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# THE SUCCESS OF SCIENCE-INDUSTRY R&D COOPERATION. A FUZZY-SET APPROACH

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**Purpose:** This study focuses on the causal mechanisms by which a series of organizational factors like commitment, communication, experience, dependence and trust collectively affect on the success of science-industry R&D cooperation. The purpose of this paper is to identify multiple paths of complex causal recipes that can lead to success of science-industry R&D cooperation.
**Design/methodology/approach:** The study uses fuzzy-set qualitative comparative analysis (fsQCA), a technique that provides a holistic view of the examined interrelationships, compared to traditional net effect approaches that assume symmetric and linear relationships among variables.
**Findings:** Results indicate that different causal paths, exactly five configurations, explain success R&D contracts. Particularly, the findings reveal that the availability of commitment and communication are important, sufficient conditions because they appear in at least three of the five configurations that result from the analysis. In this way, a series of conclusions and implications have been obtained that can be very useful, both in the academic world and when trying to lead and manage cooperation agreements.
**Research implications:** A comprehensive theoretical model was developed and tested that identifies the organizational factors of the success of science-industry R&D cooperation. The presented model and comprehensive research using fs/QCA allows to overcome the fragmentation of this specialized literature.
**Practical implications:** The results contain a number of practical recommendations that can be useful in the conduct and management of cooperation agreements. During the establishing and developing contract stages, it is recommended to design managerial and organizational mechanisms that ensure a high degree of commitment and communication in combination with experience (configuration number 1) and/or with dependences (configuration number 4).
**Originality/value**: Vital value of this paper is the use of fs/QCA, a technique that is an important novelty, at least in the field of R&D cooperation relationships between companies and research organizations. This method allows testing the configuration of conditions in relation to a specific outcome (e.g. success of science-industry R&D cooperation) in a way that is not possible using a linear additive approach.

**Keywords:** R&D cooperation, success in science-industry cooperative agreements, organizational factors, fs/QCA.

**Category of the paper:** Research paper.

## 1. Introduction

There are many reasons justify cooperative relationship between companies and research organizations such as the integration of science and industry, the appearance of industries based on science, the use of science as a means to generate competitive advantages on the part of the firms, the facilitate knowledge acquisition and exploitation of novel scientific discoveries, the possibility to complement firms' scarce internal resources, or the opportunity to enlarge firms' social networks (e.g. Audretsch, Leyden, and Link, 2012; Soh, and Subramanian, 2014; Mowery et al., 2015; Giannopoulou, Barlatier, and Penin, 2019). As research institutions are knowledge-intensive organizations, research indicates that partnerships on the border between science and industry are one of the basic ways in which companies can gain access to significant, innovative knowledge. Such alliances enhance the idea that companies might not conduct all R&D activities internally, forcing them to expand and look outside their own boundaries to complement their in-house R&D efforts (Lin, 2014).

For the purpose of this paper, this type of R&D cooperation between companies and research organizations can be defined as the connection between basic research (performed at universities, laboratories, research centers) with applied research (carried out in industries) in such a way that, as a result of a joint operation of both parts synergies can be created that will improve the economic and technological potential of a country, and consequently, increase its level of competitiveness.

Because every cooperative relationship is born to achieve specific goals, assessing the success of a collaboration agreement is fundamental in order to know to what extent certain goals have been achieved. Therefore, it can be assumed that the success of a cooperation agreement depends on achieving the intended goals that were set at the early stages of the relationship. In the literature, success is measured by objective measures by means of stability, continuity, the survival of the relationship and the evolution of the relationship over time, as well as subjective measures for example the level of partner’s satisfaction. However some of the most common limitations in the literature on science-industry R&D cooperation are, in fact, the lack of integration regarding the variables, dimensions and measures employed the definition of the unit of analysis and the shortage of empirical evidence. Therefore, it is invariably important to conduct further research to test and evaluate this type of relationships and to identify the different configurations of factors that lead to success in this type of cooperative relationships.

This study is intended to provide the some theoretical basis and empirical evidence to identify multiple paths of complex causal recipes that can lead to success of science-industry R&D cooperation. With this aim, the main theoretical and empirical studies on this subject have been revised, selecting those factors with the greatest significance and relevance in the literature concerned. Hence, a series of key organizational factors, relevant for the success of the cooperation, have been identified. In fact, they are organizational features that form part of the partners' behavior and have an influence on the behavior of the rest of the partners. Next to overcome the methodological challenges of testing the configurations of selected factors, the current research used fuzzy set qualitative comparative analysis (fs/QCA), a set-theoretic configurational approach with the ability to handle high degrees of complexity in how different causal conditions combine to bring about an outcome. Rather than estimating the average net effect of a particular organizational factors, the study assesses how multiple, alternative configurations of selected factors explain the success of science-industry R&D cooperation. The findings suggest that there are five different configurations, causal paths that lead to productive R&D collaboration.

The remainder of the paper is structured as follows. First, the determining organizational factors of science-industry R&D cooperation success were analyzed. Then the sample used was described together with the measures used for each variable involved. Finally, the main results obtained were shown and discussed, and conclusions were drawn regarding future research directions.

## 2. Theoretical background – determining organizational factors in the success of science-industry R&D cooperation

Literature on science-based collaborative R&D partnerships suggests different organizational factors that help explain the performance of such alliances. A detailed description and discussion of each of these factors is provided below.

The first of the organizational factors analyzed was a commitment of the partners that is defined as the extent to which the partners get involved in the interorganizational relationship. Literature dealing with the relationship between companies and research organizations analyzes commitment from various points of view. In the study by Dowling et al. (2004), regarding the conceptualization of a successful partnership model, indicated that implementation of such model is depended on the level of commitment of the partners. This comprises the eagerness shown by both parties as proved by the partners' beliefs and behaviors. There are several aspects that should be considered such as the volume of resources contributed by the partners, or the support of seniors executives and the involvement of personnel directly involved in the relationship. The higher the contribution and use of resources, the higher the support of management and other staff, the higher the partner's degree of commitment. Given that each cooperation agreement requires a high level of commitment of partners participating in the project, there are many studies that measure the impact and influence of each partner's commitment on the outcome of the agreement. Research indicates that the higher the participation and involvement of some or all senior executives, the more effective the

R&D cooperation will be (e.g. Gritzo, Fusfeld, and Carpenter, 2017; Plewa, and Quester, 2006) and mutual the prospects for continuity of survival of such relationships have a positive impact on the relationship's outcome.

As second organizational factor, communication can be described as an exchange of information process, concepts as well as ideas between individuals who belongs to different organizations. One of the most important factors considered to be the most successful, as described in scientific papers, is open and frequent communication (e.g. Ankrah, and Al-Tabbaa, 2015; Haire, and Dodson-Pennington, 2002). The development of an appropriate communication system that ensures regular exchange of information between partners is essential for the agreement success. Frequent and open communication allows individuals and groups to develop common purposes and concepts about their situation through the development of both formal and informal communication links, which keep members informed and involved (Haire, and Dodson-Pennington, 2002; Sink, and Jackson, 2002). Efficiently functioning partners share technical data, information enabling them to achieve their goals and solve possible conflicts as well as make better decisions in changing situations. This communication serves to strengthen mutual trust between the parties. Thus, the success of R&D cooperation can be affected by open and frequent communication, which is considered an important factor. This is equally important for establishing informal relationships and communication links.

In relation to science and industry alliances, the company's decision to make an alliance with research institutions depends on academic performance. Due to the fact that the generation of knowledge is associated with a certain degree of uncertainty, companies will be more willing to deal with research institutions with a more solid reputation. If research achievements have an impact on society and the economy, the capacity of the research institution to generate company awareness will increase, thus increasing the likelihood that companies will know about that organization (Kathoefer, and Leker, 2012). According to previous research, in this study, as another organizational factor, experience in the form of recordings of achievements and historical successes, which is key to attracting funds and partners, has been taken into account. Hence, it was assumed that experience positively contributes to more profitable R&D partnerships. For the purposes of this study, experience has the form of publications reflecting the quality of research and stimulating future research activities. Publications in well-indexed scientific journals reflect not only the quantity, but also the qualitative aspects of research (Kao, and Hung, 2008). The significant role of the articles is due to the fact that researchers submit articles to journals with a double-blind peer review system and journals publish these articles in accordance with the academic quality standards. Therefore, the right approach is to limit research productivity only to scientific papers appearing in top journals.

In science-industry R&D cooperative relations, another important factor in the literature is the dependence related to the extent to which the activities carried out by each partner are linked to the activities carried out by other partners participating in the cooperation agreement.

It is assumed that the level of dependence depends on the resources of cooperating partners, and the two organizations are interdependent when one of them has resources that are beneficial to the other (Gulati, 1998) or which can help achieve specific goals (Andaleeb, 1996). According to the resource dependence theory, the level of dependence between the two organizations is related to the size and availability of resources and information held by the other partner for joint research, which would have been unthinkable had it not been for the cooperation agreement. In accordance with the transaction costs theory, dependence is the outcome of the type of investment made by the partners for the development of the alliance (Ganesan, 1994). It should be noted, however, that while some studies show a negative relationship between dependence and satisfaction of the parts, other authors have shown that high dependency does not necessarily mean lower satisfaction (e.g. Blankenburg et al., 1999). These recent studies consider that organizations with a high dependency will mainly attribute the results of relationships to their partners, which leads to a higher level of satisfaction.

As indicated by the literature, trust between partners (the last factor considered in this study) is very important factor for creating and developing interorganizational relationships, which can be based on both interpersonal and institutional relationships (Canhoto, et al., 2016; Hemmert, Bstieler, and Okamuro, 2014; Bjerregaard, 2010; Philbin, 2008; Cullen, Johnson, and Sakano, 2000). Trust can be defined as "the expectation that one part will promise to fulfill its obligations, behave in a predictable way and negotiate and act fairly if the possibility of opportunistic action presents itself" (Zaheer et al., 1998). There are two basic aspects in interorganizational trust (Zaheer et al., 1998). First honesty means acting in the belief that your partner will keep his word and act honestly. Second, benevolence refers to the belief that the partner will behave honestly when new conditions appear, for which no commitment has been made, adapting to the new situation, if unexpected changes occur. Trust arouses belief among partners about fair treatment and mutual help in solving any problems that may occur. For this reason, trust can help reduce apparent barriers to cooperation. When the level of trust in cooperation is low, partners are less likely to share the necessary information and knowledge needed to ensure successful cooperation (Inkpen, and Tsang, 2005). Therefore, high-level trust between partners will promote rich information exchange to acquisition more valuable information and knowledge. Trust contributes to the success of relationships between research organizations and companies by fulfilling their respective goals, increasing the chances of relationships surviving. In fact, trust between companies and cooperating research organizations is essential for the development of the relationships and contributes to its success (Davenport et al., 1999).

## 3. Data and methods

The research area was cooperation agreements in the field of research and development, in which at least two partners participate: a company and an external organization specializing in research and technological services. To perform the analysis, a sample was selected that is sufficiently indicative for the phenomenon under study. In this way, the selected contracts are projects carried out by technology centers in Poland that meet the following requirements: (1) the contract was concluded between January 2018 and January 2019; (2) two types of participating partners: a company and a research institution. Thus, by 31 January 2000, the number of projects meeting the requirements was 131. Since a company can participate in more than one project, the total number of sample companies is 53. In most cases, these contracts involve two or three partners. Regarding the type of partner cooperating with the company, 76% correspond to universities, 24% to technology centers. Finally, these contracts last for an average of three years, include the performance of activities related to new information and communication technologies as well as the latest technologies. The author conducted in-house surveys in firms and face-to-face interviews with Senior Manager, Project Leader, and Project Team Members. If an interviewee could not understand or was not willing to answer certain questions during the in-house survey, investigator gave explanations to avoid incomplete answers.

Due to the search for a combination of factors that are sufficient to explain the outcome – success of science-industry R&D cooperation, fuzzy set qualitative comparative analysis (fs/QCA) was used in this study. Fs/QCA is particularly suitable for cases with small data samples, however, allowing generalization of conclusions and implications to larger populations (Rihoux, and Ragin, 2009). Fs/QCA implies complex causality and focuses on asymmetrical relationships that detect configurations sufficient to achieve a specific result. Configuration is a combination of factors, conditions in fs/QCA terminology (commitment, communication, experience, dependence and trust in this study), that are minimally necessary and/or sufficient to achieve a specific outcome (success of science-industry R&D cooperation in this research). Fs/QCA is considered to be the most appropriate method for this study, because: it allows to explore configurations of conditions (multiple paths of complex causal recipes) that in conjunction lead to a particular outcome (e.g. success of science-industry R&D cooperation); it allows for equifinality, i.e., multiple causal pathways that lead to the same outcome of interest. Respectively, fs/QCA offers the unique opportunity to identify configurations of conditions, which are difficult to identify by means of other methods.

The first step in fs/QCA is to calibrate outcome and conditions into fuzzy sets, thus categorizing significant groups of cases in the range from 0 to 1 (Ragin, 2008). To arrive at continuous set membership values (in the range between 0 and 1), the log odds method described by Ragin (2008) is applied. Fuzzy-set values range from full membership (1) to full non-membership (0). The crossover point (0.5) shows neither in nor out of the set. For each outcome and conditions, those observations falling in the percentile-90 are considered to represent full set membership. Percentile-10 is the threshold value for indicating full non-membership. The crossover point is defined by the median. After calibration, the next step is to build a truth table, a matrix space with $2^k$ rows, where $k$ is the number of conditions. Each empirical case corresponds to a configuration depending on which conditions the case meets. Each column represents a condition (Fiss, 2011). The next step is reducing the number of rows in the truth table. Although several algorithms can logically minimize the truth table, in the case of fs/QCA the most common choice is the version of the Quine-McCluskey algorithm. By using Boolean algebra, the algorithm returns a set of combinations of causal conditions, each combination being minimal enough to get the outcome. All analyses used the fs/QCA 2.5 software package.

To measure outcome and conditions that constitute the analysis model, various types of measures were used. In most cases, scales consisting of a set of items were used, which were assessed in range from 1 to 7. As for the outcome, that is, the success of the R&D cooperation, one measure have been used refers to the level of global satisfaction of the parts of the agreement. Most studies consider satisfaction as an acceptable indicator of the achievement of objectives in a cooperative agreement. Therefore, satisfaction with the perception of partners was identified on some aspects of the cooperative relationship. Therefore, five items were proposed that relate to specific global aspects of the project, such as partner performance, contract development and global project results (Mohr, Spekman, 1994).

As for organizational factors, commitment has been measured by five items which rate the commitment expressed by the senior executives and by the rest of the participants in the organization, as well as the emotional commitment, prospects of continuity and the wish to invest (Burnhamn, 1997; Randazzese, 1996; Davenport et al., 1999). For measuring the frequency and content of communication, a four items scale based on measures developed by Mohr and Spekman (1994), and Olk and Young (1997) was proposed. The measure of experience based on the proposal of Kao and Hung (2008), was the number of articles published in scientific journals indexed on the Web of Science. The measure for dependence is formed by four items referring to the cost of changing partner, the resources of the other partners to which the organization has had access and the investments made in specific assets as a result of the agreement (Mohr, and Spekman, 1994; Andaleeb, 1996). And the last to measure trust was used a four item scale representing integrity and benevolence developed on the basis of the research of Ganesan (1994), Mohr and Spekman (1994), Kumar et al. (1995) and Geyskens et al. (1996).

## 4. Results

This section presents the results of the analysis, explaining which configurations of conditions lead companies to the outcome (i.e. success of science-industry R&D cooperation). The first step is to examine the conditions necessary for the outcome. A condition is necessary when its consistency score exceeds the threshold value of 0.9 (Schneider, Schulze-Bentrop, and Paunescu, 2010). In this study no necessary conditions were found. Following Ragin's (2009) recommendation, this study reports the intermediate solution. Table 1 shows each configuration's consistency and the resulting test against the consistency threshold of 0.74 (Woodside 2013). Black circles (●) indicate the presence of a condition, white circles (○) denote its absence, and blank cells indicate 'don't care' conditions. The consistency and coverage for individual solution terms (configurations) and the overall solution (total set of configurations) are shown. Raw coverage refers to the total percentage of cases with the associated outcome that is represented by a solution term. For example, 34% of the cases that represented the success of the R&D cooperation are represented by configuration number 1 in table 1. Unique coverage refers to the percentage of cases that is only represented by the regarding configuration and not simultaneously by another configuration, i.e. cases that fit to configuration 1 but not to configuration 2, 3, 4 or 5. Consistency refers to the percentage of cases of a configuration that result in the associated outcome. For example, 86% of the cases fit to configuration 1 in table 1. For the individual configurations, the consistency of the explained outcome is respectively 86%, 97%, 93%, 89% and 81% while the overall solution consistency of the configurations of paths of complex causal recipes that can lead to success of science-industry R&D cooperation is 83%. The overall coverage of 65% indicates that the five solution terms jointly cover 65% of the cases.

**Table 1.**
*Sufficient configurations of conditions for outcome -success of science-industry R&D cooperation*

| **Causal conditions** | **Configurations no.** | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| Commitment | ● | | ● | ● | ● |
| Communication | ● | ● | | ● | |
| Experience | ● | ● | | | ○ |
| Dependence | | ○ | ● | ● | ● |
| Trust | | ● | ● | | |
| Consistency | 0,86 | 0,97 | 0,93 | 0,89 | 0,81 |
| Raw Coverage | 0,34 | 0,19 | 0,27 | 0,31 | 0,23 |
| Unique Coverage | 0,04 | 0,02 | 0,03 | 0,05 | 0,06 |
| Solution Coverage | 0,65 | | | | |
| Solution Consistency | 0,83 | | | | |

Note. Filled circles indicate above-threshold levels of the respective condition. Empty circles indicate below-threshold levels. Blank cells indicate 'don't care' conditions.

The first and second configurations number 1 and 2 (table 1) show that a sufficient conditions for success of science-industry R&D cooperation is the combination of presence of communication and experience with presence of commitment in configuration 1 or presence trust and absence of dependence in configuration 2. Configurations number 3, 4 and 5 combine presence of commitment and dependence with presence of trust in configuration 3 or presence communication in configuration 4 or absence of experience in configuration 5. Overall, the presence of commitment occurs as a condition in each configurations, except for configuration number 2. The analysis also shows that the commitment condition leads to success of science-industry R&D cooperation only when combined with the presence or absence of specific attributes. The presence of communication occurs as a condition in three of the five configurations (configurations number 1, 2 and 4), just like the presence of dependence (configurations number 3, 4, and 5). Summarizing, all the analyzed conditions, instead of having an individual effect, are part of sufficient configurations leading to success of science-industry R&D cooperation.

## 5. Conclusions and discussion

Due to the short number of studies which show empirical evidence about the success of science-industry R&D cooperation, and the lack of integration in the use of variables, dimensions and measures, the purpose of this paper has been the recognition of the organizational factors which have an influence on the success of this kind of cooperative relationships and identification multiple paths of complex causal recipes (configurations) that can lead to such success. To do so five organizational factors were selected, namely commitment, communication, experience, dependence and trust. Because the interest of this research is not so much which factors are necessary but which combinations of factors are sufficient to explain the outcome, this study uses fuzzy-set qualitative comparative analysis (fs/QCA). The results confirm that organizational factors are very important for the success of cooperative agreements, highlighting the importance of the behavior of partners during the implementation stage and pointing out that they can occur in different configurations simultaneously leading to the same results i.e. success of science-industry R&D cooperation. These findings are consistent and expand the empirical evidence of previous research.

The involvement of commitment to the success of science-industry R&D cooperation has been highlighted in four of the five configurations obtained (configurations number 1, 3, 4, and 5), which is in line with earlier reports that every cooperative agreement requires a high level of commitment by the partners involved in the project. Interestingly, in two cases, commitment is combined with the presence of communication, while in the first configuration, there is additionally the presence of experience (configuration number 1), and in the second configuration the presence of dependence (configuration number 4). In turn in the other two cases, commitment is connection with the presence of dependence and presence of trust in configuration number 3 and absence of experience in configuration number 5.

This research has also shown the importance of communication for success of science-industry R&D cooperation, which is present in three of the five configurations (configuration number 1, 2 and 4). It also refers to earlier studies that emphasize the role of communication as the process through which information is transmitted, participatory decision-taking is prompted, activities are coordinated, power is executed and the existence of commitment and loyalty between the organizations involved in the cooperative agreement is encouraged (Collier, Gray, Ahn 2011).

When analyzing the effect of experience, the additive effect of this factor is important in the causal recipe in two configurations. That is, experience positively contributes to the explaining the outcome and occurs in connection with the presence of commitment and communication in configuration number 1 or the presence of communication and trust in configuration number 2. However, in the case of configuration number 5, presence of commitment and dependence leads to success of science-industry R&D cooperation despite the absence of experience. Therefore, lack of experience can be compensated by the simultaneous presence of high level of partner commitment and high dependence.

In the case of dependence, in three cases it leads to success of science-industry R&D cooperation in connection with the presence of commitment and trust (configuration number 3) or presence of commitment and communication (configuration number 4) or presence of communication without experience (configuration number 5). The analysis also confirms that trust has an impact on success of science-industry R&D cooperation in connection with the presence of communication and experience without dependence in configuration number 2 or presence of commitment and dependence in configuration number 3. This acknowledges earlier reports that trust builds a flexible working environment that contributes to the free exchange of information, partners show a higher commitment to the agreement, higher motivation to achieve their joint goal, and higher willingness to sustain the alliance in the long term.

Following Ragin's (2008) recommendation, the two causal paths – configurations, with greater raw coverage (configurations 1 and 4) deserve further attention. In both cases, the impact of commitment and communication on success of science-industry R&D cooperation has been highlighted. Although configuration number 1 presents these previous conditions in combination with presence of experience, and in configuration number 4 in combination with presence of dependences.

In summary, because science and technology must serve society, the use of scientific-industry cooperation with research and development partners is one of the main mechanisms through which companies gain access and significant knowledge. Results indicate that different causal paths, exactly five configurations, explain success R&D contracts. Particularly, the findings reveal that the availability of commitment and communication are important, sufficient conditions because they appear in at least three of the five configurations that result from the analysis. In this way, a series of conclusions and implications have been obtained that can be very useful, both in the academic world and when trying to lead and manage cooperation agreements. First, a comprehensive theoretical model was developed and tested that identifies the organizational factors of the success of science-industry R&D cooperation. The presented model and comprehensive research using fs/QCA allows to overcome the fragmentation of this specialized literature. Another contribution of this paper is the use of fs/QCA, a technique that is an important novelty, at least in the field of R&D cooperation relationships between companies and research organizations. The unique potential of fs/QCA as a research method should be emphasized. This method allows testing the configuration of conditions in relation to a specific outcome (e.g. success of science-industry R&D cooperation) in a way that is not possible using a linear additive approach. In cases where the interaction of the variables included in the study is mutually significant, fs/QCA offers more accurate predictions of the outcome relative to the linear approach.

In addition, the results contain a number of practical recommendations that can be useful in the conduct and management of cooperation agreements. During the establishing and developing contract stages, it is recommended to design managerial and organizational mechanisms that ensure a high degree of commitment and communication in combination with experience (configuration number 1) and/or with dependences (configuration number 4). To conclude, it should be stated that this study is a starting point for future research, which should be aimed at expanding theoretical and empirical evidence regarding the success of science-industry R&D cooperation.

Despite covering an existing gap in the literature, this research has some noteworthy limitations. First, the findings draw on a single study. The robustness of the results reported here, therefore, requires replication studies. The fs/QCA was based on a relatively small number of cases, and the knowledge of cases was more limited than in some other case study methods. Therefore, conducting more interviews in one case can contribute to a better understanding of the success of science-industry R&D cooperation. Further, the current study uses subjective measures rather than actual data. Although this is a limitation, some studies report such measures to be satisfactory reflections of actual firm performance.

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