International Food and Agribusiness Management Review
Volume 22 Issue 2, 2019; DOI: 10.22434/IFAMR2018.0023

Received: 30 January 2018 / Accepted: 9 November 2018

Resource complementarities in R&D network for innovation performance: evidence from the agricultural sector in Brazil and Spain

RESEARCH ARTICLE

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Abstract

This article deals with interorganizational networks for the development of technologies and innovation, the sharing of resources to generate competitive advantages, and the complementarity of resources within the context of interorganizational relations. The aim was to establish the relationship between the complementarity of resources in networks and innovation performance. This research used qualitative comparative analysis and content analysis to investigate 25 networks in the agrobusiness sector in Brazil and Spain. Findings revealed that there is complementarity among resources in a network created to innovate; to produce innovation a combination of resources in the networks is necessary, there is a country effect on the resources set connected to innovation, the network is a structure that favors innovation development but its 'management' is essential to achieving success.

Keywords: innovation performance, agricultural technology, resource-based view, R&D networks, qualitative comparative analysis (QCA)
JEL code: L14, O32, Q16

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1. Introduction

The extensive body of literature about innovation makes it clear how important it is for corporate performance and therefore for corporate survival, as it increases value creation (Anderson *et al.*, 2004; Kyrgidou and Spyropoulou 2013). A general aspect of an innovation is that the innovation should have been implemented. A new or improved product is implemented when it is introduced into the market (OECD, 2005).

Many companies have decided to close their research and development (R&D) departments due to high maintenance costs, according to Powell and Giannella (2010). The emergence of management norms and structures that facilitate knowledge-sharing with other actors is also important, as well as the uncertainty about the direction that technological development is taking. So, firms have to develop another innovation generation model: the networks.

Innovation in networks can involve companies and other actors, such as government, universities, research centers, financial agents, and even users. Therefore, a network configuration can be present in dyadic relationships (between two actors) or in multilateral relationships (between three or more actors) (Pellegrin *et al.*, 2007).

A network is a very particular organization model. A network can be defined as long-term relationships between two or more firms. Its objective is providing economy of scale and/or of scope and/or reducing transactions costs to the companies (Thorelli, 1986). According to Thorelli (1986) it is possible to create a network between firms when there is a common domain between the partners: product or service, market, operation, territory or time.

One of the specific characteristics of a network is complementarity of actors' resources (Lavie, 2006). Resources are tangible and intangible assets, defined as physical, human, financial and organizational, that a company controls or has access to, and that can be used to create and implement strategies (Barney, 1991). In some cases, firms have a shortage of resources or control only a few specific resources (Imai, 2000; Tolstoy and Agndal, 2010). In a network firms can use the partner resources (Rothaermel and Deeds, 2004). This is a very consolidated theme.

Therefore, innovation can serve as a performance measure within a network that has this scope, irrespective of the type of actor involved. From a theoretical point of view, it is possible to assume that: (1) networks are important for developing technology and innovation, especially for organizations that have a shortage of resources or only a few specific resources (Imai, 2000); (2) sharing resources and having cooperative relationships have a beneficial effect on a company's competitiveness (Kim and Choi, 2014; Oliver, 1990); (3) a resources complementarity exists within an inter-organizational network (Lavie, 2006); and (4) innovation can be a performance measure (Dushnitsky and Lenox, 2005; Keil *et al.*, 2008). In this sense one justification to create a network is to share resources. And resources are also connected to innovation. So, there are some gaps that this paper is trying to explain: what if the complementary resource set is able to generate innovation in a network?

This study was conducted to compare innovation networks within the agricultural research sectors of two countries, Brazil, which is well-known worldwide as a leading producer of food products, and Spain, which is one of the few European countries with programmes for improving plants based on genetically modified organisms (GMOs) and which is the European country with the largest area planted with GMO crops (James, 2015).

These two countries have set up two public companies: the Brazilian Agricultural Research Corporation (EMBRAPA – Empresa Brasileira de Pesquisa Agropecuária), and the National Institute for Agriculture and Food Research and Technology (INIA Instituto Nacional de Investigación y Tecnología Agraria y

Alimentaria), in Spain. They are very important companies in their countries, and they work with networks to develop agrobusiness innovation.

The core of the rationale for Embrapa as the object of study is that it is recognized as one of the most innovative and award-winning companies in Brazil, as it generates a considerable amount of patentable innovations and has developed innovations that have a positive impact agriculture at the national and global levels.

Besides Brazil, this research is also in Spain, investigating institutions of the agricultural sector, in order to analyze the results of the variables in this study in different realities. In this way, in Spain we investigated the INIA. The choice of this institution was to be a reference in the agricultural sector, to chair the Commission for Coordination of Agricultural Research of the Autonomous Communities of Spain and to have partnerships with several agricultural research institutes in Europe and South America.

This paper contribution demonstrates that: (1) there is complementarity among resources in a network created to innovate; (2) to produce innovation, a combination of resources in the networks is necessary; (3) there is a country effect on the resources set; (4) the network is a structure that favors innovation development, but its management is essential to achieving success.

In addition to this introduction, the article is structured in four major parts. First, we perform a literature review in order to present a theoretical framework about resources complementarity, networks and innovation. In the second part, we present the methods. In the third section, we describe our findings. And finally, in the last part we offer a discussion and present our conclusions.

2. Theoretical background

A company can be described as a collection of productive resources with which different managers can make various decisions (Penrose, 1959). The first concept about resource came from Penrose (1959) and is strengthened by later studies (Barney, 1991; Dierickx and Cool, 1989; Peteraf, 1993; Wernerfelt, 1984). Among these studies, Barney (1991) developed the resource-based view (RBV). Companies are heterogeneous in relation to the imperfectly imitable resources that exist between them (Barney, 1991). Thus, the RBV (Barney, 1991) and other seminal contributions relating to the concept of resources (Amit and Schoemaker, 1993; Dierickx and Cool, 1989; Penrose, 1959; Peteraf, 1993; Wernerfelt, 1984) establish a nexus between a company's resource structure and competitive advantage.

Companies that are able to accumulate valuable, rare, difficult-to-imitate, and non-substitutable resources gain a competitive advantage over their rivals (Barney, 1991). However, such resources have more recently been characterized as valuable, rare, difficult-to-imitate and exploited by organizations. Barney and Clark (2007) refer to this concept as the VRIO model – an initialization for value, rarity, imitability, and organization.

The RBV literature also includes a debate about resources geared to innovation systems, in particular highlighting the complementarity of these resources between the actors involved (Gawer and Cusumano, 2002; Rosenberg, 2006). Resources at organizational level are developed and used to implement strategy by establishing and defining the limits of what a company can do (Dierickx and Cool, 1989; Peteraf and Barney, 2003). Strategic resources contribute to a firm's success. Galbreath (2005) pointed out that organizational assets, such as culture, human resource management policies and corporate structure, can significantly affect a firm's success. In contrast, tangible resources may still have a viable place in the firm's performance. Carraresi *et al.* (2016) did some research with 67 small and medium enterprizes. Their findings showed that information that firms acquired about market and consumers is valuable for enhancing the marketing capability and improving firm performance. Information in this sense is a resource, rare, difficult-to-imitate and exploited by the firms as Barney and Clark (2007) reported.

But resources are not available and may be found not only at the company level but also outside a company, meaning within networks (Gulati, 1998, 1999; Tolstoy and Agndal, 2010)). The paper by Tolstoy and Agndal (2010) studied new international product ventures. Both technological resources and market and reputational resources from the network have a positive impact on this kind of venture.

Inter-organizational relationships 'are the relatively enduring transactions, flows, and linkages that occur among or between an organization and one or more organizations in its environment' (Oliver, 1990, p. 241). This same concept can be employed for networks, because according to Huggins (2010) and Marhold and Kim (2017) the availability of resources within a network means that the companies involved should have the capacity for innovation performance. Therefore, an innovation network can be understood as a heterogeneous inter-organizational model whose actors interact through collective actions to pursue innovation (Pellegrin *et al.*, 2007).

Even though the RBV was thought of as a way to explain the creation of a competitive advantage for a company (Barney, 1991; Hauschild and Knyphausen-Aufseβ, 2013), it can also be applied within the context of networks (Lavie, 2006). Networks can be used by the organizations to manage strategic uncertainties (Kogut, 1991). The firm's ability to set up and manage strategic and technological alliances can be considered as a distinct organizational capability for gaining competitive advantage (Kim and Choi, 2014; Minshall, 1999). So, the complementarity of resources between members is a crucial factor (Kogut, 1988; Lin *et al.*, 2009). Innumerable difficulties are involved in generating resources within a company and in obtaining it externally, because in many cases these resources are not marketable (Dierickx and Cool, 1989) and/or transferable (Peteraf, 1993). So, a network represents one way of addressing such difficulties.

In these terms, networks facilitate the relationship development that makes it possible to access and share necessary resources. And this access makes it possible to combine network resources with those of a company (Bulgacov *et al.*, 2012). Networks allow access to integrated complementarities in terms of knowledge, learning, capacities, and specializations (Caner and Tyler, 2015; Lundvall, 1998; Nelson, 1995; Walter *et al.*, 2015). The network collaboration for new product development is frequently intended to exchange resources which are valuable to both the sender and receiver, because they possess characteristics of inimitability and immobility (Perks, 2004).

Therefore, networks represent an alternative method of organizing production and can be used by companies that seek to improve their competitive standing (Teece *et al.*, 1997). In view of these possibilities, as well as other reasons relating to cooperation, we note the complementarity of resources between partners as being one of the principal motivations to operate within a network of cooperation (Barney and Hesterly, 2004).

Indicators for different types of resources in the context of R&D organizations (Pike, Roos and Marr, 2005) like research centers or networks can be:

- human resources (HumR): R&D capacities, business alignment, management capacity, partnership capacities, learning;
- organizational resources (OrgR): intellectual property, processes, organizational culture, brand and image, organizational structure, and organizational strategy. One more organizational resource can even be included, namely detailed information about the operating market, as proposed by Gonçalves *et al.* (2011);
- physical resources (PhyR): installations, products and materials, equipment and service infrastructure; and
- financial resources (FinR): company money or another equivalent financial asset that can be converted into money.

It is also possible to find resources at the level of innovation systems (Carvalho and Sugano, 2012; Gök and Peker, 2017; Musiolik and Markard, 2011; Musiolik *et al.*, 2012). Strategic solutions provided by these networks also serve to generate advantages that are difficult for competitors to imitate (Lorenzoni and

Baden-Fuller, 1995). Therefore, the so-called innovation network (Freeman, 1991) is a heterogeneous inter-organizational model whose actors interact by means of collective actions directed by innovation (Pellegrin, 2006, Kühne *et al.*, 2015). Thus, innovation can occur as the result of the learning experiences of actors with different knowledge backgrounds (Lundvall, 1992).

From an innovation point of view, there are also market incentives within networks. For instance, when product innovation occurs within networks it can be less costly and can be performed in less time (Nieto and Santamaria, 2007; Powell and Gianella, 2010).

Company performance has been one of the most pressing strategic issues in recent decades (Furrer *et al.*, 2008; Brenes *et al.*, 2017). It is a multi-dimensional concept that can be measured in several ways (Bentes *et al.*, 2012; Gonçalves *et al.*, 2013). It can vary according to the company's objective, which may be to improve the culture of innovation, increase profitability, increase client satisfaction, or increase income, for example (Gonçalves *et al.*, 2011).

The performance dimension adopted for this work is innovation (Wang and Li-Ying, 2015). The importance of innovation performance comes from enabling research institutions to reach their objectives and companies to gain a competitive advantage (Keil *et al.*, 2008; Sarvan *et al.*, 2011). The most popular innovation performance measures according to Dushnitsky and Lenox (2005) are: (1) to research published advertisements for new products; (2) to research numbers of patents (Griliches *et al.*, 1991); (3) patent citations (Trajtenberg, 1990); and (4) R&D statistics (Henderson and Cockburn, 1994). Andreassi (2007) states that the indicators most often found for measuring technology innovation are found in the proxy 'R&D statistics', the costs of R&D, and a company's gross sales. A patent is an indicator of the innovative process outcome most often found in the innovation literature.

The concept adopted in this study refers to technological innovation, with innovation referring to new products that should be useful to the market or society (OECD, 2005; Schumpeter, 1997). This sense of usefulness cannot be measured by the filing of a patent but by the sales that the innovation generates for the organization overseeing the network. In this research, the measure for innovation performance (Dushnitsky and Lenox, 2005) in inter-organizational networks of R&D projects (Jones and Lichtenstein, 2008; Todeva, 2006) derives from the creation of a tangible product that has reached the market and been measured on the basis of market value or royalties collected by the technology under consideration (cultivar).

3. Material and methods

This study was conducted using qualitative comparative analysis (QCA) and content analysis.

QCA contributes in an essential way for four reasons (Wagemann, 2012): (1) it offers to the comparative research a systematic, precise and grounded method in mathematics (Boolean algebra and fuzzy algebra) and formal logic; (2) a way to analyze even a small or medium-sized of cases, because the number could be very high for the use of techniques used in the case studies, but at the same time very low to develop a statistical analysis; (3) allows the number of variables to exceed the number of cases; (4) the QCA method analyzes hypotheses based on set-theoretic relations (hypotheses such as 'if ... then ...').

Ragin (1987) points out that the comparative method requires the researcher to become familiar with the cases relevant to the analysis. In this perspective, content analysis was a complementary method, which also allowed the deepening of the knowledge of each case, as well as the expansion of the explanatory capacity of the study phenomena.

Content analysis is a set of techniques for analysis of the communications that uses systematic procedures and objectives of description of the content of the messages, whose intention is the inference of knowledge

regarding the conditions of production or, where appropriate, of reception, which uses quantitative or non-quantitative indicators (Bardin, 1977).

In this sense, content analysis was chosen as an appropriate procedure to analyze the data collected (in interviews) and that were worked in consonance with the objective of this method. The purpose of content analysis is the manipulation of messages (content and expression of this content) to evidence the indicators that allow to infer about a reality other than that of the message (Bardin, 1977).

To analyze data in the current study, both QCA and content analysis were chosen due to its adequacy to the study of the proposed phenomenon. According to Mozzato and Grzybovski (2011), the multiple choices can be made and, in some cases, should be multiple to provide a more appropriate or comprehensive approach to the topic to be studied. The following describes how the cases were chosen, the data collection, and the treatment procedures.

3.1 Case analyses and unit selection

The analysis unit is an R&D and innovation projects inter-organizational network. The study compares innovation networks within the agricultural research sectors of two countries: Brazil, which is well-known worldwide as a leading producer of food products, and Spain, which is one of the few European countries that has programmes to genetically improve plants with GMOs, like Brazil. The following criteria were used to select the case studies: (1) they should be both successful and unsuccessful networks, as recommended by Ariza and Gandini (2012), that can be measured based on the royalties generated for the two companies that oversee the innovation networks; (2) available information should be enough to consider the innovation network as a unique case, as highlighted by Flyvbjerg (2004); and (3) it should be possible to perform a comparison between the cases, as proposed by Ragin (1987). The intermediary number of cases in this study can be considered average in studies using QCA, as most applications are found in a wide interval of ten to fifty cases (Rihoux and Ragin, 2009) and ten interviews are required for theoretical saturation (Eisenhardt, 1989).

A questionnaire was carried out among managers of each of the 25 selected interorganizational networks. These networks evolved from R&D and innovation projects and include 450 organizations supported by two public companies: EMBRAPA in Brazil (eight successful and nine unsuccessful networks) and INIA in Spain (eight successful networks), that is, the networks that innovate the most and those that innovate the least. The successful cases were identified based on their revenue in terms of royalties over the last five years.

The Spanish cases selected from the genetically modified plant segment in the agricultural research sector were identified with the help of the department of International Scientific Relations at the Sub-directorate of the Multilateral Relations Division at INIA, which indicated the most successful cases. In Brazil, it was referred to a study prepared by the Strategic Management Council (SMC) at the Ministry of Agriculture, Livestock & Supply (MALS) showing the farm income for different species and cultivars produced using EMBRAPA technology.

3.2 Data collection

The study used a combination of primary and secondary sources. Primary data were obtained using a questionnaire (see supplementary questionnaire) and semi-structured interviews (see supplementary interview script) for the results analysis. The secondary data were obtained from documentary analysis, exclusively for selected cases, from reports, internal and restricted databases belonging to EMPRAPA and INIA, and public information databases. Internal EMBRAPA material included information not accessible to the public, such as digital reports and archives described as follows: (1) lists of cultivars (with information about their names, species, dates of registration and protection, name of the licensee, duration of the partnership, etc.); (2) proposed adequacy of cultivars (including information such as the average income for groups of cultivars

belonging to the same species); (3) confidential financial spreadsheets; (4) R&D projects; and (5) final market research reports. The protection of cultivars database at the MALS was also used in this analysis and helped to identify the leader of the network.

In the case of Spain, an analysis of worksheets with internal information about the data of Spanish researchers and of specific documents available to the general public was conducted. These resources consisted of: (1) Memoria INIA 2011 (INIA, 2012); (2) the PD&I National Plan 2008-2011 (España, 2007); (3) the INIA National Strategic Plan 2014-2017 (INIA, 2014); and (4) project data. The documentary analyses conducted in Brazil and Spain served as basis for case selection, as described in Section 3.1.

Questionnaires and interviews were also used to collect data applied to the leaders of the 25 networks studied. In order to use the questionnaire, it had to be adapted to another language. As this is a complex process (Alexandre and Coluci, 2011) and to enable us to make methodologically correct adaptations, we followed the five steps proposed by Beaton *et al.* (2000): (1) initial translation; (2) synthesis; (3) translate text back to the original language; (4) have this reviewed by a committee or experts; and (5) conduct a pretest. A pretest was conducted both in Brazil and in Spain by researchers from the targeted institutions. Minor adjustments were made and the questionnaires were sent to the networks leaders. The categories presented in instrument are shown in Table 1.

The questionnaires contain indicators related to the different types of resources according to those established by Pike *et al.* (2005). Based on Gonçalves *et al.* (2011), one of the OrgR was detailed information about the market sector. One field after questions about each type of resource was left blank in the questionnaire, thus leaving space to add other innovation resource if necessary. However, none of the respondents suggested any other resources.

To classify innovation performance (Andreassi, 2007; Dushnitsky and Lenox, 2005) as successful or unsuccessful in Brazil, information relating to trading values or royalties earned by the technologies (cultivars) resulting from inter-organizational projects was used. In Spain, cases with successful performance were selected with the help of INIA, which identified the leaders of more innovative R&D projects, i.e. products that have reached the market or society.

Interviews were conducted with the leaders of the networks that evolved from projects. These particular actors were chosen because, in this type of network, members enter or leave during the different stages of innovation generation, and only the leading organization and its representative remain employed at the organization throughout all stages of the process. We used a semi-structured framework for the interviews to collect potentially relevant and more confidential information. The questions were generated based on the constructs and indicators in the theoretical framework, which were present in the questionnaire (Table 1), to broaden the explanatory power of the subject being investigated. The original text was translated from Portuguese into Spanish with the help of an expert.

3.3 Data treatment

The documentary analysis was conducted using Excel, which made it possible to filter specific cases that were then grouped into three sections: networks with high levels of innovation performance (successful cases) in Brazil; networks that had not been successful with innovation (unsuccessful cases in Brazil); and (successful) innovation networks in Spain. It was impossible to obtain any responses about unsuccessful cases in Spain because INIA has no access to the amounts of royalties for the commercialization of technology, or the results of innovative projects developed by regional public research institutions supported by INIA. Each group was individually analyzed and then in conjunction as a whole in order to conduct a comparative analysis between the successful and unsuccessful cases in Brazil, thereby broadening the empirical diversity. This same process was also used between successful networks in Brazil and successful networks in Spain

Table 1. Variables that influence innovation performance: indicators and codes.[1]

Variables	Indicators[2]	Codes
Resources – tangible and intangible (Barney, 1991; Pike *et al*., 2005; Barney and Clark, 2007; Gonçalves *et al*., 2011)	**Physical resources (for innovation)**	
	Installations	PhyR1_Installat
	Equipment	PhyR2_Equipment
	Products & materials	PhyR3_Prod_Mater
	Service infrastructure	PhyR4_Infra_Service
	Human resources (for innovation)	
	Capacity for research & development (R&D)	HumR1_R&D_Cap
	Management capacity	HumR2_Manag_Cap
	Business alignment	HumR3_Busin_Align
	Partnership capacity	HumR4_Partn_Cap
	Learning	HumR5_Learning
	Financial resources (for innovation)	FinR1_Inst_limite
	Funding from the Institution (EMBRAPA or INIA), by means of a public notification/bid, within the maximum limit stipulated as a reference	FinR2_Inst_Acima
	Funding from the Institution (EMBRAPA or INIA), by means of a public notification/bid, over and above the maximum limit stipulated as a reference	FinR3_Externos
	Funding exclusively from other external organizations	FinR4_Inter &Exter
	Both external and internal funding	
	Organizational resources (for innovation)	
	Intellectual property	OrgR1_Intel_Prop
	Organizational structure	OrgR2_Org Struct
	Processes	OrgR3_Processes
	Image and trademark	OrgR4_Imag_TradeM
	Organizational culture	OrgR5_Organiz Cult
	Detailed information about the market sector	OrgR6_Busi_Inf
	Organizational strategy	OrgR7_Org Strat
Innovation Performance **(**result or dependent variable) (Schumpeter, 1997; OECD, 2005; Dushnitsky and Lenox, 2005; Andreassi, 2007; Figueiredo, 2009)	**Innovation**	
	Derived from the creation of a tangible product (variety) that reaches the market or society	Innovat_Performance
	Average profitability value (royalties and/or sale of seeds) during the period 2010-2015 (last 5 years)	

[1] Based on the original proposed by Ariza and Gandini (2012).

[2] For each indicator, the values were used as follows: 1= presence; 0 = absence.

in order not to impose limitations on any successful networks (empirical diversity limited to one country) due to the endogenous characteristics that might be peculiar to either of the countries.

Questionnaires results were treated using Tosmana (tool for small-n analysis), software for a crisp-set qualitative comparative analysis (csQCA). This analysis method is used for binary data, along with Boolean algebra where 1 (one) symbolizes the presence of the fact/indicator in a question and 0 (zero) shows that it is absent. QCA offers comparative research a systematic and more precise method based on mathematics (Boolean algebra) and formal logic (Ragin 1987).

The software Tosmana perform analysis on Boolean and on Multi-Value Data sets. The configuration of the calculation can be done from the analysis window named (MV)QCA. Tosmana shows the expressions in the solution with analysis window from the menu bar: Analysis >> Start (MV)QCA. After, start the calculation with the Full Analysis button. If the output mode is set to 'text only', the results will be shown in the results window. Else, the result report will appear in a new window of the Internet Explorer (Cronqvist, 2017).

The QCA method allows combinations of causal conditions in relationships between groups to be examined and to be expressed using logical equations. In our study, the causal elements are the resources that are sufficient and/or necessary for a network to generate innovation. For the sake of simplification and taking into account the examples of Boolean algebra interpretations proposed by Ragin (1987), the indicators are represented by letters of the alphabet, bearing in mind that these follow the same order. That is to say, because it is the first variable, (v1) represents the letter A, the second variable, (v2), represents the letter B, and so on up to the letter E (v5). A capital letter represents the presence {1} of the indicator, and a lowercase letter represents its absence {0}. This combination of conditions implies (→) in the result or outcome (letter Y).

QCA makes possible to consider three kinds of causal complexity: equifinality, conjectural causation, and asymmetric causation (Wagemann, 2012), also in an agribusiness context (Brenes *et al.*, 2017). It has gained relevance in recent decades as a tool in several sciences in the United States and Europe. However, in Latin America QCA has been employed only infrequently (Ariza and Gandini, 2012; Wagemann, 2012).

The transcripts of the interviews were then analyzed based on the categories shown in Table 1 using content analysis, one of the data analysis methods most often used in the field of business administration in Brazil and at international level (Capó-Vicedo *et al.*, 2011; Dellagnelo and Silva, 2005; Martínez-Fernández *et al.*, 2012; Mozzato and Grzybovski, 2011; Vallet-Bellmunt *et al.*, 2011). The content analysis comprises three basic steps: (1) pre-analysis; (2) exploration of the material; (3) data processing and interpretation (Bardin, 1977).

4. Results

The resources that an organization controls and can use to create and implement strategies are categorized as physical, human, financial, and organizational (Barney, 1991). In the Brazilian networks, 'installations' and 'equipment' were the physical resources (PhyR) most consistently found in all networks. 'Service infrastructure' and 'products and materials' were also found in over 75% of the networks. Among human resources (HumR), those that stood out in particular were 'R&D capacity', which were found in all networks, and 'partnership capacity', which was absent in only one of the 17 Brazilian networks investigated.

Regarding financial resources (FinR), most networks have both external and internal funding for their projects (64.11%), while new networks (52.94%) were only funded by EMBRAPA. In terms of organizational resources (OrgR), 'organizational structure' was the most common (76% of the networks), while both 'image and trademark' and 'intellectual property' were found in 64% of the networks.

In the Spanish networks, the PhyR that stood out most were 'products and materials', found in seven of the eight networks (87.5%), and 'installations' and 'equipment', found in six networks. Among HumR, the most notable were 'R&D capacity', found in all networks, and 'partnership capacity', which was absent in only one of the eight successful Spanish networks investigated. Regarding OrgR, the ones most often mentioned were intellectual property, found in 75% of the networks, and 'organizational structure', present in 50%.

Regarding FinR, half of the networks in Spain receive funding from INIA and other external organizations (four networks) for their projects, and three networks were financed solely by INIA. In terms of OrgR, the ones most often mentioned were 'intellectual property', found in 75% of the networks, and 'organizational structure', found in 50%.

Bearing in mind that performance is multi-dimensional and that there are several ways of measuring it (Bentes *et al.*, 2012; Gonçalves *et al.*, 2013), one of the questionnaire items was whether or not performance is measured in the organizations that participate in the networks. The findings show that in practically two thirds of these networks, that is to say, in 64.71% of the cases investigated in Brazil (eleven networks), the participating organizations do not measure performance.

Those networks where performance was measured in some way (six networks) indicated that this was done in the following circumstances: (1) for the launch of a cultivar; (2) for scientific and technological output; (3) to analyze scientific and technological contributions; (4) in the case of private partners to determine the market level of seeds produced and the market share in each region; (5) for the technologies (cultivars) launched; and (6) to establish their share of cultivars in the seed market.

Results about measuring or not measuring performance in Spain are similar to the Brazilian ones, as it was found that in 62.50% of the eight Spanish networks this type of evaluation does not take place. In the three networks where performance was measured in some way, three indicators were given: (1) the number of experiments involving successful varieties (harvested); (2) the publication of scientific and technical texts; and (3) the number of years that a cultivar (variety) had been marketed.

In the QCA of networks in Brazil, the summary of results for Brazil can be seen in Table 2. The results showed that no logical equations were found for the PhyR or FinR in the QCA of the Brazilian networks. This is because the configurations with the presence or absence of these resources were similar to successful (outcome 1) and unsuccessful outcomes (outcome 0).

Only two networks had unsuccessful configurations about HumR analysis, with the absence of three of the five resources investigated, and another two successful networks containing the presence of four resources as those included among the five HumR listed in the questionnaire.

With the software Tosmana it is possible to remove the non-observed combinations in the empirical cases, called 'logical remainders', or those that can be described by a shorter logic expression or a more parsimonious minimal formula (Boolean minimization). Therefore, with only two cases with a set of exclusive combinations to explain their success or lack of it, an attempt was made to analyze the equation without the minimization using the logical remainders for both the unsuccessful and the successful networks, according to the recommendations of Rihoux and De Meur (2009).

There is a possible interpretation for non-successful innovation performance among a series of HumR – two cases that have an exclusive combination of groups. The outcome of poor innovation performance (zero outcome) is influenced by a combination of certain elements, namely when it does not include 'management capacity' as one of its HumR and concomitantly when there is an absence of the 'learning' resource, even though the required HumR of 'capacity for R&D' and 'business alignment' are present:

HumR1_R&D_Cap{1}*HumR2_Manag_Cap{0}*HumR3_Busin_Align{1}*HumR5_Learning{0}.

The outcome of the influence of the HumR variable in successful innovation performance, represented by a rating of one (1) (outcome 1), shows two sets of alternative combinations, that lead to successful networks – two (BR_Suc_2) and five (BR_Suc_5), as follows:

HumR1_R&D_Cap{1}*HumR2_Manag_Cap{1}*HumR3_BusinAlign{1}*HumR4_Partn_Cap{1}*HumR5_Learning{0}+HumR1_Capac_PampD{1}*HumR2_Manag_Cap{1}*HumR3_Busin_Align{0}*HumR4_Partn_Cap{1}*HumR5_Learning{1}.

Table 2. Summary of the analysis of the relationship between 'resources' and 'innovation performance' in Brazilian networks.

Resources/innovation performance	Equation/conditions and networks					
	General equation	**Necessary condition**	**Sufficient condition**	**Condition not necessary, not sufficient**	**Condition superfluous/absent in the equations**	**Networks**
Physical/unsuccessful	No logical configuration is possible. In other words, there is nothing to minimize					
Physical/successful	No logical configuration is possible					
Human/unsuccessful	A*b*C*e	(A) Research & development capacity (R&D) (b) Management capacity (C) Business alignment (e) Learning	No condition of equation is sufficient	There is no necessary or sufficient condition	(d) Partnership capacity	BR_Uns_1 BR_Uns_9
Human/successful	A*B*C*D*e+A*B*c*D*E	(A) Research & development capacity (R&D) (B) Management capacity (D) Partnership capacity	No equation of condition is sufficient	(c) Business alignment (e) Learning	Not applicable	BR_Suc_2 BR_Suc_5
Financial/unsuccessful	No logical configuration is possible					
Financial/successful	No logical configuration is possible					
Organizational/ unsuccessful	a*B*c*d*e*F*G + A*B*C*d*e*F*G +A*b*C*D*e*F*g +A*b*c*D*e*f*G +A*B*c*D*E*f*G +A*B*c*D*e*F*g	No condition of equation is necessary	No condition of equation is sufficient	(a) Intellectual property (b) Organizational structure (c) Processes (d) Image & trademark (e) Organizational culture (f) Detailed information about the market segment (g) Organizational strategy	Not applicable	BR_Uns_1 BR_Uns_2 BR_Uns_3 BR_Uns_5 BR_Uns_6 BR_Uns_7
Organizational/ successful	a*B*C*d*e*F*G +a*B*c*d*E*f*G +A*B*c*D*e*f*g +a*B*C*D*e*f*G +a*B*c*D*e*F*g	(B) Organizational structure	No condition of equation is sufficient	(a) Intellectual property (c) Processes (d) Image & trademark (e) Organizational culture (f) Detailed information about the market segment (g) Organizational strategy	Not applicable	BR_Suc_2 BR_Suc_3 BR_Suc_5 BR_Suc_6 BR_Suc_8

The findings can be described by the logical equation:

A*B*C*D*e+A*B*c*D*E→Y.

This definition can be read as follows: the presence of 'A', combined with the presence of 'B', combined with the presence of 'C', combined with the presence of 'D', and combined with the absence of 'e' or, combinations of the presence of 'A', the presence of 'B', the absence of 'c', the presence of 'D' and the presence of 'E', leads to result 1 (one), that is to say, innovation performance, which represents the success networks of in Brazil BR_Suc_2 and BR_Suc_5.

Regarding OrgR in Brazil, organizational structure resource was the only condition required for all networks of success. In addition, the logical equation that represents the group of combinations for the OrgR that influence a successful outcome can be defined as follows:

a*B*C*d*e*F*G+a*B*c*d*E*f*G +A*B*c*D*e*f*g+a*B*C*D*e*f*G+a*B*c*D*e*F*g →Y

In the five groups of combinations, it is worth noting that there are five condition combinations, in that organizational resource B, which refers to 'organizational structure' is necessary to be combined with more than one variable to attain a successful performance in innovation.

The explanations that form the basis of the relationship of the influence of 'resources' with a dependent variable (excellent innovation performance) and that include the innovation networks in Spain, are summarized in Table 3.

In Spain, the outcomes for PhyR and FinR do not explain performance in a representative manner. With regard to physical resources, in the QCA of the Brazilian networks, which included the successful Spanish networks, there are two networks (BR_Suc_5 and BR_Suc_7) that influenced performance with the presence of the 'products and materials' resource, combined with the absence of all the others. Regarding financial resources, there are two Spanish cases that achieved success even though they had not been financed by the INIA. This means they achieved success with funding only from other external organizations, something that did not happen in Brazil.

In the HumR analysis, in addition to the two networks in Brazil, half of the cases in Spain (four networks) are explained by a group of HumR in that 'R&D capacity', found in all cases, is the resource needed for innovation in order to be combined with the presence of other HumR.

The analysis of OrgR present in all the networks continues to show that 'organizational structure' has a particular importance, as its presence is necessary in seven of the nine possible explanatory combinations.

The outcome showed nine condition combinations that explain the results for a group of 13 successful networks in Brazil and Spain. It was not possible to simplify results with a minimized equation because it generated nine distinct logical equations that can explain the innovation performance in these networks.

With the inclusion of the networks in Spain, the following combination therefore stands out in particular:

A*c*d*e*f*g (OrgR1_Intel_Prop{1}*OrgR3_Processes{0}*OrgR4_Imag_TradeM{0}*OrgR5_Organiz_Cult {0}*OrgR6_Busi_Inf{0}*OrgR7_Org Strat{0}).

As this is present in three of the successful networks in Spain (SP_Suc_1, ES_Suc_5, and ES_Suc_6). Another set of conditions that are present in two networks, in that one is found in each country being investigated (BR_Suc_3 and SP_Suc_2), is:

a*B*c*d*E*f*G (OrgR1_Intelec_Propert{0}*OrgR2_Org_Struct{1}*OrgR3_Processes{0}*OrgR4_Imag_TradeM{0}*OrgR5_Org_Cult{1}*OrgR6_Busi_Info{0}*OrgR7_Org Struct{1}).

The presence of the 'organizational structure' resource, although not necessary for all sets of combinations, is necessary for most of them.

Interviews made it possible to identify the resources – acquired from other organizations belonging to the network – that the leading organization does not possess. Unsuccessful (LBU) and successful network leaders in Brazil (LBS) provided information about the resources acquired through the networks.

As a result, two unsuccessful networks leaders (LBU_1 and LBU_5) did not have a clear view about the resources their organization did not have and had acquired through the network. However, various sections of the interviews that stood out in particular PhyR were the infrastructure necessary for technological validation (cultivar) in different regions of Brazil (LBU_2, LBU_6, LBU_7, LBS_3) and specific laboratories (LBU_8). It expanded the distribution of the outcomes of R&D. In addition, emphasis was also given to HumR (LBU_9, LBS_1, and LBS_2), financial resources (LBS_1 and LBS_6), and general resources, including different types of physical, financial, human, and OrgR (LBS_1, LBS_4, LBS_5, and LBS_7).

In Brazil, HumR and FinR, and PhyR are used to validate technologies in different regions of the country and in specific laboratories. This means that these networks acquired different types of resources, whereas in Spain the emphasis is on PhyR and HumR.

When asked about which network resources are distinctive in terms of generating innovation, network leaders in Brazil highlighted HumR; involving personnel, partnership capacities, technical knowledge, and R&D capacity, PhyR; involving products and materials, installations and equipment, laboratories, experimental fields, and vehicles, FinR, OrgR; involving intellectual property, processes, organizational culture of commitment and detailed market information. However, the Spanish networks managers highlighted FinR and PhyR as being priorities concerning experimental or testing fields and HumR (qualified personnel).

Finally, one question asked was how the complementarity of network resources could contribute to the innovation process. In reply, the network leaders in Brazil emphasized that this contribution involves: including and sharing experts. This means: HumR that involve knowledge or R&D, as highlighted by the leaders of the Brazilian networks 1, 5 and 6 (LBU_1, LBS_5 and LBS_6), forming a network with heterogeneous organizations in terms of resources with a view to obtaining those resources they do not possess (LBU_1, LBS_4, and LBS_7), remedying the deficiencies of the research institutions in the marketing process to publicize and commercialize technologies within the market (LBU_2, LBU_8, LBU_9, and LBS_1), expanding the allocation of PhyR and FinR (LBU_2, LBS_3, and LBS_5), and making complementarity essential for the production of seeds (technologies) and the validation of new technologies in different regions of the country that have very different environmental conditions (LBU_5, LBU_6, LBS_2, and LBS_3).

The interviews conducted with network leaders in Spain revealed many similarities with the situation in Brazil. Their answers highlighted how innovation gains from knowledge (LES_1, LES_2, and LES_8); to help them to acquire new resources that could not be obtained by operating in isolation (LES_5 and LES_7), to facilitate actions to adopt technology through the market or society (LES_3), to expand the allocation of PhyR (infrastructure) (LBS_8), and to expand the process of validation for new technologies in different regions of the country to develop the final project (LES_7).

Table 3. Summary of the analysis of the relationship between 'resources' and 'innovation performance' in Brazilian and Spanish networks.

Resources/ innovation performance	**Equation/conditions and networks**					
	General equation	**Necessary condition**	**Sufficient condition**	**Condition not necessary, not sufficient**	**Condition superfluous/ absent in the equations**	**Cases**
Physical/ successful	a*b*C*d	(a) Installations (b) Equipment (C) Products & materials (d) Service infrastructure	No condition of equation is sufficient	No condition is necessary or sufficient	Not applicable	BR_Suc_5 BR_Suc_7
Human/ successful	A*B*C*D*e+ A*B*c*D*E+ A*b*c*d*e	(A) Research & development capacity (R&D)	No condition of equation is sufficient	(b) Management capacity (c) Business alignment (d) Partnership capacity (e) Learning	Not applicable	BR_Suc_2 BR_Suc_5 SP_Suc_2 SP_Suc_5 SP_Suc_6 SP_Suc_8
Financial/ successful	a*b*d	(a) Institutional financing – INIA – within the stipulated limit (b) Institutional financing – INIA – over & above the stipulated limit (d) Financing with internal & external funding	No condition of equation is sufficient	Not applicable	(c) Financed exclusively by other external organizations	SP_Suc_4 SP_Suc_7
Organizational/ successful	a*B*c*e*f*G+ A*c*d*e*f*g+ A*B*d*e*f*g+ A*B*c*d*e*f+ a*B*C*d*e*F*G+ a*B*c*d*E*f*G+ a*B*C*D*e*f*G+ a*B*c*D*e*F*g+ a*b*C*d*e*f*g	No condition of equation is necessary	No condition of equation is sufficient	(a) Intellectual property (b) Organizational structure (c) Processes (d) Image & trademark (e) Organizational culture (f) Detailed information about the market segment (g) Organizational strategy	Not applicable	BR_Suc_2 BR_Suc_3 BR_Suc_5 BR_Suc_6 BR_Suc_8 SP_Suc_1 SP_Suc_2 SP_Suc_3 SP_Suc_4 SP_Suc_5, SP_Suc_5, SP_Suc_7 SP_Suc_8

5. Discussion and conclusions

5.1 Contributions and implications

'In a network created to innovate there is complementarity among resources'. The idea about complementarity of resources was developed by authors like Oliver (1990), but is still a fashionable theme because it is present in many recent papers by, for instance, Kim and Choi (2014). In a network, firms search for partner resources because they have a shortage of resources or only a few specific resources (Imai, 2000). As pointed out in literature, to achieve innovation complementarity resources are required along with resources contained within a network (Lavie, 2006; Tolstoy and Agndal, 2010; Wang and Li-Ying, 2015) and, as Hauschild and Knyphausen-Aufseβ (2013) suggest, existing dimensions and measures of resource-relatedness should be combined.

To produce innovation in the studied networks it was necessary to combine PhyR and FinR, which were not sufficient in themselves, with HumR and OrgR. This study offers information about their relative relevance and ability to explain the innovation as a performance measure. It was possible to identify those resources combinations that are contradictory, i.e. networks that have the same resources and that produce both successful and unsuccessful outcomes. It was also shown that the complementarity of resources that exists in the context of networks is one condition that makes it possible to attain distinctive performance. It has been confirmed in other research studies (Lavie, 2006; Carraresi *et al.*, 2016) but has not been demonstrated decisively and specifically in the agrobusiness research. This is especially true with regard to innovation, as illustrated in the studies by Carvalho and Sugano (2012), Gök and Peker (2017), Huggins (2010), Kühne *et al.* (2015), Marhold and Kim (2017), Musiolik and Markard (2011), Musiolik *et al.* (2012).

As for the PhyR involving networks in Brazil, there is no logical configuration for performance innovation outcomes, if the selected indicators alone (physical resources) are used. The same situation occurred in the case of FinR, which corresponds to the established theory on the matter, as physical and/or financial resources alone were not enough to achieve innovation. This is shown in the relevant literature (Barney, 1991), as these resources are not rare or difficult to imitate.

Another aspect that should be emphasized in this study is that among the HumR mentioned, 'capacity for R&D' was seen to be a necessary condition to attain innovation performance in all the networks and that the 'management capacity' and 'partnership capacity' resources also stood out in all the networks that achieved successful outcomes. In this particular case, the tangible resources may to some degree play a relatively important role in a firm's success (Galbreath, 2005).

'To produce innovation a combination of resources in the networks is necessary'. Human knowledge must be associated with other resources to produce a better performance. This fact was reinforced by the comments made by Dierickx and Cool (1989) about how a combination of resources is more important than the resources themselves and by the study of Tolstoy and Agndal (2010) about a firm's ability to extract value from network resources, manifested by the combinations of complementary resources that cut across organizational boundaries.

The seminal article about RBV by Barney (1991) did not provide a list of the resources contained in his categorization (physical, human, financial and organizational resources). Our theoretical contribution fills this gap, as this work classifies and indicates the resources that are more often present in innovation networks and also provides evidence that only PhyR or only FinR in the Brazilian networks do not influence innovation performance because they need to be combined with HumR or OrgR. These findings, as highlighted by Wagemann (2012), corroborate the idea that there is the possibility of considering several aspects of causal complexity.

In this respect, one of the aspects shown is equifinality, which consists in the fact that more than one sufficient condition can exist (though is not necessary) to attain an outcome. In this study, this was exemplified by the following equation: HumR + OrgR → Y, where both the HumR analysis and the OrgR represent sufficient conditions for performance innovation. In other words, if HumR are not present, the same result could be obtained with the presence of alternative OrgR and vice versa. Another aspect is conjectural causation, where a condition alone is not enough to generate a result, as it must exist to be combined in the context of more than one variable (Wagemann, 2012). Therefore, we highlight the physical resources and financial resources of networks studied in Brazil, where separate analysis showed no influence on performance, but the combination of both (PhyR * FinR → Y) influences the innovative performance.

'There is a country effect on the resources set'. According to the findings, the PhyR of 'installations' and 'equipment' are necessary conditions for implementing innovation in every agricultural sector network in Brazil. Consequently – and analogous with the VRIO model proposed by Barney and Clark (2007) – we can say that these two conditions are resources used solely for competitive parity. However, if these conditions are combined with others, they can influence innovation performance success. Therefore, within the scope of an RBV, one resource that generates competitive parity can generate innovation when combined with other resources.

The study also shows that when discussing OrgR and comparing the networks in two different nations, each country imposes its own characteristics. It should be said that nearly every successful network in these two countries used some type of 'organizational structure' resource but that, exclusively in the case of networks in Brazil, the 'brand and image' resource is highly present in successful networks. This supports the study by Galbreath (2005) in which organizational assets, such as corporate structure, and reputational assets can significantly impact a firm's success. Furthermore, of the seven resources needed to obtain success, at least three were required for the network to achieve success in Brazil. In the case of Spain, however, three of the networks succeeded in achieving a positive performance based solely on the 'intellectual property' resource, while all the other resources were absent. The RBV says that it is a combination of resources that enables companies to become heterogeneous (Barney, 1991).

This study went somewhat further, showing that heterogeneity is not so widespread when comparing networks within the same country but is more apparent when we compare networks in different countries. One of the possible explanations for this could be that Brazil is a larger country and has a greater number of cultivars to be developed. Consequently, fewer innovations would be required.

A strong motivation for the formation of innovation networks are the factors related to the necessary inputs to innovation processes, especially the complexity of the knowledge base necessary to innovate (Pellegrin *et al.*, 2007). It has been noted that the network that has the most impact on knowledge complementarity (Caner and Tyler, 2015) does not exist only in these countries. A study by Belussi and Porcelatto (2012) showed similar findings in the region of Emilia-Romagna (Italy), where knowledge networks were established in biomedical sciences involving researchers not only from the region but also further afield precisely because of their need for knowledge complementarity. Our own research shows that this configuration between networks is the one with the greatest impact on knowledge sharing.

'The network is a structure that favors innovation development but its 'management' is essential for success'. Similar findings have already been revealed in other types of networks with different scopes, as shown by Castro *et al.* (2011). However, in that particular 2011 study, the aim of the networks was geared to the area of commerce in business networks. This study shows that maintaining an integrated scope and providing network management are also applicable in the case of innovation networks.

The content of the interviews with network leaders brought to light another issue that is a main priority in a group of resources. The interviews reinforced the fact that there are resources that are crucial for the development of innovation in this type of network, such as equipment and installations (experimental fields

and laboratories), combined with the HumR of management capacity, and R&D capacity. That is to say, resources related to technical knowledge are seen as being extremely important to validate technologies in different biomes and regions in both countries.

In this study innovation networks within the agricultural sectors in two countries – Brazil, and Spain – were compared. Therefore, these finding could have a significant impact on the mapping of public policies that encourage innovation, in addition to providing strategic guidelines both on an institutional and business level for public and private organizations in these two countries.

5.2 Limitations and further research

One of the limitations of this research is that QCA cannot establish whether the dependent variable increases or decreases when there is a variation in the independent variable itself or upon interacting with other variables. Another limitation is that the data values collected in Brazil and Spain represent a complexity factor, as the cultural and social context of the two countries should have been taken into account.

In addition to studies about the resources within a network environment, future studies should investigate the structural attributes of networks, which could help to provide a better understanding of their dynamics and the way they influence innovation. There is also a need for research to determine if innovation performance is influenced by the number of resources in networks and for analysis of other types of innovation based on the nature of the innovation itself (product, process, marketing, or organizational) and its degree of novelty (incremental or radical innovation). Finally, it is necessary to highlight the fact that this empirical research studied networks within the agricultural sector in the context of programmes for the genetic improvement of plants, which is a subject that could be enhanced by other research analyses in different areas of the same sector and in different sectors.

Acknowledgements

This research was financially supported by the Coordination for the Improvement of Higher Education Personnel – CAPES, Brazil, project PGCI 035/2013 and by Ministry of Science and Technology of Spain, National Plan of Research, Development & Innovation (RD&I), research project number ECO2015-67122-R.

Supplementary material

Supplementary material can be found online at https://doi.org/10.22434/IFAMR2018.0023.
Questionnaire.
Semi-structured interview script.

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