0,005	0,002	0,022	0,008	-0,028	-0,094	0,121	**0,643**	0,035	**1,261**
of Resources	(0,020)	(0,021)	(0,034)	(0,019)	(0,042)	(0,137)	(0,146)	**(0,232)*****	(0,131)	**(0,288)*****
NORWAY										
All sectors	**-0,019**	-0,023	-0,008	0,112	**0,099**	**0,113**	0,077	0,257	**0,232**	-0,145
	(0,026)**	(0,026)	(0,036)	(0,026)	**(0,038)*****	**(0,095)****	(0,137)	(0,191)	**(0,136)***	(0,199)
ICT sector	0,061	0,077	-0,016	**-0,136**	0,012	0,081	0,025	0,328	0,065	-0,034
	(0,046)	(0,072)	(0,098)	**(0,075)***	(0,096)	(0,057)	(0,285)	(0,388)	(0,294)	(0,380)
Enhancement	0,023	-0,022	0,061	**0,060**	0,027	**0,241**	0,354	0,523	0,239	-0,038
of Resources	(0,004)	(0,038)	(0,054)	**(0,037)***	(0,052)	**(0,053)*****	(0,266)	(0,385)	(0,262)	(0,371)

Note: * significant at 10%; ** significant at 5%; *** significant at 1%. Sector and country dummies included. Source: calculated by the author based on CIS 2012 data.

Appendix 8. The results on size and employees' education indicators by country groups.

Country groups/ Variables	Turnover from innovative sales		Total turnover (log)	
	Ordinary Least Squares (OLS)			
	Size based on number of employees	Percentage of employees with university degree	Size based on number of employees	Percentage of employees with university degree
GROUP 1				
All sectors	**-0,037 (0,007)*** **	**0,041 (0,010)*** **	**2,315 (0,034)*** **	**0,223 (0,051)*** **
ICT sector	-0,002 (0,023)	**0,082 (0,023)*** **	**2,446 (0,107)*** **	**-0,367 (0,104)*** **
Enhancement of Resources	**-0,053 (0,010)*** **	**0,110 (0,019)*** **	**2,356 (0,056)*** **	**-0,517 (0,106)*** **
GROUP 2				
All sectors	**-0,016 (0,004)*** **	**0,014 (0,006)*** **	**2,238 (0,020)*** **	0,019 (0,028)
ICT sector	**-0,048 (0,015)*** **	**0,032 (0,014)*** **	**2,400 (0,062)*** **	**-0,418 (0,059)*** **
Enhancement of Resources	**-0,026 (0,007)*** **	**0,041 (0,012)*** **	**2,311 (0,031)*** **	**-0,821 (0,053)*** **
GROUP 3				
All sectors	**-0,116 (0,034)*** **	0,048 (0,038)	**2,023 (0,116)*** **	**0,366 (0,128)*** **
ICT sector	**-0,148 (0,089)* **	0,111 (0,092)	**2,361 (0,336)*** **	**0,558 (0,346)* **
Enhancement of Resources	**-0,096 (0,047)** **	0,022 (0,055)	**2,093 (0,174)*** **	0,093 (0,202)
GERMANY				
All sectors	**-0,036 (0,008)*** **	**0,029 (0,012)*** **	**2,382 (0,051)*** **	-0,071 (0,075)
ICT sector	**-0,089 (0,023)*** **	**0,079 (0,024)*** **	**2,658 (0,111)*** **	**-0,194 (0,114)* **
Enhancement of Resources	**-0,019 (0,012)* **	**0,096 (0,022)*** **	**2,378 (0,084)*** **	**-1,173 (0,153)*** **
NORWAY				
All sectors	**-0,114 (0,023)*** **	0,021 (0,030)	**2,453 (0,124)*** **	-0,007 (0,157)
ICT sector	**-0,104 (0,061)* **	**0,130 (0,060)** **	**2,158 (0,242)*** **	**-0,574 (0,237)*** **
Enhancement of Resources	**-0,091 (0,035)*** **	0,036 (0,045)	**3,338 (0,245)*** **	-0,450 (0,315)

Note: * significant at 10%; ** significant at 5%; *** significant at 1%.

Sector and country dummies included.

Source: calculated by the author based on CIS 2012 data.

Non-exclusive licence to reproduce thesis and make thesis public

I, Iryna Olshanska,

(*author's name*)

1. herewith grant the University of Tartu a free permit (non-exclusive licence) to:

1.1. reproduce, for the purpose of preservation and making available to the public, including for addition to the DSpace digital archives until expiry of the term of validity of the copyright, and

1.2. make available to the public via the web environment of the University of Tartu, including via the DSpace digital archives until expiry of the term of validity of the copyright,

"University-industry collaboration in terms of Smart Specialisation concept",

(title of thesis)

supervised by Urmas Varblane and Kärt Rõigas,

(supervisor's name)

2. I am aware of the fact that the author retains these rights.

3. I certify that granting the non-exclusive licence does not infringe the intellectual property rights or rights arising from the Personal Data Protection Act.

Tartu, **25.05.2016**