Industry Collaboration with Large Research Infrastructures: What factors influence knowledge benefits for companies?

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***Abstract*—Firms' collaboration with large research infrastructure through procurement activities during the construction phase of a large-scale scientific experiment, has been previously shown to enhance suppliers' performance. The present work assesses the industry collaboration with CERN, the European Organization for Nuclear Research, for the international study on a future particle accelerator for high energy physics, the Compact Linear Collider (CLIC study). The paper sheds light on the collaboration during the development phase of the CLIC study, while the previous literature has considered collaboration benefits during intensive procurement event – a construction phase of an approved project. In the development phase companies can participate in research, development, and improvement, as well as playing a consulting role for emerging technologies application. Therefore, the aim of the manuscript is to investigate outcomes for suppliers as knowledge benefits from the early-stage collaboration with the CLIC study. The conceptual framework is built on the exclusive dataset using the survey data from 71 industrial partners of the CLIC study. The results confirm positive aspects of early-stage collaboration and shows the roles of main influencing factors by involving multiple regression model.**

Keywords—public procurement, innovation, knowledge transfer, benefits, societal impact, industry-company collaboration.

I. Introduction

Nowadays universities and industries have very close connections. The border between scientific and commercial ventures is becoming more and more transparent. In this specific formed relationship both stakeholders follow their proper interests and goals. A number of studies have assessed motivations and emphasizing factors of University-Industry collaboration (UIC). Researchers attempted to provide policymakers, industrialists, and academics with a framework to motivate and to establish systematic balanced interaction between big science and industry. Thereby Autio in his early paper [1] specifies six motivating dimensions for the partners in big science-public and industry interplay, such as educational, political, financial, epistemic (knowledge creation), strategical and technological. Beside the emphasizing factors and motivations, researchers evaluated possible collaboration barriers due to cultural, institutional, operational difference, and gave practical advices for its overcoming by the UIC management [2].

An objective of this study is to investigate knowledge benefits through procurement activities by publicly founded science organization and industries. The study aims to determine main stakeholder's attributes, also, to access the extent to which these attributes enhance or diminish the outcome. The study is relevant to a Large Research Infrastructure – CERN. The considered knowledge benefits (used also as innovation benefits) are promoted from participation in one of the multiple studies of post-LHC machine. The study is presented by Compact Linear Collider [3] collaboration and focused on one of the possible benefits associated with procurement activities therefore coming from university-industry collaboration (UIC).

CLIC is an international study on an electron positron machine aimed to the mass energy of 3 TeV. The first publication about a linear collider machine dates from 1985. Collaboration work has continued for more than 20 years, within which the last ten years saw intensive prototyping in a proof-of-concept phase. At the present time, it is considered a mature project and ready to be built but it remains a study without the final approval from European Strategy for Particle Physics.

Hence, CLIC is a good research platform for evaluating industrial benefits from the international large-scale study, at its development stage. An industrial survey has been launched as a part of the societal impact assessment of the study. The collected and analyzed industrial feedback aims to demonstrate benefits for companies from collaboration with big science or with a well-known European international research organization.

CERN has its own procurement policy with proper regulations and different governance of contractual relations [4]. Different size companies can participate and work with CERN. However, additional rules on awarding contracts could create some barriers to industries.

The present paper presents the conceptual framework derived from the UIC literature, testing hypothesis. We show the results and conclude with discussion and suggestions for future research.

II. THEORETICAL BACKGROUND

Existing literature was studied to identify the gap of the field. Our focus was on the evaluation of UIC, paying a certain attention to fundamental science research infrastructure. Hereafter, the term UIC is used as a general term of the relationship between Academy / university / research infrastructure / Big Science and industry. We presume that this assumption is appropriate for the purpose of the research and does not adduce to any misleading.

There are two main actors in UIC: industry and research infrastructure. Each of them follows its certain goals and has proper motivations [1] in gaining commercial and technical benefits.

Later studies discussed wider range of outcomes from the UIC. A similar study performed for the Large Hadron Collider [5] demonstrates direct outcomes in performance enhancing, and intermediate outcomes in terms of learning, innovation, and market penetration. The survey was launched among 640 companies and got the reply rate about 24% [6].

The study provided finding on the various benefits from the collaboration and its tendency to occur jointly. Learning and innovation benefits appears to be shaped by the quality of the supplier's relationship with CERN [6]. The study indicates significant marketing reference benefits from CERN, together with technological learning, developing of new products or services, starting new R&D and/or business units. Technologically challenging projects are also important for CERN itself to increase motivation and knowledge acquisition by staff.

Finally, the authors hypothesized that becoming a CERN supplier induces more intensive effort in R&D and knowledge creation, leading to improvements in productivity and profitability, especially for high-tech suppliers [7]. The study stated that the order value and its innovative level shape the relationship between CERN and its suppliers.

Another study discussed the influence of CERN procurement on innovation [4] with understanding of implications of restricting interaction.

Participation in ITER [8] allows firms (1) to increase their financial performance; (2) to enhance their brand image; (3) to extend network of collaborations; (4) to improve internal processes; (5) to acquire new standards; (6) to have a new vision of the company; (7) to involve new people and; (8) to invest in the local and regional territories. The abovementioned outcomes can be represented as (1) economical, (2) marketing, (3) market expansion, (4) learning, (5) R&D, (6) innovation outcomes. The study provides inferences and tools in management of companies' involvement in Big Science projects for policy makers, managers, and researchers. The tool indicates incentives to be offered to SMEs to enhance knowledge propagation and business continuities.

The further literature review was aimed to distinguish important attributes shaping and influencing UIC.

Generally, authors consider four main attributes of firms such as size, ownership status, industrial sector and geographical location [9].

The geographical location of a firm is considered as the one of the first determinants in its ability to collaborate [10]. It is so-called a 'proximity effect': the capability to collaborate decreases with increasing distance.

Finally the research [9] confirms dependence of linkage from the size and the status of the firms. Subsidiaries of large firms or independent large firms collaborate more often than small ones. The latest studies demonstrated that large groups have a higher tendency to cooperate with research universities than small independent companies do. The paper [11] came to the same conclusion: small and middle size technological enterprises refer to the low effectiveness of collaboration with institutions.

To conclude, the evaluation of the previous literature allowed to distinguish different outcomes from the UIC and the factors motivating and forming its relation.

III. CONCEPTUAL FRAMEWORK

A. Research questions

The abovementioned statements found through the literature review showed benefits from RI and industry collaboration through the procurement for the large scientific project. But what if the project is not yet approved for construction? Can it claim already creating some benefits from the relationship? Therefore, we focus on finding a reply for the following research questions:

(RQ1) Does an international study (a Big Science project) start to create knowledge benefit for companies already on the development phase?

(RQ2) What is the role of firms' attributes, such as size, age, industrial sector (operational field) and geographical location, in UIC?

(RQ3) Is the knowledge benefit affected by companies' individual attributes?

(RQ4) Do benefits change along the collaboration duration?

(RQ5) What is the role of RI in emphasizing the university-industry collaboration?

(RQ6) How procurement policy, communication during procurement activities, involving in scientific events affect the benefits form collaboration?

B. Research hypothesis

Benefits for Industry from collaboration with Big Science center does not depend on the proximity effect but do depend on other firm's attributes such as the size, the age, and the operation field of the company. Large enterprises find easier to find motivation and to invest resources in a research and development than small companies. This is reflected in the next hypothesis:

H1. Large companies obtain more knowledge benefit through UIC than smaller size companies.

H2. Younger companies are more innovative and therefore they obtain more knowledge benefits from the collaboration.

H3. Location does not affect innovation benefits from UIC. There is no proximity effect.

Spread of technology (innovation benefits) does not depend on the procurement policy of the Big Science center but depends on the collaborative network, mainly relationship with other RI.

H4. Innovation is not influenced by procurement policy of RI, but...

H5. ...innovation is influenced by collaborative network. Thus, producing parts for other scientific laboratories are likely to impact positively on the collaboration outcomes.

However, RI can emphasize the outcomes from collaboration by changing some internal attributes such as, communication with companies or/and involving in scientific activities. Because of the specific fundamental science field, a company benefits from participation in scientific conferences, use of RI facilities, and common publications.

H6. Specifically, easier the communication process (to get and to ask information about a project) more likely a company will benefit from collaboration.

H7. The more a company participates in scientific events, the more likely it will obtain knowledge.

H8. Public procurement money shapes the knowledge benefits.

Some benefits have tendency to change among the timeline of UIC. It means that companies develop some benefits and freeze others during the collaboration period. In the context of the present study, we assume that the knowledge benefit increases with the relationship duration of the collaboration.

H9. Knowledge benefit grows during the relationship between a company and a research infrastructure.

Our conceptual model, including variables and hypothesis is summarized in Fig. 1.

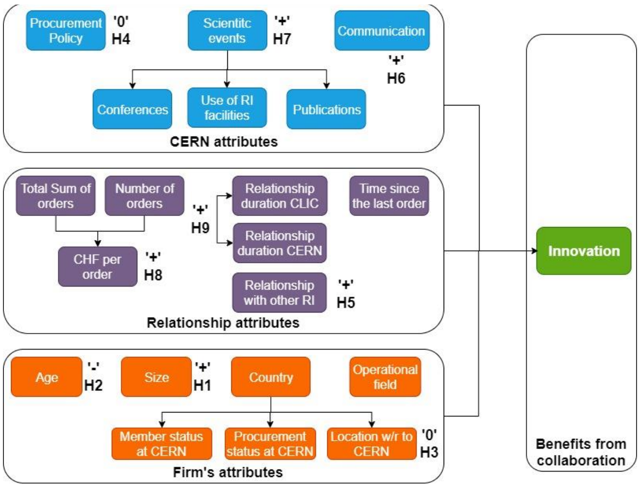

Fig. 1. Conceptual Model.

IV. RESEARCH DESIN, DESCRIPTIVE STATISTICS AND METHODS

To answer the research questions, the primary data was collected firstly through the CERN procurement database and secondly from an online survey addressed to CLIC suppliers in November 2020 via the Webropol platform [12].

A. Data collection

Our sampling was done based on the CLIC procurement database. All orders were recuperated from 2009 until beginning 2020. Based on the extracted value we found about 930 organizations including commercial companies and different research institutions. Several filters were applied. Firstly, we removed non-commercial organization and companies who provide services, education, catering etc. We focused on hi-tech firms. Secondly, we retained the procurement intensive suppliers with a total sum amount higher than 19 kCHF. The final sampling included 152 suppliers.

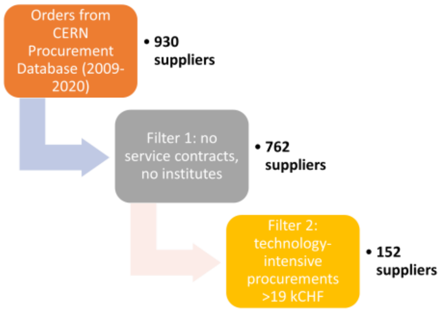

Fig. 2. Industrial settings.

B. The survey

The survey distribution was done in two steps. The pilot distribution was done by email to known suppliers in order to collect their feedback and check the clearance and understandability of questions. The pilot version was distributed among 22 suppliers in the period of February-April 2019.

Based on the pilot group we concluded that the questions were clear, and companies did not have difficulties to give their feedback. We decided to use an electronic survey platform to allow easier distribution of the survey among suppliers and easier accessibility and analysis of the results. The choice was done between different available options such as Google Form, Monkey Survey, CERN workspace platform and finally Webropol. The latest was found the most convenient and practical way of distributing and collecting feedback. The last version of the questionnaire was distributed end of November 2019 to the rest of suppliers with a reminder in two weeks, just before Christmas. The total amount of collected answers from the second round is 57 out of which54 firms gave feedback and three rejected to provide information. One of the reasons for refusal was that the size of the business with CERN is small comparing to the total turnover of the company. The final achieved reply rate was about 48.7% including the pilot group (see Figure 2).

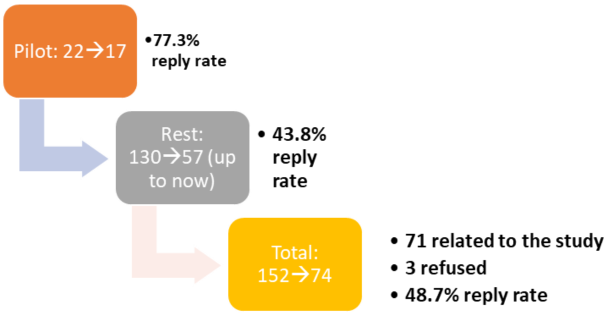

Fig. 3. Survey reply rate.

C. Descriptive statistics

The first results emerging from the direct survey replies based on responses from 74 suppliers in 16 countries, mainly from France (23%), Switzerland (18%), Italy (14%) and Germany (11%), see Fig. 4.

Fig. 4. Reply rates distribution among countries.

Respondent firms are distributed between micro, small, medium, and large-sized companies 18.31%, 32.39%, 22.54% and 26.76% respectively (Fig. 5). However, small companies slightly dominate. On average, each supplier processed 18 orders (standard deviation = 31) and received CHF 29,207 per order (standard deviation = CHF 83,152). A RI supplier collaborates with 4.46 other research infrastructures (standard deviation = 4.9).

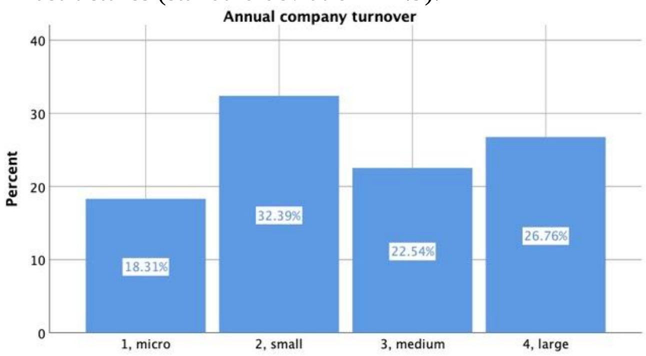

Fig. 5. Companies size based on the annual turnover.

An average relationship duration with CLIC is 7.72 years (standard deviation = 3 years, see Fig. 6) and with CERN 18.56 years (standard deviation = 18 years).

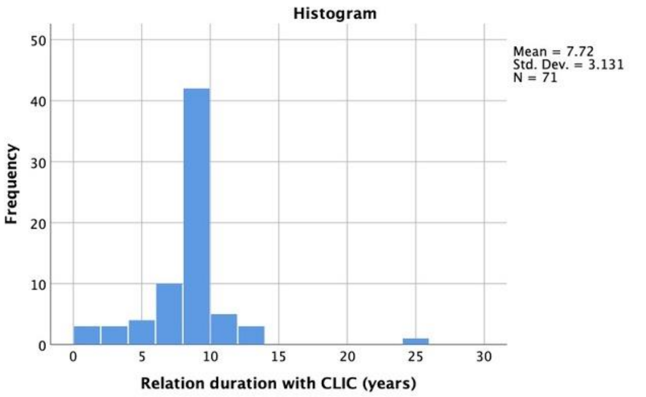

Fig. 6. Relationship duration.

An average supplier age is 42.75 years (standard deviation = 28 years, see Fig. 7).

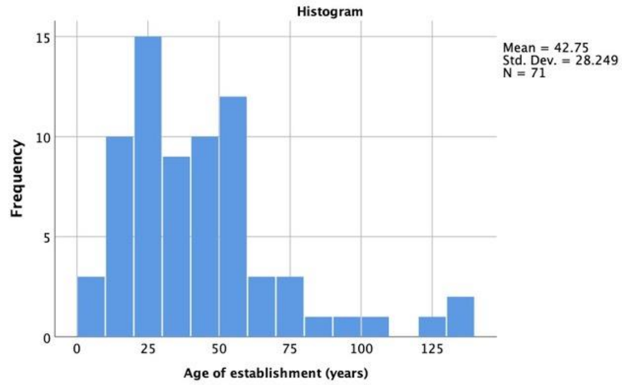

Fig. 7. Age of establishment.

Other aspects influencing UIC distinguished from the literature review are procurement policy and communication. The last can be controlled by RI to improve effectiveness of relationship. Fig. 8 shows the distribution of companies evaluating the procurement policy of CERN by two related statements from the survey: 'how difficult it was to start collaboration with CERN?' and 'how difficult do you find the CERN procurement/tender process?'. 28% and 31% companies reported easy to start the collaboration and easy procurement/tender process accordingly. More than the half of the surveyed firms indicates difficulties in both mentioned factors.

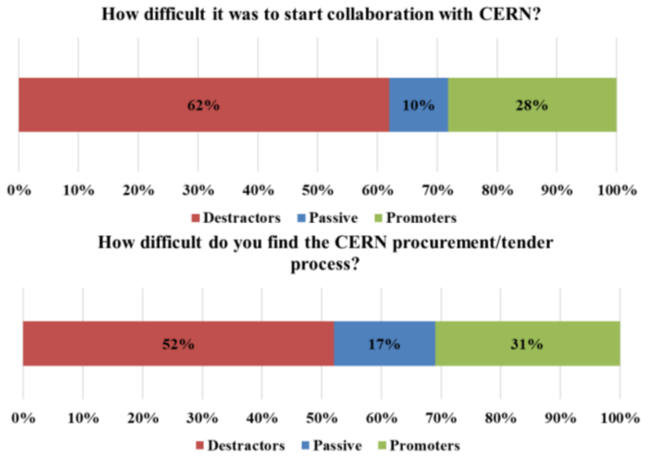

Fig. 8. Procurement policy

The largest part of the companies indicates that they know whom to contact and where to find the required information, 69% and 62% respectively, see Fig. 9.

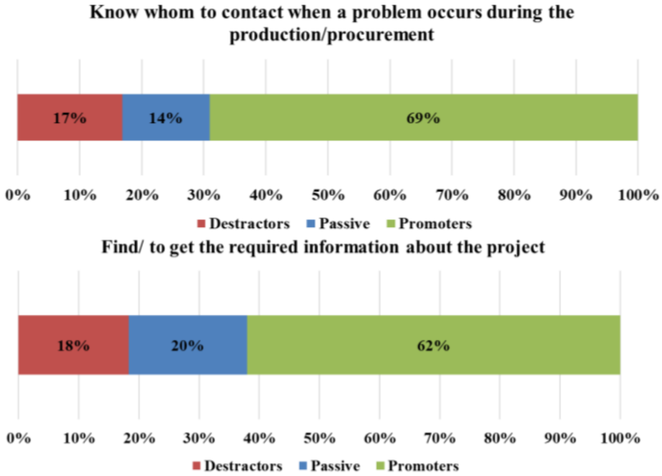

Fig. 9. Communication

D. The empirical Investigation

The data were processed by linear regression analysis, with knowledge benefit (innovation benefit) measured as the dependent variable. The aim is to identify correlations between knowledge benefit of suppliers from UIC and some of the possible factors, suggested by the concerned literature.

E. Variables

The survey responses are gathered to obtain the variables employed in the statistical analysis. The dependent variable is the knowledge benefit of a supplier from UIC.

The innovation is the variable measured in Likert scale from 1 to 5. The variable represents how a firm implements a new knowledge gained form the collaboration in other business lines. Accordingly, innovation values 1 in case of strong disagreement and 5 in case of strong agreement with the mentioned statement.

The independent variables are grouped into three categories: firms' attributes, RI attributes and relationship attributes. The firms' attributes variables are controlled.

- Firm's size is a dummy categorical variable, coded as 1 if the supplier is micro, 2 if small, 3 if medium-size and 4 if large. The value is extracted from the survey.
- Firm's age is a numerical variable, measures the age of the supplier on the year of the survey, 2020. The value is extracted from the survey.
- Country code 1 is a dummy categorical variable measuring the status of the supplier's country at CERN. It is coded as 1 if the country is non-member state, 2 if observer, 3 if associated state member, 4 if member [13].
- Country code 2 is a dummy categorical variable measuring industrial return from the CERN. It is coded 1 if the supplier is not in any list, 2 if located in a very poorly balanced country, 3 if the country is poorly balanced, 4 if it is well balanced [14].
- Country code 3 is a dummy categorical variable measuring the geographical location of the supplier with respect to CERN. It is coded as 1 if the location is more than 1500 km, 2 if less than 1500 km, and 3 if the country of the supplier is located on the border with Switzerland.
- Technology is a dummy categorical variable represents a firm's operation field and coded from 1 to 12 according to a provided technology to CERN. 1 – additive manufacturing, 2 – machining, 3 – instrumentation, 4- materials, 5 – power supplies, 6 – assembly, 7 – heat treatment, 8 – casting and molding, 9 – electronics, 10 – metrology, 11 – RF and waveguide components, 12 – vacuum components.

RI attributes are measured by the following variables:

- Procurement policy is represented by two ordinal variables "how difficult it was to start collaboration with CERN?" and "how difficult do you find the CERN procurement/tender process?", each coded from 0 to 10 according to the Likert scale and representing a not at all likely and extremely likely accordingly.
- Communication is represented by two ordinal variables "it is easy to know whom to contact when a problem occurs during the production/procurement" and "it is easy to find/ to get the required information about the project". Both variables are measured by Likert scale from 1 to 5, values 1 in case of 'strongly disagree' and 5 in case of 'strongly agree'.

The group of scientific events are captured by three ordinal variables:

- Conferences is the ordinal variable, measured in Likert scale from 1 to 5. The variable indicates a level of agreement to the statement "the company participates in scientific conferences, workshops, fairs". Coded 1 in case of 'strongly disagree' and 5 in case of 'strongly agree'.
- Use of RI facilities is the ordinal variable, measured in Likert scale from 1 to 5. The variable indicates a level of agreement to the statement "the company will appreciate a possibility to use CERN Infrastructure for their current or future needs". Coded 1 in case of 'strongly disagree' and 5 in case of 'strongly agree'.
- Publications is the ordinal variable, measured in Likert scale from 1 to 5. The variable indicates a level of agreement to the statement "the company produced publications due to business with CERNs". Coded 1 in case of 'strongly disagree' and 5 in case of 'strongly agree'.

The last group of variables presents the relationship attributes:

- Relationship duration with CLIC is calculated as the difference of the year of the current study (2020) and the supplier's first orders from CERN with CLIC study team. The item has a discrete value. The value is extracted from the CERN procurement database.
- Relationship duration with CLIC (with end date) is calculated as the difference between the year of the supplier's last and first orders from CERN with CLIC study team. The item has a discrete value. The value is extracted from the CERN procurement database.
- Relationship duration with CERN is calculated as the difference of the year of the current study (2020) and the year of the starting collaboration with CERN. The date is provided by the supplier. The item has a discrete value. The value is extracted from the survey.
- Relationship with another research infrastructure is a numerical value measured by the numbers of institutes collaborating with the supplier. The value is extracted from the survey.
- CHF per order is a numerical variable measured by the ratio of the supplier's total count of money to the supplier's total count of orders received from CLIC. The value is extracted from the CERN procurement database.
- Time since the last order is a numerical variable measured by the difference between the year of the survey (2020) and the year in which the supplier received its last order. It takes a discrete value. The value is extracted from the CERN procurement database.

Table 1 shows the full list of variables.

TABLE 1. LIST OF VARIABLES

Variable	Mean	N
Innovation/knowledge benefit		
Technical knowledge gained from CERN related technologies or services are used in other business lines	3.11	71
Firms' attributes		
Size	2.577	71
Age of the company	42.75	71
Country code 1 (status with CERN)	3.68	71
Country code 2 (balanced, data on the 18.5.2020 [14])	3.25	71
Country code 3 (Location)	2.49	71
Technology	5.80	71
RI attributes		
Procurement policy		
How difficult it was to start collaboration with CERN?	4.21	71
How difficult do you find the CERN procurement/tender process?	3.70	71
Communication		
Know whom to contact when a problem occurs during the production/procurement	3.76	71
Find/ to get the required information about the project	3.54	71
Scientific events		
The company participates in scientific conferences, workshops, fairs etc.	3.44	71
The company will appreciate a possibility to use CERN Infrastructure for their current or future needs	2.44	71
The company produced publications due to business with CERN	1.93	71
Relationship attributes		
Do you have collaboration/business with other Research Institutes (number)?	4.46	71
Relation duration with CLIC	7.72	71
Relation duration with CLIC (with end date)	4.32	71
Relation duration with CERN	18.56	71
CHF per order	29206.835	71
Time since last order	2.54	71
Total count of order	18.09	65

V. FINDINGS

A. Assumptions to use of Linear Regression Analysis

On the collected data to study impact of the factors on the innovation benefit we performed the linear regression analysis, preliminary checking for the central assumptions: 1) linearity in parameters; 2) independence of errors; 3) homoscedasticity of errors; 4) normal distribution of errors; 5) absence of multicollinearity. Due to the presence of high correlation between multiple control variables, some control variables 'Country code 1' and Country code 2' are excluded for the further analysis.

B. Linear Regression Analysis

We used a linear regression model to analyze correlations between knowledge outcome and a set of variables. Table 2 reports estimate of the regression with knowledge benefit as a dependent variable.

Thus, controlling main firm's attributes such as age, size, location and technology, the reported model presents significant effect of the relationship duration on the knowledge outcome from the collaboration. The CERN attributes, procurement and communication policy, scientific events on the contrary, do not present significant influence on the innovation outcome. The results confirm Hypothesis 4 and Hypothesis 9.

Finally, noting the role of some control variables, firm's size is linked to the knowledge benefit. The size of the company positively influences the firm innovation, in line with Hypothesis 1. It can be explained as the big companies usually dispose more resources to involve in innovation with less risks. Larger companies generally have a good pillow for sustainable function, and it is an increasingly common practice having a separate department for innovation or for collaboration with RI. The study in [11] came to the same conclusion: small and middle size technological enterprises refer to the low effectiveness of collaboration with institutions.

According to our assumptions, there is no presence of the geo-proximity effect. Which means that the innovation in our specific case is not affected by the distance from the RI. It confirms Hypothesis 3. The statement contradicts to other researchers in this field [9] that indicates that the role of proximity is even more important in intensive bilateral relations with a university. Consequently, additional investigation is required.

TABLE 2. LINEAR REGRESSION ANALYSIS

Dependent variable: Technical knowledge gained from CERN related technologies or services are used in other business lines	
Size	0.221 (0.153)*
Age of the company	-0.119 (0.006)
Country code 3 (Location)	0.036 (0.292)
Technology	-0.018 (0.044)
Procurement Policy	
How difficult it was to start collaboration with CERN?	0.055 (0.064)
How difficult do you find the CERN procurement/tender process?	-0.052 (0.073)
Communication	
Know whom to contact when a problem occurs during the production/procurement	0.064 (0.226)
Find/ to get the required information about the project	-0.023 (0.262)
Scientific events	
The company participates in scientific conferences, workshops, fairs etc.	0.232 (0.142)
The company will appreciate a possibility to use CERN Infrastructure for their current or future needs	0.239 (0.135)
The company produced publications due to business with CERN	-0.031 (0.197)
CHF per order	-0.202 (0.0)
RI relationship with CERN	
Relation duration with CLIC	0.252 (0.061)*
Relation duration with CLIC (with end date)	0.013 (0.102)
Relation duration with CERN	-0.172 (0.017)
Relationship with other RI	
Do you have collaboration/business with other Research Institutes (number)?	0.215 (0.040)
Time since last order	0.124 (0.09)
R	0.629
R square	0.396

Note: Robust standard errors in parenthesis. ***, **, * denote significance at the 1%, 5% and 10% level, respectively.

C. Discussion

The study answers to the research questions and validate four out of nine hypotheses. It demonstrates the role of firms, CERN and relationship attributes in generating innovation benefit. In this paper we use it as synonym to the knowledge benefit, following the paper [15] where knowledge and technology transfer is debating in the analysis of innovation. However, the presented analysis is not enough to reject the rest of the hypotheses and will be repeated by studying separately an impact of each group of main stakeholders' and relationship attributes on the knowledge benefits from the collaboration. Moreover, the most part of the theoretical background is built on the UIC literature, since there is still a lack of research in big science comparing to the volume of research into universities [16].

VI. CONCLUSION

A. Limitations

This study was limited by focusing only on the procurement activities of the CLIC Accelerator studies [17], not considering the CLIC Detector and Physics study [18]. The latest involves the use of emerging technologies as well, and a wide range of collaborative network with other RI and industries. Secondly, the procurement activities were limited to the period from 2009 to the beginning 2020. However, the time slot represents more procurement intense and prototyping period of the study.

B. Concluding remarks

In spite of its limitations, the study certainly adds to our understanding of the important factors of UIC. Although the current study is based on a small sample of participants, the finding will be of interest to high level managers both of RI and of industries to be able to emphasize the outcomes from the collaboration.

The findings from this study makes several contributions to the current literature. Firstly, it confirms the presence of the benefits for companies already at the early stage of an international study, mainly starting already with the development phase. The role of firms' attributes in the created collaborative outcomes is in line with other research. There is a change of benefits along the collaboration duration but this phenomena requires additional studies. Meanwhile, there is no evidence that CERN procurement policy has an influence of the fact of getting innovation benefits, even taking into account that more than half part of companies rates the difficulty to start collaboration and a tender process from 4 to 10. Opposite to the rating of the communication features which along with the previous one neither do not influence the innovative outcome for firms, but more than half companies do not have any difficulties to get the required information.

Beside mentioned scientific and managerial contributions of the study the results are a part of societal assessment of CLIC study and represents a technological impact area.

C. Future work

A natural evolution of this work is to analyze other outcomes from the CLIC-industry relationship. Firstly, following [6] we assume that the various relationship benefits tend to occur together. A supplier, which derives one type of benefit from CERN procurement activities, is more likely also to derive other types of benefits from the same relationship. The LHC study [6] demonstrates the high degree of inter-correlation between learning, innovation, performance impacts from technological procurement by government-funded science organizations. Secondly, we distinguish a similar list of benefits to the one already discussed in the theoretical background section [8]: marketing, market expansion, learning, R&D. Therefore, further research could usefully explore the link between RI's, firm's and relationship attributes and individual benefits. The mentioned study will (1) build a complete picture of the outcomes from UIC, (2) explore bias between the benefits under influence of different attributes, and (3) evaluate a bias between the benefits with the time. If some benefits have tendency to change among the timeline of UIC. It means that companies develop some benefits and freeze others during the collaboration period.

ACKNOWLEDGMENT

We would like to thank all industrial partners for valuable contribution to this study and fruitful collaboration.

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