Nonlinear Effects of Inter Firm Competition on Innovation in Cooperative Research Networks

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Abstract – Cooperative R&D Consortia (CRDC) are collaborative partnerships composed of multiple organizations (e.g. firms, universities, research institutes), pooling resources, knowledge and expertise to pursue common research and innovation. The aim of this research is to explore how CRDC affects organizational innovation performance through knowledge sharing mechanisms and network structure. This study seeks to evaluate the effect of participation in these consortia on firms' innovation outcomes and the determinants of successful collaboration. The research is based on a mixed method approach with surveys of firms interacting with CRDC and social network analysis to map collaboration patterns. Our results show that CRDC firms with formalized, robust communication structures and supported knowledge sharing practices have more innovation capabilities. The network enhances firms at central positions in the network's access to these diverse knowledge streams, and the rates of patent filings and product innovations increase. Unfortunately, smaller firms fail to fully leverage these benefits as they lack absorptive capacity. These results underline the relevance of good governance structures and fair knowledge exchange to fully exploit CRDC's innovative potential.

Keywords – Cooperative R&D Consortia (CRDC), Knowledge-Sharing Mechanisms, Innovation Performance, Social Network Analysis, Collaboration Patterns, Absorptive Capacity, Governance Structures, Organizational Innovation.

I. INTRODUCTION

Competitive intensity refers to a scenario characterized by vigorous rivalry resulting from a high number of market participants and a scarcity of viable growth possibilities. Since competition escalates, a firm's outcomes will become stochastic rather than deterministic, since its behavior is significantly shaped by the actions and circumstances of rivals. Consequently, in the context of escalating competition, predictability and certainty decline. In periods of reduced competition, companies may use their current systems to maximize the transparent predictability of their actions. Nevertheless, in the face of strong competition, companies must adjust properly. The company must undertake risk-taking and aggressive measures that need audacious learning and exploration to escape pricing or promotion conflicts. Liu and Atuahene-Gima [1] said that in the face of intense competition, organizations must innovate in goods and processes, seek new markets, devise unique competitive strategies, and analyze their differentiation from rivals.

Ragatz, Handfield, and Scannell [2] have shown that cooperation serves as a strategy to alleviate the pressures associated with cost and time reduction in the novel process of product development. Within this process, collaboration through an engaging procedure among stakeholders is essential, encompassing agreements on technology transfer and partnerships with colleges for the joint exploitation or development of patents for product development. Research and development (R&D) cooperation yields many benefits, chief among them being the cartelization, spillover, complementarity, subsidization, and national commitment factors. "Conversely". However, there are drawbacks as well, such as "the potential for anti-competitive consequences, the conflict of corporate culture, and the incentive for free riding".

Companies experiencing elevated competition intensity may become fewer appealing partners, limiting their collaborative prospects for growth support. Although cooperation may mitigate competitive impacts, it also incurs administrative, coordination, and informational expenses that might impede organizational development. Consequently, competitive intensity influences cooperation, thus impacting progress. The intricate interplay between competitive intensity and technical surroundings, together with their impact on the creation and results of cooperation, has not been explicitly examined. Strategy scholars have highlighted the need to examine the possibilities and restrictions encountered by organizations due to their resource base and industry features when analyzing a firm's development choices.

Innovation is characterized as: "the advent of novel produces, novel production approach, the opening of novel marketplaces, utilization of novel supply resources, and novel competitive types resulting in the restructuring of industries"; a novel or improved production or products procedure that is effectively commercialized"; "the initial marketplace advent of a novel process or product whose designing significantly diverges from previous practices"; "specific technical knowledge regarding superior methods compared to the current state of art". An interactive procedure started by the identification of a novel service opportunity or/and marketplace for a technology-oriented innovation, resulting in manufacturing, development, and advertisement efforts purposed at attaining the business success of the innovation.

Innovation is the primary driver for organizations to achieve competitive advantage and may provide enduring motivation to enhance organizational performance in the competitive market. A multitude of experts contend that businesses must concurrently engage in exploration and exploitation innovative activities to attain optimum performance. While several academics have examined the impact of exploration and exploitation innovation on firm performance, the transition from innovation to performance may be influenced by other possible variables. Enterprises of varying ages have distinct innovation strategies; for instance, start-ups prioritize acquiring differential advantages to capture market share and emphasize the significance of innovation more than established firms. Innovation is a high-risk investment endeavor, influenced by both internal and external environmental forces.

In order to understand the role of Cooperative R&D Consortia (CRDC) in improving innovation performance, we study knowledge sharing mechanisms, collaboration patterns and governance structures. We analyze how these consortia support organizational innovation, absorptive capacity and effective knowledge exchange, focusing on patent filings and other innovation outputs through social network analysis. The remaining parts of the article have been arranged in the following manner: Section II provides a discussion of the theoretical model and hypotheses regarding the impact of competition, discrepancy, and consortium-facilitated interaction. Section III defines the research design, data collection, data processing, and statistical analysis of this research. Section IV and V presents a detailed discussion of the findings obtained in this research. Section VI summarizes the research highlighting the significance of Cooperative R&D Consortia (CRDC).

II. THEORETICAL MODEL AND HYPOTHESES

Impact of Competition on Corporate Innovation Inside the Collaborative R&D Consortia

In management literature, the conclusions regarding the influence of rivalry on creativity within cooperative environments are likewise contradictory. Intense rivalry may inhibit corporate innovation in collaborative R&D owing to diminished trust and mutual commitment stemming from worries about opportunism. In very competitive environments, Casadesus-Masanell and Zhu [3] observe that several enterprises just replicate their rivals' concepts in product innovation. In contrast to cooperative R&D with suppliers, customers, universities, and research institutions, which are recognized for enhancing innovation, partnerships with rivals have been shown to have a detrimental effect.

Huang and Yu [4] demonstrate that non-competitive partnerships are more likely to improve the performance of enterprises' internal R&D operations compared to competitive collaborations. Conversely, collaboration among rivals may promote the exchange of information. The closeness provided in collaborative environments enables companies to more rigorously assess their rivals and enhance their understanding of emerging technology initiatives. They propose that rivals may cultivate non-finite, symbolic, and idiosyncratic resources, including altruism, trust, and reciprocity, inside a cooperative network. Consequently, collaboration with rivals may serve as a mutually beneficial strategy for capability enhancement, provided that a balance between value creation and value appropriation is attained. This corpus of literature exhibits variability in conclusions and mostly concentrates on one-on-one rivalry in dyadic interactions, while neglecting multi-party partnerships.

An R&D consortium may include enterprises, academic institutions, research organizations, and industry associations collaborating on a certain product or technological domain. The business members may possess competitive, supplier, and complimentary ties with each other. Consequently, not all members are market rivals to a certain business. This research examines the existence of market rivals from the viewpoint of a central member business within a consortium's multiple interactions. A reduction in the number of non-rivals will diminish the advantages of complementarity of resources. This diminishes the incentive for mutual understanding, leading to less dedication to collaborative R&D endeavors. A small degree of rivalry for a focus business within a cooperative consortium may enhance the benefits of resource similarity with rivals while preserving accessibility to matching resources from non-rivals. This prompts a focus business to increase its dedication to cooperative innovations instead of engaging in either little or excessive rivalry inside an R&D consortium. It is plausible to postulate that:

H1: A correlation (inverted U-shaped) exists between levels of rivalry faced by a focus business and its innovative performance inside a cooperative R&D consortium.

Controlling Influence of The Discrepancy in The Size of Business within R&D Consortia

The size of enterprises may influence the pace of consortia creation. Previous research on alliances revealed an ambiguous correlation between size and the establishment of coalitions. Zhao, Xia, and Shaw [5] identified a negative correlation, Mathews [6] identified a positive correlation, and Delcamp and Leiponen [7] found the correlation to be insignificant. Due to the strong correlation of 0.90 between cash flow and size in this research, one of these variables will be included into one specification. Firms within a low disparity consortium that exhibit comparable size disparities often encounter a more balanced and equitable competitive landscape. This creates an equitable environment and serves as a beneficial incentive for companies to co-innovate without being overshadowed by bigger or more powerful entities. In such consortia, the competitive incentive, or competition's function as a catalyst for innovation, is heightened due to enterprises being on roughly equal ground. Competition increasingly focuses on the quality of innovation rather than resource-driven advantages, with little disparities in resources or skills. All participants are urged to engage actively in the innovation, optimizing the use of common expertise and resources. Consequently, businesses inside low disparity consortia are more inclined to participate in increased innovation activities, since the competition fosters a collaborative, equitable, and inventive atmosphere. Consequently, we may postulate that:

H2: The favorable impact of a focus company's competition intensity on its innovative efficiency in a cooperative R&D consortium would be reinforced by minimal firm size disparities in the consortiums.

Moderating Influence of Consortium-Facilitated Interaction

The literature on R&D consortia widely agrees that the existence of (even hypothetical) market rivalry among member businesses may cause them to diminish their efforts in the collaboration due to concerns about knowledge leaking. This may adversely impact horizontal consortia, including enterprises from the same industry, but vertical or inter-sectoral consortia could be less susceptible to this issue. Competitive pressure may provide a challenge for major enterprises with significant market shares. Nevertheless, Chen [8] indicates that SMEs with minimal market shares may fear inadvertently conveying crucial information to partners who may potentially be rivals. This apprehension might be exacerbated by the tendency of SMEs to use intellectual property rights less for safeguarding their discoveries. Although rivalry among like enterprises was mitigated by their vested interest in finishing the collaborative R&D project, excessive resemblance is improbable to provide novel and beneficial information. Diversity among partners may be essential for acquiring the diverse expertise, skills, and resources that SMEs need to execute an R&D project and capitalize on its outcomes.

Excessive competitive intensity may undermine the advantages derived from consortium-organized interactions. The rapid dissemination of information and knowledge during interactions could be detrimental. It will exacerbate apprehensions over the inadvertent dissemination of critical understanding and unavoidable leaking of critical information resulting from intense competition. Furthermore, they may exhibit a greater tendency towards quiet, opting to assume the role of listeners in consortium-based encounters, therefore reducing the dissemination of their major expertise. They could choose for a cautious competitive approach to minimize their commitment to cooperative R&D operations, therefore securing a relative competitive rivalry. Consortium-arranged engagements may provide a controlling function, altering both the adverse impacts and incentives of competitive rivalry on innovations by enhancing the dissemination of knowledge. Therefore, we may postulate that:

H3: A focus firm's competitive intensity would have a stronger impact on its innovative effectiveness in the cooperative R&D group if there was a high level of consortium-organized contact, and vice versa.

III. METHODOLOGY

Research Design

A quantitative study design is applied by this present study to examine the relationships between firm innovation and competition intensity in cooperative R&D group. By grounding the methodological framework in established theoretical perspectives and statistical analyses, the approach is tested robustly against the proposed hypotheses. Multiple independent variables (i.e., competition intensity, firm age, firm size, and R&D investment) affect the dependent variable of interest (i.e., firm innovation). To formalize this relationship, we conceptualize firm innovation (IO) as a function of several key inputs, mathematically represented as:

$$IO = f(RP, N, P, T) \tag{1}$$

In this equation, RP is the number of research projects, N is the number of new products, P is total patents filed and T is years of the research projects. Incorporating these variables allows us to view a full view of innovation output in the context of the research.

Data Collection

The process of data collection involves two different phases; qualitative data collection first and quantitative data acquisition second. In the qualitative phase, a structured survey instrument was administered to obtain firms' perceptions about the competitive landscape, innovation capabilities, and organizational structures which govern their R&D consortia. The survey included a Likert scale where respondents could express their levels of perceived competition intensity. This intensity is mathematically expressed as:

$$CI = \frac{\sum_{i=1}^{n} s_i}{n} \tag{2}$$

The perceived competition score for firm i is symbolized by $S_i$and the total number of firms included in the survey is nnn. This formula makes it easy to average out the perceived degree of competition among the participating firms. In the subsequent quantitative phase, we supplement the qualitative findings with numerical metrics extracted from reputable industry reports. Focus is on critical variables such as firm age (FA), firm size (FS), R&D investment (RDI) and competition intensity (CI). Firm age is operationalized as the difference between the current year and the year of establishment, mathematically defined as:

$$FA = Current\ Year - Year\ of\ Establishment \tag{3}$$

Total revenue is used to quantify firm size and total expenditure on R&D activities as R&D investment. Competition intensity is evaluated through the firm's market share as a proportion of the total market share of its competitors, articulated as:

$$CI = \frac{Firm's\ Market\ Share}{Total\ Market\ Share\ of\ Competitors} \tag{4}$$

Meticulous data for FA, FS, RDI, and CI were compiled to create an exhaustive dataset that is the basis for following analytical phases of research.

Data Processing

Rigorous data preprocessing followed through which data was made consistent and outliers removed from the dataset. Multicollinearity is reduced by mean centering variables, allowing the analysis to produce robust results. The mean-centering process can be expressed mathematically as follows:

$$X_i' = X_i - \bar{X} \tag{5}$$

X_i' (originally given variable) and $\bar{X}$ (mean to that given variable) are used in this equation. It is important to prepare the data for the following statistical analysis, and this transformation is crucial. In addition, interaction terms are formed for potential moderating effects among the independent variables. This is articulated through the following formula:

$$X_{interaction} = X_1' \times X_2') \tag{6}$$

This interaction term enables us to understand the details of how different independent variables may all work together to impact the dependent variable, from which we can get further into understanding exactly what is happening.

Statistical Analysis

Negative binomial regression is the core analytical approach employed in this study to analyze count data that exhibit over dispersion. The model's structure can be represented mathematically as:

$$Y \sim NB(\mu, \theta) \tag{7}$$

Y denotes the count of innovations that the firm produces, μ is the expected count, and θ represents the dispersion parameter, in this representation. The expected innovation output (μ) is modeled as a function of the independent variables, articulated as follows:

$$\mu = \exp(\beta_0 + \beta_1 \cdot CI + \beta_2 \cdot FA + \beta_3 \cdot FS + \beta_4 \cdot RDI + \beta_5 \cdot X_{interaction}) \tag{8}$$

The coefficients in this equation provided β_0, intercept; $\beta_1, \beta_2, \beta_3, \beta_4$, and β_5, coefficients capturing the effect of competition intensity, firm age, firm size, R&D investment, and their interaction on the expected count of innovations. The combination of this comprehensive modeling approach enables the identification of key predictors of firm innovation. Goodness of fit of the model is evaluated based on some metrics and statistical tests such as BIC (Bayesian Information Criterion) and AIC (Akaike Information Criterion). AIC is calculated using the formula:

$$AIC = -2 \cdot \ell + 2k \tag{9}$$

The BIC is computed similarly as shown in Eq. (10) below:

$$BIC = -2 \cdot \ell + k \cdot \ln(n) \tag{10}$$

where ℓ denotes the log likelihood of the model, k is the number of estimated parameters and n denotes the total number of observations. These criteria allow different models to be compared and the most parsimonious model having a good fit of the data to be chosen. Wald tests are used to test the validity of each independent variable is the model. The Wald test statistic is computed as follows:

$$W = \left(\frac{\bar{\beta}_i}{SE(\bar{\beta}_i)}\right)^2 \tag{11}$$

Here, $\bar{\beta}_i$ is the estimated coefficient for the i variable; $SE(\bar{\beta}_i)$ is the standard error associated with that coefficient. These statistical results are interpreted in terms of the research questions and provide valuable insights into the dynamics of firm innovation and competition intensity in cooperative R&D consortia.

IV. RESULTS

For each variable, you can see their descriptive statistics and bivariate Pearson correlations in **Table 1**. The bivariate correlation coefficient between competition intensity and business innovation is minimal and statistically insignificant (r = 0.05, p > 0.05), suggesting the absence of a straightforward linear link, as proposed in H1. Overall, there are no significant correlations (where r is < .7) for primary control variables and independent variables, indicating a degree of independence. Prior to creating the interactive terms, the independent variable quantities that make up the interactive and squared terms were mean-based because some correlations may still pose a multicollinearity risk in evaluation of terms. Graham [9] assert that multicollinearity seems to have had no impact on the regression findings, as the VIF (Variance Inflation Factor) of variable quantities, which ranged from 1.061 to 4.331 with a 1.710 mean VIF, remains below 10.

Table 1. Correlations, Standard Deviation, and Means of Variables

Variables	*Mean*	*S.D.*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Innovations	134.84	288.06											
Competitive rivalry	0.23	0.20	0.04										
Disparity in size	0.72	0.12	-0.07	-0.52**									
Interactions	10.81	6.33	0.34**	-0.10*	0.04								
Consortium ages	8.07	5.32	0.07*	-0.03	0.18*	0.02							
Consortium sizes	70.88	45.67	-0.11*	-0.24**	0.48**	-0.24**	0.66**						
Firm age	65.92	26.41	0.25**	-0.12**	-0.13*	0.08	-0.03	0.38**					
Size of firm	6344.55	10,387.11	0.43**	0.01	0.01	0.07	-0.05	0.07	0.36**				
Sales/R&D	4.35	5.09	0.37**	-0.49**	-0.04	-0.12*	0.02	0.08	-0.16**	0.36**			
ROA	6.51	5.28	-0.12**	-0.07	-0.11**	-0.04	-0.12**	-0.11**	0.10	0.04	-0.16**		
Firm sector	0.01	0.07	-0.07	-0.05	-0.07	-0.11**	-0.05	-0.03	-0.08*	0.09**	0.08**	0.10	
Firm industry	0.01	0.10	-0.04	-0.07	-0.02	0.03	0.02	0.03	-0.01	0.05	-0.03	0.01	0.00

*N = 649; ***p < .001, **p < .01; *p < .05*

Regression analysis has been done in **Table 2** to assess business innovation within a cooperative group by negative binomial regression analysis. Our study developed every model to achieve an increased gain in LR χ^2, Log likelihood, and Pseudo R^2 compared to M_1, which served as the foundational model integrating all control variable quantities. Consequently, the significant levels of the freshly included independent variable quantities in the subsequent models may be unequivocally compared. Furthermore, Prob >= chibar2 is about 0.0001 in every model, confirming the suitability of the binomial regression (negative). In M_1, the control variable quantities, with the exception of ROA, have significant impacts. All of the linear independent variables are further added to M_2, which shows that firm innovation is positively correlated with both consortium-organized interaction (β = 0.091, p < 0.01) and intensity of competition (β = 2.217, p < 0.01), but not significantly correlated with firms' size disparity in consortia (β = 0.256, p > 0.1).

M_3 analyzes competitive intensity in two dimensions: linear and quadratic. Robust evidence substantiates H1, indicating an inverted U-shaped (curvilinear) correlation between rivalry intensity for the focal firm and its innovativeness within the cooperative group, evidenced by negative quadratic functions (p < 0.010, β = −7.822), and positive linear coefficient (p <

0.010, β = 4.731). M_2 and M_3 were compared to see which one most effectively represented the quadratic functions. Theoretical assumption is substantiated by substantial enhancements in LR χ^2, Log likelihood, and Pseudo R^2 (where p is < 0.010) between these models, demonstrating that curvilinear models present a more accurate fit to the data. In M_3, the disparity in business size across groups ($p < 0.010$, $\beta = -2.338$) and engagements between groups ($p < 0.010$, $\beta = 0.078$) significantly influence firm innovation, with the former exerting a negative impact and the latter a positive one.

Table 2. Examination of Corporate Innovative Performance and Competitive Intensity

Variables	*M_1*	*M_2*	*M_3*	*M_4*	*M_5*
Interactions × Competitive rivalry					-0.777**
Interactions					-0.153
Size disparity × Competitive rivalry				-16.120**	
(Competition)²				-13.588***	
Disparity in size²					1.011
Competitive rivalry	2.217***	2.322***	2.239***	2.387***	
Interactions × Competitive rivalry²					9.209
Interactions × Disparity in size			0.847		
Disparity in size			-2.339***	-1.139	-2.393***
Firm industry		Included	Included	Included	Included
ROA	0.015	0.012	0.014	0.015	0.015
Sales/R&D	0.041**	0.042**	0.042**	0.045***	0.044***
Firm size	0.0005**	0.0005**	0.0004**	0.0004**	0.0004**
Firm age	0.003	0.002	0.003	0.004	0.004
Consortia size	0.012	0.010	0.010	0.010	0.011
Consortia ages	0.055***	0.054***	0.053***	0.054***	0.053***
LR chi²	291.13***	368.48***	410.81***	418.38***	420.89***
Log likelihood	-3155.526	-3114.077	-3066.866	-3065.048	-3061.507
Constant	2.688***	2.772***	3.415***	3.610***	3.617***
LR chi²	291.13***	368.48***	410.81***	418.38***	420.89***
Log likelihood	-3155.526	-3114.077	-3066.866	-3065.048	-3061.507
Pseudo R²	0.039	0.056	0.062	0.063	0.064
Observations	669	669	669	669	669

*Notes: Dependent variable: firm innovation; ** p < 0.05, * p < 0.1, ** p < 0.05, *** p < 0.01*

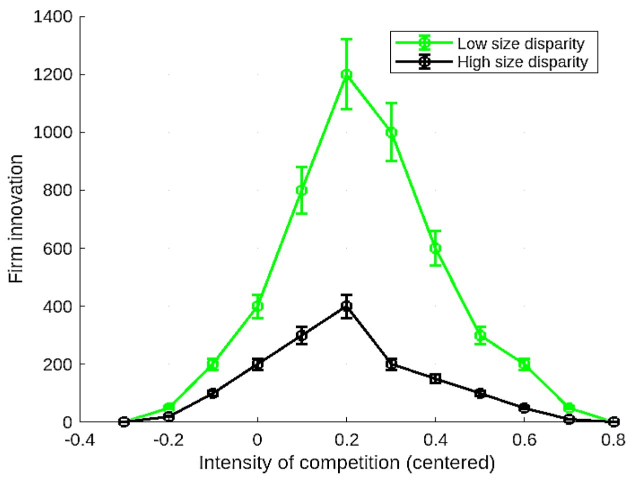

Fig 1. Moderating Influence of Disparities in Firm Size within R&D Consortia.

The importance of the inverted U-shaped association was further assessed using the three-step methodology proposed by Liu et al. [10]. M_3 has shown a statistically significant negative quadratic function component ($p < 0.010$, $\beta = -7.822$). Secondly, the command "u-test" was used to evaluate the slopes at the upper and lower boundaries of the Xrange. The first value is markedly positive (XL = 4.73, $p < 0.01$), but the subsequent value is notably negative ($p < 0.010$, XH = −10.911). Furthermore, the data X-range (0 to 1) is suitably positioned at the inflection point ($-1/2^2 = 0.30$). To construct the confidence interval for the turning point, it is recommended to use the Fieller method [11] to mitigate biases arising from deviations from normality and to address finite sample bias. Furthermore, the data X-range encompasses the 95% confidence interval (0.23 ~ 0.37). Therefore, the importance of the correlation (inverted U-shaped) is considerable. M_4 examines the controlling influence of disparity in size across consortium businesses (H2). Mean-oriented quadratic-linear and linear correlation components are derived from M_3. Lineal correlations between size disparity and competitive intensity are negative and significant ($p < 0.050$, $\beta = -16.121$), whereas quadratic-linear interaction between competitive rivalry and size disparity is not significant ($p > 0.100$, $\beta = 11.751$). This suggests that the size discrepancy among businesses within groups only controls linear impact, as posited by H2. M_4 exhibits substantial enhancements in LR χ^2, Log likelihood, and Pseudo R^2 ($p < 0.010$) relative to M_3, so partially validating its moderating function.

To further understand the controlling impact of discrepancy in company size, the methods outlined by Lin et al. [12] were used to illustrate the linear regression based on correlation terms derived from the mean-oriented variable quantities in **Fig 1**. A single sd. from mean, +/-1, was used to demonstrate the link between company innovation (y-axis) and the competitive intensity (in the x-axis) for low and high companies in R&D consortiums. Innovation within firms begins to exhibit a declining pattern near the parabola's inflection edge after the positive impact. Nevertheless, its value and the rate of change in the context of significant disparities in business size within R&D consortia are often lower than those seen with minimal disparities, although maintaining an inverted-U shape.

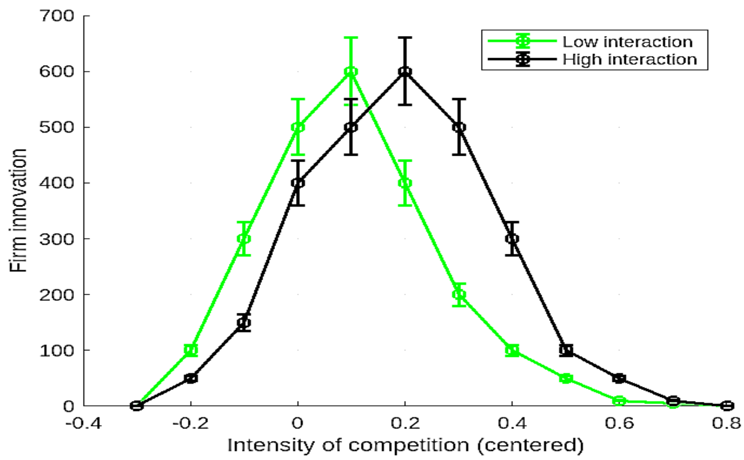

Fig 2. Controlling Influence of Consortium-Based Interactions.

M_5 further investigates the controlling impact of consortium-arranged contact (H3). Linear correlations between consortium-based interactions and levels of competition yields no significant findings ($p > 0.100$, $\beta = -0.151$), however the quadratic-linear interactions demonstrate a significant and negative effect ($\beta = -0.778$, $p < 0.050$). The controlling impact of consortium-based interactions on curvilinear correlations, as seen by substantial enhancements in LR χ^2, Log likelihood, and Pseudo R^2 ($p < 0.010$) relative to M_3, may provide a more accurate fit, corroborated by H3. **Fig 2** illustrates the estimated effect of the interaction. The U-shaped curve has a sharper gradient when the degree of consortium-organized interaction is elevated. This indicates that the inverted U-shaped relationship may be reinforced by the collaboration facilitated by the consortium.

In accordance with H3, the production of innovative goods from the cooperative R&D collaboration rises under low competition and declines under moderate rivalry when the amount of consortium-organized involvement is elevated. Through the comparison of the significance and sign of coefficients in M_3, M_4, and M_5, we used OLS (ordinary least squares) regression to validate the robustness of the findings. **Table 3** presents a comparison between OLS regression and NB (negative binomial) regression. Furthermore, based on the skewed competitive intensity distribution, it is advisable to transform it into a dummy variable with a median of 0.18 for a rigorous assessment. The results are mostly reliable with **Table 2** however only linear assessment would be done because of the presence of dummy variables.

Table 3. Analogy of Signs and Importance of Coefficients of NB And OLS

Variables	*M_3*		*M_4*		*M_5*	
	OLS	NB	OLS	NB	OLS	NB
Interactions × (Competitive rivalry)²	—	—	—	—	—	—
Interactions × Competitive rivalry	—	—	—	—	(+)	(–)
Disparity in size × (Competitive rivalry)²	—	—	—	(+)	—	(+)
Disparity in size × Competitive rivalry	—	—	(+)	—	—	—
(Competitive rivalry)²	—	—	—	—	—	+
Competitive rivalry	+	+	+	+	+	+
Interactions	—	+	—	—	+	+
Disparity in size	+	+	(+)	—	—	—

Notes: Parentheses: nonsignificant findings

V. DISCUSSION

Coopetition is a dynamic in which partners simultaneously engage in collaboration and competition. Research suggests that an optimal equilibrium between cooperation and competition enhances knowledge acquisition and improves organizations' innovation outcomes. A primary reason corporations adopt a coopetition approach is to internally address capability gaps that would otherwise incur significant development costs, which their partners possess. According to these writers, coopetition may provide advantages like economies of scale, diminished uncertainties and risks, and reduced product growth timeframe. Interactions dynamics in this connection are distinct, since conflicts of interest accompany the need of establishing a trust-based relationship with reciprocal obligations. The positioning of each participant inside the coopetition network may significantly influence their respective results. We propose that players in more central offices might get more benefits regarding information acquisition, which may directly enhance their competitive advantage. Coopetition partnerships among big competitive firms are characterized by elevated stress levels, with a significant danger of partner theft.

The research was driven by ostensibly paradoxical arguments about the function of coopetition and sought to investigate the circumstances under which it may positively influence creativity inside an R&D consortium. Co-opetition and invention are often interrelated phenomena. Competing companies collaborate in research and development for several reasons, often associated with fundamental and applied study, market access, and innovation processes and exploration potential. Mutual learning among partners is an often-anticipated advantage of R&D collaboration. The growth of co-opetitive behaviors in R&D within a certain sector is intimately linked to businesses' use of open innovation methods. In the microprocessor sector, the competitive dynamics between smaller newcomers (AMD and Intel) and IBM have influenced patent practices of these enterprises and fostered technological coopetition during the last 3 decades. AMD and Intel effectively contended with IBM in product markets while also engaging in co-opetition in patent markets and technology [13].

Certain academics discovered compelling evidence in the examination of R&D cooperative systems across competing enterprises. Technological resources are essential for enterprises to get high-quality complementary resources from partners. A substantial body of material exists about the advantages of businesses' earlier experiences in R&D interactions for futuristic R&D engagements. Schiavone and Simoni [14] discovered that the previous foreign experiences of around a thousand German advanced enterprises significantly influenced their capacity to engage in worldwide R&D co-opetition. They discovered that companies might acquire knowledge in managing R&D collaborations via experience gained from previous analogous inter-firm interactions. Mishra, Chandrasekaran, and MacCormack [15] indicate that the level of overall alliance experiences of partners influences the success probability of engaged R&D engagements. Likewise, Wei et al. [16] examined the impact of businesses' earlier involvement in global R&D systems on propensity to engage in subsequent inter-organizational R&D complex systems. The strategic effectiveness in selecting partnerships and centrality-oriented networking capacity of companies, cultivated through previous experiences in prior R&D networks, significantly enhance their likelihood of participating in futuristic R&D inter-organizational consortia, surpassing the impact of their general experience-based partnering capabilities.

The results illuminate inverted U-shaped correlation between company innovation and competition intensity inside the cooperative R&D group, aligning with previous research in other settings. The concept posits that novel technology advancements may provide substantial competitive advantages and enhance returns temporarily, until competitors replicate and close the gap with the inventors. Innovation rises at low competition levels, peaks at an optimal point, and thereafter diminishes as competition escalates, ultimately disincentivizing inventions due to the reduction of monopoly rents from innovation. The inverted U-shaped connection arises from the escape competition effect at low competition levels, transitioning to a Schumpeterian impact when more rivalry starts to deter R&D investment. Mulkay [17] used patents to quantify innovation and the Lerner index to assess competitiveness, in addition to productivity. Subsequent study, examined in the next section, has used other metrics of innovation and technological disparities. They evaluate the model's predictions using firm-level data and discover that the inverted U-shaped relationship is corroborated by a Herfindahl index measure of competitiveness, but not by a price–cost margin.

A central business within a moderately competitive cooperative consortium may attain a maximum level of innovation performance. Haans, Pieters, and He [18] have proposed a significant 'new' theory, termed the inverted-U relationship, which models the connection between competition and innovation within the Schumpeterian growth framework. In summary, if the initial level of competition is minimal, the inverted-U hypothesis forecasts a beneficial effect of increasing rivalry on innovation efforts. Conversely, at elevated levels of early rivalry, heightened competitiveness diminishes the motivation for innovation. In addition to its technical complexity, the nonlinear model has significant intuitive appeal, particularly since it reconciles the perspectives of Newell and Molenaar [19].

Furthermore, the research revealed that R&D group may generate a more conducive environment to enhance the advantages of competitive rivalry and mitigate its expenses for collaborative innovation by modifying the disparities in company size and facilitating coordinated interactions inside the consortium. The conclusion suggests that a significant gap in business size might diminish linear impact of competitive intensity on organizational innovation, while it does not influence quadratic impacts. This indicates that a research and development consortium with little size discrepancy enables the focus business to realize more benefits from collaborative R&D efforts. This aligns with prior evidence indicating that collaboration is more probable when partners possess comparable status and power, as significant disparities in firm size create power asymmetry, leading to various issues that hinder cooperative innovation, including perceptions of injustice and free-riding. The disparity in size among rivals within a cooperative framework exacerbates the detrimental impact of competition (increased opportunism) and diminishes the motivational benefits of competition (reduced incentive). Thus, it demonstrates that a consortium with little discrepancy in business size is more favorable for the coopetition approach to positively influence innovation.

Conversely, the empirical findings suggest that consortium-based interactions may enhance curvilinear link between business innovation and competitive intensity, aligning with our hypothesis. Cheng [20] emphasized that social interaction or contact is essential for knowledge transfer and exchange across enterprises. Interactions among managers from various divisions within a corporation have been shown to significantly enhance intra-firm knowledge-sharing. In-person social interactions serve as a communication medium especially effective for the transmission of tacit, uncodified information.

Intensive social engagement facilitates the social creation of knowledge via a learning discourse. Several activities held by the consortium may facilitate interfirm engagement to expedite the exchange of information and expertise. The fast dissemination of knowledge poses a dual challenge for collaborative research and development. In the context of a focus company facing little rivalry, consortium-organized interactions foster active communication and collaboration with other enterprises for reciprocal learning.

VI. CONCLUSION

This research provides important findings, which highlight the vital role that Cooperative R&D Consortia (CRDC), have in accelerating organizational innovation by facilitating knowledge sharing and coordination across divergent industries. It is through the analysis of governance structures and network dynamics that we find that well-structured consortia not only help to transfer knowledge efficiently but also increase participant absorptive capacity and result in a tangible increase in innovation outputs such as patents and product development. Despite this, these consortia have many hurdles, from coordination, trust and intellectual property rights, which can often constrain a consortium from achieving its full potential. The future CRDCs will need to overcome these barriers via better governance mechanisms and more direct communication paths. Future research will investigate how the digital work of the future will continue to improve efficiency and effectiveness of CRDC's, through the use of digital collaboration platforms and artificial intelligence. In addition, high tech industries sector specific consortia could be more closely scrutinized for unique patterns of knowledge transfer and innovation. Since industries are continuing to globalize and speed increases in technology, CRDCs can expand into cross border partnerships indicating new means of managing complex international collaborations.

CRediT Author Statement

The author reviewed the results and approved the final version of the manuscript.

Data Availability

No data was used to support this study.

Conflicts of Interests

The author(s) declare(s) that they have no conflicts of interest.

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There are no competing interests

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