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Systemic Approaches to Coopetition: Technology and Service Integration in Dynamic Ecosystems Among SMEs

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Abstract: In the globalized, technologically advanced landscape, coopetition—simultaneously cooperating and competing—has become a key strategy for innovation and enhanced value creation. This research focuses on the impact of technology-driven coopetition networks in the Portuguese ornamental stone sector, using a framework based on Service-Dominant Logic (S-D Logic). It emphasizes the importance of resource integration, service exchange, and institutional arrangements in successful coopetition. Employing a two-phase experimental approach with selected small and medium enterprises (SMEs), this study assesses customer perceptions of product quality under traditional best practices versus those enabled by technology-driven coopetition networks. The results indicate a notable improvement in the customer-perceived quality and outcome consistency. The statistical analysis shows that these networks allow firms to better align with customer expectations, optimize resource allocation, and improve operational coordination. The findings highlight the strategic potential of coopetition networks, particularly when augmented by advanced technologies like IoT-based systems. These networks facilitate sustainable value co-creation and operational resilience by enabling firms to share expertise, distribute tasks, and synchronize efforts. This research contributes to the coopetition and S-D Logic literature by offering a practical framework for firms aiming to boost competitiveness and sustain growth in dynamic service ecosystems.

Keywords: coopetition; IoT; business transformation; service-dominant logic; value co-creation; innovation

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1. Introduction

In an era characterized by market globalization and resource asymmetry, the business network landscape has undergone profound transformations, giving rise to diverse and complex network structures [1]. One such structure, coopetition—defined as the simultaneous collaboration and competition between firms—has emerged as a crucial strategy for reshaping organizational dynamics and network ecosystems [2]. Coopetition enables firms to leverage competitive advantages [3] while mitigating external risks and uncertainties [4]. Despite increasing academic attention to this phenomenon [5], significant gaps remain in understanding how coopetition networks facilitate or obstruct value creation and capture [6]. These gaps are particularly pressing given the transient nature of coopetition networks, which often dissolve prematurely before achieving their intended objectives [7].

The existing research primarily examines coopetition through two dominant lenses. First, the competitive dynamics perspective explores firm behavior and market structuring as critical drivers [8,9]. Second, the resource-based view positions coopetition as a strategic pathway to accessing unattainable resources, enabling firms to exploit unique capabilities for a competitive advantage [2]. While these perspectives provide valuable insights, they primarily focus on dyadic relationships, neglecting the broader complexities of multi-party interactions in networked environments [10].

A critical shortcoming in the literature lies in the limited exploration of value creation mechanisms and the crucial role of technology within coopetition networks [11]. Although theoretical frameworks such as game theory, the resource-based view, paradox theory, transaction cost theory, and network theory have been widely applied [5], there remains a lack of clarity regarding how value is created, distributed, and sustained among diverse stakeholders [2]. This is particularly concerning as unmet expectations often drive the premature collapse of coopetition networks [7]. Furthermore, research in the financial technology sector demonstrates that coopetition arises when firms clearly understand their core competencies and strategic focus, enabling them to collaborate with external partners who complement their strengths [12,13]. These studies suggest that coopetition is not an equilibrium state but evolves as firms develop new capabilities and adapt to dynamic market conditions. Recognizing the increasing significance of technology in modern business ecosystems, this study addresses the following research question: What framework is best suited for coopetition networks to meet customer expectations?

To answer this question, the research adopts Service-Dominant Logic (S-D Logic) as its theoretical foundation [14]. S-D Logic emphasizes that value is co-created through resource integration and reciprocal service exchange processes among actors in service ecosystems [15], positioning customers as essential participants in the value creation process [16]. This perspective highlights the importance of partner collaboration ecosystems in coopetition networks to align firms' collective efforts to meet customer expectations [17]. By leveraging advanced technologies, such as IoT-based systems, firms can optimize their resource-sharing capabilities and operational coordination [18], enabling them to deliver outcomes that resonate more effectively with customer needs [19,20].

This research tests the hypothesis that transitioning to technology-driven coopetition networks enhances value co-creation by enabling firms to align their offerings with customer expectations better. By fostering collaborative processes and integrating shared resources, coopetition networks can improve the perceived product quality and operational consistency, critical in meeting customer requirements and driving sustainable value co-creation.

To empirically test this hypothesis, this study examines the Portuguese ornamental stone sector, an industry of national significance with a global presence. Comprising predominantly SMEs, this sector has demonstrated exceptional economic performance, with exports exceeding imports and a considerable market reach beyond Europe.

The Portuguese ornamental stone sector holds significant historical, cultural, and economic importance. Since the 15th century, this sector has contributed to iconic monuments worldwide, showcasing Portugal's deep-rooted expertise in stone craftsmanship [21]. According to the Portuguese Stone Federation, this sector ranks ninth globally in the International Stone Trade and second in international trade per capita, exporting to 116 countries [22].

Coopetition, in the context of this study, refers to a strategic interplay where companies collaborate and compete simultaneously to achieve mutual benefits that would be unattainable independently. This article is structured as follows: The literature review explores the role of technology in enabling resource integration and value co-creation within coopetition networks. The research design outlines the methodological approach to address the research question and test the proposed hypothesis. The study develops and validates a framework for enhancing customer expectations through technology-driven coopetition networks by investigating the interplay between coopetition, technology, and value co-creation.

2. Literature Review

Coopetition has gained increasing recognition in recent business literature as a key strategy for enhancing competitive advantage and fostering innovation within networks [23]. Coopetition serves dual strategic purposes: a deliberate move to strengthen market power [24] or a dynamic response to external opportunities and threats [25]. A firm's knowledge structure often influences the decision to engage in coopetition, which shapes its strategic choices to cooperate, compete, or adopt a combination of both [26]. At the core of coopetition's strategic value lies its orientation toward innovation, enabling firms to bridge knowledge gaps and effectively address market challenges [9].

Coopetition networks arise at the intersection of cooperative and competitive interests, where firms recognize the mutual benefits of collaboration despite direct competition in certain areas [23]. These interactions often extend beyond dyadic relationships, evolving into multi-firm networks where participants collaborate equally to achieve common goals [27].

Scholarly perspectives on coopetition are diverse. Some researchers conceptualize these relationships as hybrid networks characterized by paradoxical interactions between cooperation and competition [2]. Analytical frameworks generally fall into two primary lenses: (1) competitive dynamics, which emphasize the structural and behavioral aspects of relationships [27], and (2) the resource-advantage perspective, which views coopetition as a strategic mechanism to access otherwise unattainable resources, enhancing firms' competitive capabilities [28].

Despite the varying viewpoints, the prevailing consensus highlights the firm-centric nature of coopetition, where individual competitiveness often takes precedence over collective value creation within networks [2].

Empirical research underscores the advantages of coopetition, including access to new markets, external knowledge sharing, risk and cost distribution, and enhanced scalability through asset complementarity [29]. Coopetition has been linked to increased innovation, particularly in supply chain security and knowledge creation processes [9]. Table 1 provides an overview of key definitions and perspectives on coopetition.

Table 1. Coopetition: definitions and perspectives.

Coopetition: Definition and Perspectives	Source
Coopetition represents a hybrid activity combining cooperation and competition within firms.	[30]
Coopetition describes a triadic relationship where collaboration among firms influences competition with others.	[31]
Coopetition involves simultaneous competition and collaboration within the same relationship.	[25]
Coopetition is a hybrid behavior where firms engage in both competition and cooperation.	[24]
In a coopetition relationship, firms typically cooperate in upstream activities and compete in downstream activities.	[30,32]
Coopetition is a dyadic and paradoxical relationship that emerges when two firms cooperate in some activities.	[33]
Coopetition involves simultaneous cooperative and competitive interactions across multiple levels of analysis.	[34]
Coopetition is the balance between cooperation and competition in a competitive environment.	[35]

While coopetition delivers notable advantages, several critical research gaps persist:

- RG1: The predominant focus on individual competitive benefits overshadows processes for collective value creation. How can value creation in coopetition networks be effectively addressed?
- RG2: Variability in firms' motivations leads to unresolved dysfunctions within coopetition networks. How can dysfunctions in coopetition networks be managed?
- RG3: Despite coopetition's recognized complexity, discussions on coordination mechanisms for balancing collaboration and competition still need to be improved. How can coordination among actors in coopetition networks be facilitated?

Moreover, coopetition networks are prone to significant challenges, including uncertainty, competitive pressures, and risks like knowledge leakage. These challenges sometimes outweigh the benefits, leading to the premature dissolution of coopetition relationships [36].

2.1. Value Creation Through the Lens of Service-Dominant Logic

The conceptualization of "service" as a cornerstone of economic exchange can be traced back to the mid-19th century with early thinkers like Frederick Bastiat (1848). However, in the early 21st century, Lusch and Vargo (2004) revolutionized this discourse by introducing S-D Logic [16]. This paradigm shift placed operant resources—intangible assets such as knowledge, skills, and capabilities—at the forefront of value creation [37], challenging the traditional operand resource view that prioritized tangible goods. In the S-D Logic perspective [38], goods are not the primary creators of value but serve as vehicles for service delivery, embodying the application of specialized competencies to benefit others [39].

At its core, S-D Logic redefines value creation as a co-creation process, emphasizing that value emerges through interactions among various actors within a networked ecosystem [25]. This perspective aligns with foundational theories such as the resource-based view [40], competency core theory [41], and corporate core competencies theory [42], underscoring its broad applicability to contemporary discussions on value generation (Table 2).

Table 2. Value creation for service-dominant logic.

	Core Concept	Source
Phenomenological Nature	Value is experiential and perceived differently by various service ecosystem actors across diverse contexts.	[43]
Resource Integration and Exchange	Value is co-created through the integration and exchange of resources among multiple actors, including firms, customers, suppliers, and government agencies.	[44]
Well-Being Enhancement Through Resources	Value co-creation occurs as actors enhance their well-being by relying on operant resources (knowledge and skills) and operand resources (tangible tools).	[45]
Multidimensional Nature	Value comprises individual, social, technological, and cultural components and is derived through interactions among actors within intersecting institutional frameworks.	[46–48]
Emergent Property	Value is emergent and cannot be predetermined; it arises through the ongoing relationships between actors and the system, shaping the service ecosystem's identity.	[19,44]
Resource-Enacting Phenomenal Practices	Beneficiaries participate in value co-creation through phenomenal practices, where their experiences enact and exchange services to generate value.	[38]

Historically, classical economists like Adam Smith (1776) and David Ricardo (1817) approached value through the lens of labor theory, focusing on tangible production. However, modern economic discourse has evolved to embrace value co-creation, which highlights the collaborative roles of suppliers, partners, and customers in generating value [49]. This evolution—from coproduction to co-creation and ultimately to value co-creation within service ecosystems—reflects an enhanced understanding of value as multifaceted and dynamic [50].

Under S-D Logic, service ecosystems are viewed as complex adaptive systems where value is derived and continuously re-evaluated through actor interactions. Instead of viewing value as a predefined delivery, S-D Logic emphasizes the role of value propositions as facilitators of co-creative interactions [14]. This perspective further distinguishes between value-in-exchange (traditional market transactions) and value-in-use (value derived through application and interaction), emphasizing the process-oriented and relational nature of value creation and realization [14].

2.2. Value Networks and Technology as Catalysts for Collaborative Value Creation

Granovetter (1985) emphasizes that economic behaviors are embedded within network relationships, advocating for a more nuanced understanding of how cooperation and competition operate at multiple levels [51]. Other historical perspectives on networks, rooted in sociology and organizational theory, highlight their structural implications for value creation [52]. However, recent literature has called for re-examining network concepts to align theoretical insights with the practical realities of contemporary industries and management practices [5].

Building on this foundation, Mariotti (2002) introduces the concept of a value network, describing it as an interconnected ecosystem where information, technology, and human interactions converge to generate value across nodes. Mariotti highlights the role of technology in facilitating exchanges that transcend spatial and temporal boundaries, enabling dynamic collaboration and interaction among network participants [53].

The concept of "network" plays a dual role in modern economic and social ecosystems, encompassing both networking and the structural configuration of interconnected systems. This duality highlights networks as platforms where diverse actors—individuals to organizations—interact and collaborate to achieve economic, social, and environmental objectives [5]. Within the framework of S-D Logic, networks are reconceptualized as interconnected systems of actors who contribute specialized competencies and engage in reciprocal value propositions [54]. This perspective shifts the focus from transactional exchanges of goods and services to collaborative interactions and relationships as the primary drivers of value creation [55].

Under this view, technology plays a transformative role in shaping and redefining value networks [56]. Traditionally viewed as a societal tool for addressing needs [57], technology is now recognized within S-D Logic for its dual nature as both an operand resource (an enabling tool) and an operant resource (a source of knowledge and innovation) [58]. This nuanced understanding positions technology as a critical enabler of value co-creation by fostering new resource integration, collaboration, and innovation [37].

The convergence of digital transformation and technological innovation further amplifies technology's role within value networks. Wieland et al. (2017) explore this interplay, emphasizing how technological advancements drive service innovation, enabling network actors to integrate resources more efficiently and create enhanced value [15]. In modern ecosystems, technology connects actors and facilitates adaptive and dynamic relationships, supporting the emergence of new value propositions and resource exchanges.

Drawing on this critical evaluation of value creation mechanisms and the role of technology in coopetition networks, a theoretical framework can be formulated to test the hypothesis that transitioning to technology-driven coopetition networks enhances customer-perceived quality, thereby fostering value co-creation. This framework aims to uncover how technological advancements catalyze collaboration, drive innovation, and contribute to the sustainable success of coopetition networks.

3. Methodology

This research design is grounded in critical decisions regarding its theoretical foundation, which provides a framework for investigating complex phenomena across diverse fields such as medicine, computer science, engineering, management, and economics [59]. Integrative approaches, known for their ability to analyze both individual components and the system as a whole, are particularly suited for exploring the multifaceted nature of coopetition networks [60].

This study employs an integrative methodology to comprehensively understand service-centric networks [61]. It shifts the focus from firm-centric views to a service-oriented lens emphasizing institutional change and collaborative value creation [14]. By facilitating processes such as logistics, learning, and knowledge transfer, coopetition within ecosystems drives innovation and enables firms to achieve collective and individual benefits [62].

Coopetition ecosystems incorporate multiple innovation processes [63] facilitated by sharing resources and fostering an environment that enhances the network's collective capacity for innovation [64]. Scholars further argue that innovation in these networks is not merely an outcome but also a driver of dynamic reconfigurations within institutional spaces [8]. These reconfigurations are shaped by ongoing interaction and co-creation, underscoring the importance of continuous adaptation within service ecosystems [17].

3.1. Integrative Framework and Hypothesis Development

Building on S-D Logic, this study proposes an integrative framework to address existing gaps in the coopetition literature [65]. The framework encompasses three interconnected components: (1) Framing Networks and Service Ecosystems—understanding the foundational role of networks and their transformation into service ecosystems as platforms for value co-creation; (2) Framing Coopetition and Value Creation—articulating how coopetition facilitates innovation and dynamic value creation processes within service ecosystems; and (3) Bridging Theoretical Gaps—leveraging this integrative perspective to address gaps in the coopetition literature, particularly in service ecosystems and institutional networks.

Building on these systemic constructs, this study implements a Technology-Driven Coopetition Network to test the hypothesis that transitioning to technology-driven coopetition networks enhances customer-perceived quality, thereby fostering value co-creation.

3.2. Evaluation Metrics for Assessing Value Co-Creation in the Ornamental Stone Industry

From the perspective of S-D Logic, value emerges as the result of a co-creative process in which the customer is a fundamental actor [16]. Higher alignment with customer expectations leads to higher co-created value. Among the various indicators suggested in the marketing literature, the perceived product quality is considered one of the most reliable and widely adopted Key Performance Indicators (KPIs) [66].

In stone SMEs supplying ornamental stone products, customer orders often involve multiple items, such as kitchen countertops, facades, flooring, staircases, thresholds, and baseboards [22]. However, as stone is a natural product, its raw material is inherently heterogeneous, even within the same material type (e.g., granite, limestone, marble, or slate).

When a company secures an order, it must produce multiple product types using various raw materials, often lacking the full production capabilities or technical know-how to handle all aspects efficiently. Companies can distribute portions of their orders to other network members with the necessary expertise and production capacity by participating in a technology-driven coopetition network. This collaboration occurs while ensuring customer identity confidentiality and preserving market integrity.

As a result, companies operating within a coopetition framework are better positioned to meet or exceed customer expectations, thereby improving perceived product quality.

3.3. Measuring Value Co-Creation Through Perceived Product Quality

In value co-creation, the Perceived Quality of Products (QpP) is defined as the degree to which the delivered product meets or surpasses the customer's initial expectations. For this study, the Key Performance Indicator for Perceived Product Quality (KPIQpP) is quantified using a five-point Likert scale, where a score of 1 indicates that the product quality falls significantly below expectations, and a score of 5 indicates that it far exceeds expectations.

To evaluate the value co-creation gain (VCG) of transitioning from traditional best practices (BP) to a technology-driven coopetition network (CP), the gain in value co-creation can be calculated as a percentage improvement using Equation (1), where (1) KPIQpP(BP) represents the average customer rating for the perceived product quality under best practices (conventional methods), and (2) KPIQpP(CP) represents the average customer rating for the perceived product quality within the coopetition network.

$$\text{VCG}\ (\%) = \frac{\text{KPIQpP(CP)} - \text{KPIQpP(BP)}}{\text{KPIQpP(BP)}} \times 100\% \tag{1}$$

This systematic metric quantitatively assesses how technology-enabled coopetition networks influence customer perceptions of quality. Applied to the Portuguese ornamental stone sector, it offers valuable insights into how cooperative efforts enhanced by technology can drive improvements in the perceived product quality and foster greater value co-creation.

This integrative framework offers theoretical insights and practical pathways for rethinking coopetition, aligning the methodological approach with advancements in S-D Logic. It underscores the importance of continuous innovation and value co-creation processes within institutional networks, positioning coopetition as a transformative strategy for fostering sustainable growth and collaboration in dynamic service ecosystems.

4. An Integrative Framework for Institutional Coopetition Networks

4.1. The Evolution from Value Networks to Service Ecosystems

The transition from value networks to service ecosystems represented more than a shift in terminology—it reflected an evolution in theoretical focus. From traditional perspectives, enterprises within value networks collaborate to enhance the value of tangible and intangible products, with the primary goal of capturing market share through added value [67]. However, this perspective underwent a transformative shift with the contributions of Vargo and Lusch (2011), who redefined value creation within the S-D Logic framework. They advocated moving from static value networks to dynamic service ecosystems, where resource integration is the central mechanism for connecting people, technology, and institutions, facilitating value co-creation through service exchange [68].

A critical advancement in this evolution was the recognition of the role played by institutions and institutional arrangements in enabling value co-creation within service ecosystems. Lusch and Vargo (2014) conceptualized service ecosystems as self-regulating systems composed of resource-integrating actors whose interactions are governed by shared institutional logic and mutual value creation objectives [69]. Based on Scott's (2001) definition, institutions within these ecosystems are seen as structured sets of rules, norms, and beliefs that enable and constrain actors' behaviors, rendering social interactions predictable and meaningful [70].

The role of institutional logic within service ecosystems, as explored by Koskela-Huotari and Vargo (2016), extends beyond organizational boundaries. Institutional logics operate at a supra-organizational level, coordinating actions and governance through material–symbolic languages that align actor behaviors within the ecosystem [71,72]. This perspective underscores the network-centric nature of modern ecosystems, where value is co-created through the integration of resources, collaboration, and adherence to shared institutional logic [72].

By focusing on the systemic and adaptive nature of service ecosystems, S-D Logic provides a comprehensive framework for analyzing the complex interplay among actors, resources, and institutions. This dynamic interplay enables the ongoing process of value co-creation, positioning service ecosystems as both drivers of innovation and platforms for fostering collaborative value creation [56].

4.2. Navigating Dual Dynamics: Framing Coopetition and Value Creation

In business literature, coopetition has been conceptualized as embodying two distinct yet interconnected dimensions. Bengtsson and Kock (2014) describe these dimensions as "parallel lanes," where firms collaborate with rivals in specific markets or activities while maintaining competitive postures in others [73]. This duality creates strategic opportunities and operational challenges, requiring firms to balance these opposing forces to achieve sustainable outcomes carefully [2].

Contrasting this "dual-lane" perspective, other scholars introduce the concept of syncretic rent-seeking behavior [74]. From this viewpoint, coopetition is not a simple balance of distinct strategies but rather an integrated approach operating along a single continuum where cooperation and competition coexist in dynamic tension [75]. This perspective emphasizes that firms must navigate the complexities and trade-offs inherent in these dual dynamics, developing strategies to harmonize collaborative and competitive intents effectively.

The inherent tensions within coopetition networks necessitate mechanisms for managing these dynamics. Scholars highlight the importance of establishing cooperative norms, rules, and institutions to guide actor interactions and mitigate conflicts [26]. This institutionalized approach aligns closely with the S-D Logic framework, which positions service ecosystems as systems of shared institutional logic that facilitate value co-creation [58]. Drawing on Scott's (2001) institutional theory, institutions within service ecosystems act as higher-order structures, providing the symbols, rules, and organizing principles needed to address tensions and paradoxes inherent in coopetition networks [56].

Within this institutional framework, value cooperation in coopetition networks emerges through dynamic service exchanges among various actors, including firms, competitors, customers, and regulatory authorities [76]. This process is inherently experiential and iterative, as actors continuously learn and adapt. By observing and assessing what creates value—and what does not—actors adjust their behaviors and interactions to align with evolving expectations [77].

As with any ecosystem, this dynamic learning environment fosters an ongoing cycle of adaptation and innovation, ensuring the survival and growth of coopetition networks. Firms that embrace this adaptive capacity can better navigate the dual dynamics of cooperation and competition, unlocking opportunities for sustainable value creation and enhancing their collective resilience within the network [77].

4.3. Addressing Coopetition Challenges Through the Lens of Service Ecosystems

Coopetition networks provide platforms for firms to acquire and integrate resources and capabilities, enhancing their competitive advantage and innovation capacity [78]. This aligns with the S-D Logic perspective, which positions all actors as resource integrators and views value as co-created through dynamic service exchanges. Institutions—understood as shared rules, norms, and meanings—are crucial in enabling and constraining actions, ensuring coordinated value co-creation within complex service ecosystems [79]. To address critical challenges within coopetition networks, this section explores how the service ecosystem perspective provides solutions to the identified research gaps (RG1, RG2, and RG3).

Bridging RG1—Overcoming the Focus on Individual Competitive Benefits to Enable Collective Value Creation: Focusing on individual firm competitiveness often overshadows collective value creation processes. Through the lens of S-D Logic, value creation is conceptualized as a shared process where firms collaborate to integrate resources and generate mutual benefits. In coopetition networks, actors must recognize that value emerges not from isolated outcomes but from reciprocal exchanges and service integration across the ecosystem. Institutions play a critical role in facilitating this transition. By establishing shared norms, expectations, and collaborative frameworks, institutions encourage firms to shift from a firm-centric mindset to a network-centric approach. Resource integration within coopetition networks ensures that firms collectively enhance operational efficiency and deliver value propositions that align with customer expectations. This process addresses RG1 by repositioning value creation as a collective endeavor that benefits all network participants [62].

Bridging RG2—Managing Variability in Motivations to Overcome Dysfunctional Coopetition: Variability in firms' motivations can lead to unresolved dysfunctions, including trust issues, competitive misalignment, and resource misuse. Addressing these challenges requires the implementation of institutional arrangements that establish organic governance mechanisms and align actor behaviors. Through shared norms, social rules, and evaluative frameworks, institutions serve as stabilizing forces that guide interactions within the network. By adopting a service ecosystem perspective, firms can effectively navigate tensions between collaboration and competition. Shared institutional logic provides actors with common goals and a structured approach to resolving conflicts. For example, confidentiality agreements, operational norms, and incentive mechanisms can reduce opportunism and align motivations, enabling firms to balance their competitive and cooperative intents. This structured governance ensures that coopetition relationships remain productive, addressing RG2 by reducing dysfunctions and fostering trust-driven coordination [26,80].

Bridging RG3—Facilitating Coordination Mechanisms to Balance Collaboration and Competition: Coopetition's inherent complexity necessitates effective coordination mechanisms to balance collaboration and competition. Institutions within service ecosystems play a dual role in facilitating coordination: they act as mechanisms for collaboration and evaluative frameworks for assessing performance. From an S-D Logic perspective, coordination emerges through actor-generated institutions, such as shared social norms, rules, and expectations, streamlining interactions and resource exchanges. Technologies, such as IoT systems and digital platforms, also function as critical enablers of coordination, allowing actors to share resources, track progress, and align operational activities dynamically. Technological solutions provide structural support for balancing the dual dynamics of coopetition by enabling firms to connect their processes and exchange services seamlessly. This systemic approach to coordination addresses RG3 by providing firms with actionable tools and institutional frameworks to facilitate collaboration without compromising competitive interests. Effective coordination ensures the sustainability of coopetition networks, enabling firms to achieve mutual gains and co-create value over time

By addressing these research gaps, the service ecosystem perspective provides a comprehensive understanding of coopetition networks. Institutions and institutional arrangements serve as foundational elements for (1) facilitating collective value creation through resource integration and shared norms; (2) managing variability in motivations by establishing governance mechanisms that align actor behaviors and reduce dysfunctions; and (3) enhancing coordination through shared frameworks, technological enablers, and evaluative mechanisms that balance collaboration and competition.

The dynamic interplay between actors, institutions, and technology underscores the importance of adaptive governance and resource alignment within coopetition networks. This perspective ensures that value is co-created sustainably while mitigating the risks of conflict, fragmentation, or co-destruction. By adopting this framework, firms can navigate the challenges of coopetition, leveraging collective capabilities to foster innovation, operational efficiency, and customer-aligned value creation.

Through the lens of S-D Logic and service ecosystems, this study demonstrates how coopetition networks can address key challenges and bridge existing gaps in value creation, actor alignment, and coordination mechanisms. By leveraging institutions and technological solutions, firms can build resilient networks that enhance value co-creation and drive sustainable growth.

5. Institutional Constructs and Systemic Building Blocks for Coopetition Networks

Understanding institutions involves recognizing their regulative, normative, and cultural–cognitive dimensions in coopetition networks. These institutional elements become critical when organized actors—often called institutional entrepreneurs—identify opportunities to pursue shared, highly valued interests within a network [81]. Within this institutionalized environment, cognitive institutional arrangements act as enablers for transforming coopetition networks into fertile ground for value co-creation [70]. This transformation aligns with the S-D Logic perspective, which envisions value co-creation as actors engaging in meaningful experiences within nested and overlapping service ecosystems. These ecosystems operate under governance and evaluation mechanisms provided by institutional arrangements [79].

Highlighting the critical role of dynamic interactions in networks, S-D Logic conceptualizes networks as fluid configurations of institutions [71]. These configurations, built upon reciprocal connections among actors, drive technological and market innovations that ensure the resilience and endurance of coopetition networks [15].

Building on this service ecosystems perspective, the following set of systemic constructs can be proposed for understanding and developing coopetition networks:

Coopetition Network Institutionalization (Systemic Construct 1): (1) emphasizing the bidirectional relationship between institutions and actor behaviors within networks, (2) institutions emerge organically through bottom-up processes, evolving from micro-level practices (actor-specific behaviors) to mezzo-level arrangements (network norms), and (3) coopetition practices at the micro level catalyze the development of actor-generated institutions, setting the stage for future value creation interactions within the network.

Coopetition Network Coordination (Systemic Construct 2): (1) at the micro-level, firms (competitors and partners) engage in resource exchange within networks to co-create value; (2) coordination mechanisms—such as shared motivations, norms, and expectations—facilitate seamless resource integration; and (3) the outcomes of value co-creation are governed and evaluated by actor-generated institutions and broader institutional arrangements.

Coopetition Enabled by Technology in the Network (Systemic Construct 3): Technology plays a simultaneous dual role within coopetition networks, acting as both an enabler (operand resource) and an initiator (operant resource). As an institutional enabler, technology reshapes resource integration patterns, enhances innovative capacity, and effectively empowers actors to co-create value.

These systemic constructs give rise to specific Systemic Building Blocks essential for constructing effective coopetition networks.

Building Block 1—coopetition actors are the primary agents of value co-creation, including firms, customers, and other stakeholders. These actors navigate the dual roles of collaboration and competition within the ecosystem. Building Block 2—the collaborative effort among actors to combine diverse resources, capabilities, and competencies to enhance the network's collective value proposition. Building Block 3—the mechanism through which integrated resources are offered and utilized, enabling mutual benefits and value co-creation among network participants. Systemic Building Block 4—coopetition institutions and institutional arrangements are the rules, norms, and cultural–cognitive elements that guide coopetition actions and governance, ensuring alignment across the network. Systemic Building Block 5—the broader context within which resource integration and service exchange occur. Multiple, interlinked layers of coopetition and collaboration characterize these ecosystems.

The role of technology as both an enabler and initiator of coopetition is captured in two additional building blocks. Building Block 6—technology that acts as enablers of coopetition actions by providing tools and platforms for resource integration and service exchange. Building Block 7—technology that acts as initiators of coopetition actions, driving innovation and enabling strategic reconfigurations through advanced capabilities and insights.

Figure 1 illustrates the systemic structure of coopetition networks, emphasizing the role of technology-enabled collaboration in service ecosystems. It is divided into two interrelated levels: Coordination Level (mezzo-level): (1) coopetitors establish nested and interlocking service ecosystems to enhance collaboration; and (2) ecosystems are shaped by institutional arrangements, such as governance structures, shared norms, and mutual expectations. Operational Level (micro-level): (1) actors integrate resources for mutual benefit, optimizing efficiency and value creation, and (2) technology plays a pivotal role in facilitating service exchange and strengthening interactions within the ecosystem.

At their core, coopetition networks leverage technology within service ecosystems to drive value co-creation, balancing cooperation.

This framework provides a comprehensive approach to understanding and developing coopetition networks within service ecosystems by identifying and integrating the Systemic Building Blocks. It underscores the crucial role of institutions in shaping actor interactions, facilitating resource integration, and governing service exchanges. Additionally, it highlights technology as both an enabler and catalyst for coopetition, reinforcing the dynamic and interconnected nature of modern service ecosystems.

This approach offers theoretical and practical insights into the structural and operational dynamics of coopetition networks, positioning them as key drivers of value co-creation, innovation, and sustainable growth within complex business ecosystems.

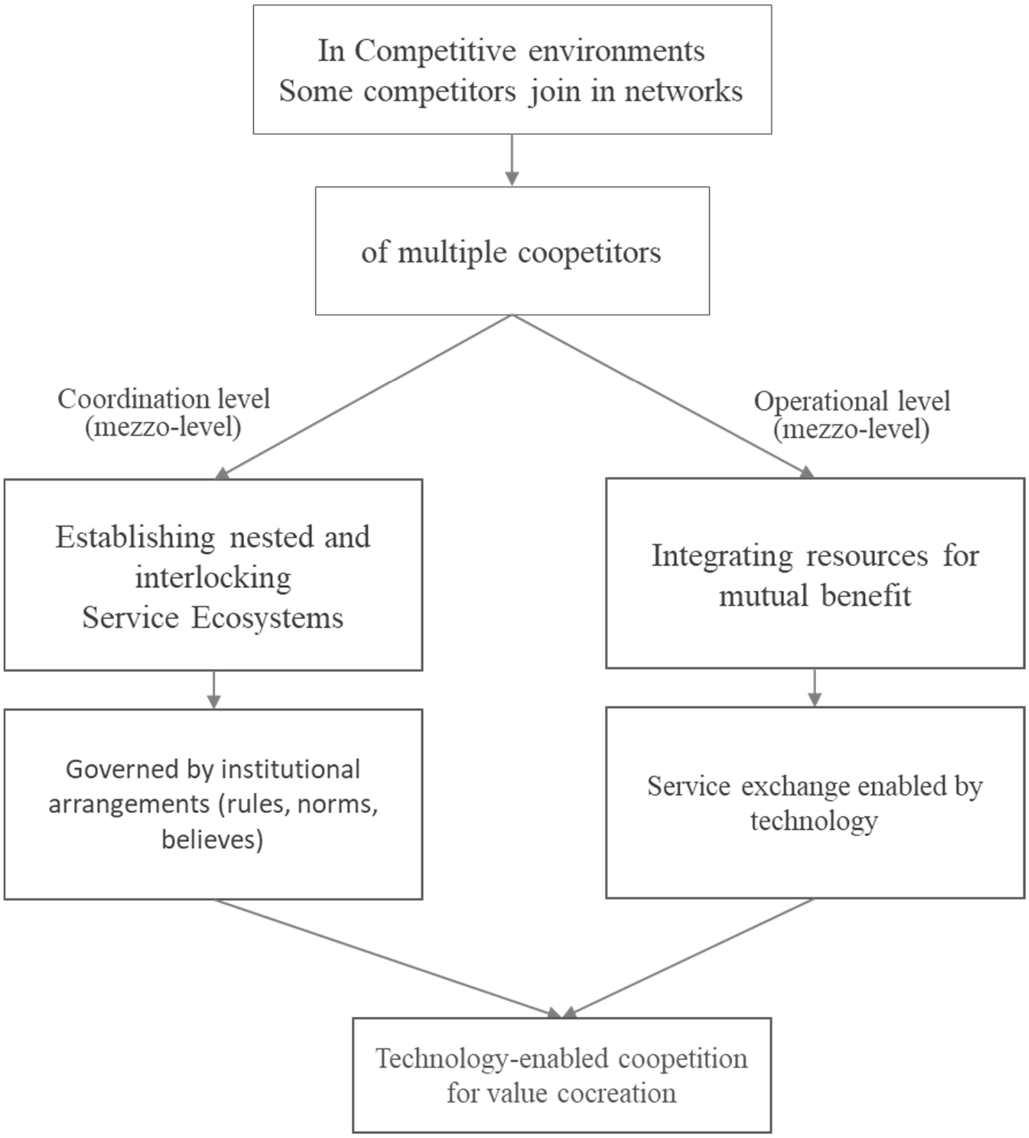

Figure 1. Systemic framework for technology-driven coopetition networks.

6. Implementing an Experimental, Technology-Driven Coopetition Network

This section details the application of the proposed framework to establish an experimental, technology-driven coopetition network within the Portuguese ornamental stone sector. The network integrates a select group of technologically advanced SMEs identified as key actors within the industry.

Institutional arrangements such as confidentiality agreements and standardized operational norms are implemented to facilitate effective collaboration. These governance mechanisms play a vital role in fostering trust, ensuring alignment of objectives, and maintaining consistency across participants. By establishing a foundation of mutual accountability, these measures support the integrity of the network while enabling efficient and seamless coordination among its members.

6.1. Experimental Design: Population and Sample

The Portuguese ornamental stone sector holds significant historical, cultural, and economic importance. Since the 15th century, Portuguese stone craftsmanship has contributed to iconic monuments worldwide [82]. Today, according to the Portuguese Stone Federation, the sector ranks ninth globally in the International Stone Trade and second in per capita international trade, exporting to 116 countries. Predominantly composed of SMEs, the sector has demonstrated strong economic performance, with exports surpassing imports by 660%. In 2021 alone, the sector generated a turnover of EUR 1.23 billion, supporting over 16,600 direct jobs, particularly in inland regions [22].

To identify companies eligible for this study, specific criteria were established to ensure participation by technological leaders representing best practices in the sector. Companies had to meet the following requirements: (1) export finished products to at least two continents, (2) digitally integrate production shop-floor machinery with their ERP systems and Building Information Modeling (BIM) systems used by architects, and (3) employ more than 20 workers.

A total of 23 companies were identified as meeting these criteria, and invitations to participate were extended to all of them. However, only six companies agreed to participate in the experimental coopetition network due to concerns about costs and potential operational disruptions.

Although developing a new IoT system was outside the scope of this research, Cockpit4.0—a state-of-the-art platform for the ornamental stone sector [83]—was evaluated as a tool to transform operational technology and facilitate the experimental, technology-driven coopetition network. Some enhancements were made to the platform to maximize its potential for fostering collaboration. These enhancements included new functionalities to enable secure connections between competitor firms. The resulting advanced IoT-based system was specifically designed to connect rival ornamental stone companies, enhancing technological capabilities and fostering a collaborative industrial environment conducive to a coopetition network.

Figure 2 below illustrates the implementation of the experimental, technology-driven coopetition network.

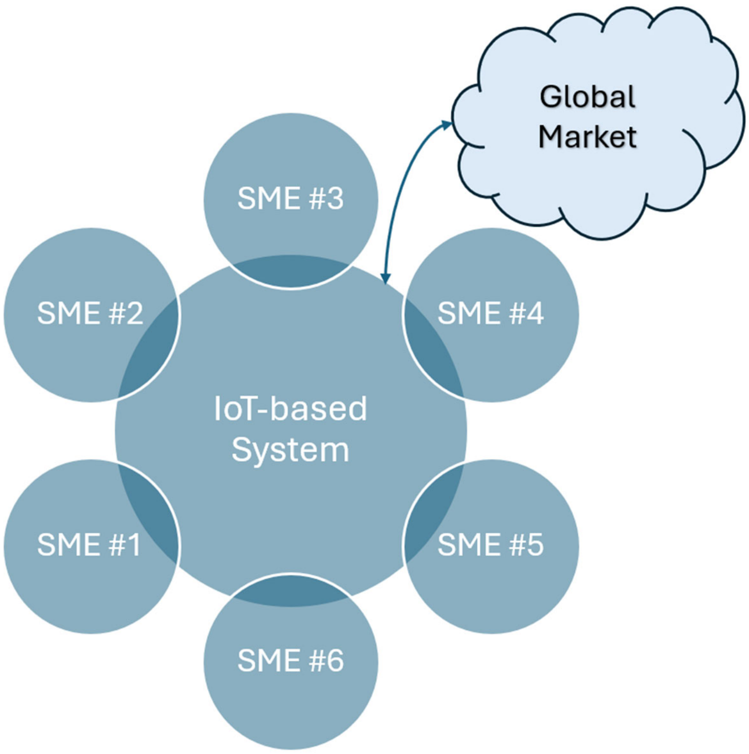

Figure 2. Implementation of the experimental technology-driven coopetition network.

The six SMEs were successfully integrated into the experimental coopetition network, facilitated by the IoT-based system. These firms demonstrated advanced technological capabilities, mainly by integrating their production machinery with BIM systems that architects use. This strategic integration enabled seamless information and resource sharing, allowing the firms to evaluate how technology-driven coopetition could enhance value co-creation collaboratively.

To address concerns about proprietary information, a comprehensive confidentiality agreement was established. This agreement safeguarded sensitive operational data, including customer details, employee information, resources, and competitive positioning. By ensuring the confidentiality of proprietary knowledge, all participating firms could collaborate effectively within the coopetition framework without compromising their competitive advantages.

6.2. Data Collection and Analysis

The data collection process was conducted over two consecutive 60-day periods to evaluate the impact of transitioning from conventional best practices (BP) to technology-driven coopetition network practices (CP). This structured approach enabled a comparative analysis of customer-perceived product quality (KPIQpP) under both operational models.

Phase 1: The first 60-day period, from April to June 2024, established a baseline customer feedback measurement under current best practices (BP) at the participating companies. During this phase, customers provided ratings based on their perceived product quality using a 1-5 Likert scale. This phase served as a reference point for assessing the subsequent effects of competition.

Phase 2: The second 60-day period was conducted from September to November 2024. During this phase, the six participating firms were integrated into the experimental technology-driven coopetition network, enabling real-time collaboration while maintaining competitive autonomy. Firms could exchange key operational data through the IoT-based system, enhancing efficiency, flexibility, and responsiveness in production and logistics. The IoT system provided real-time visibility into network-wide resource availability, allowing firms to optimize workflow and mitigate bottlenecks:

Shared Activities (Cooperation): (1) Raw Material Optimization—firms could access and share excess raw materials available in the network, reducing procurement delays and minimizing waste; (2) Production Capacity Coordination—companies could share machine availability, allowing them to outsource specific tasks within the network to meet deadlines and balance workloads; (3) Warehouse and Logistics Support—firms could utilize available warehouse space in partner facilities, improving inventory management and reducing storage inefficiencies.

Retained Competitive Activities: (1) Customer Ownership and Market Positioning—each company maintained exclusive relationships with its customers, ensuring brand differentiation and protecting market share; (2) Pricing and Sales Strategies—while firms collaborated operationally, pricing structures, sales tactics, and contract negotiations remained independent; and (3) Product Design and Customization—each firm retained complete control over the design, finishing, and customization of its products, maintaining its unique value proposition.

By leveraging this hybrid model of collaboration and competition, the coopetition network enabled firms to enhance operational efficiency while preserving strategic independence.

The customers provided feedback on the perceived product quality using the same Likert scale as in the baseline phase, allowing for a comparative analysis between the BP and CP models. The feedback was collected from customers interacting with the companies during the analyzed period. While some customers participated in both phases, others did not. Additionally, all responses were anonymous, preventing the direct pairing of individual customer assessments over time. Table 3 summarizes the everyday data collected, on average, from the customers during the Phase 1 and Phase 2 periods.

Table 3. Customer-perceived product quality (KPIQpP) under best practices (BP) and coopetition practices (CP).

Day	KPIQpP (BP)	KPIQpP (CP)	Day	KPIQpP (BP)	KPIQpP (CP)	Day	KPIQpP (BP)	KPIQpP (CP)	Day	KPIQpP (BP)	KPIQpP (CP)
1	2.0	3.3	16	2.5	3.2	31	3.2	3.6	46	3.5	2.5
2	2.5	3.5	17	3.3	3.3	32	2.5	3.9	47	3.5	3.5
3	3.0	2.7	18	4.3	3.8	33	3.6	3.3	48	3.0	2.8
4	3.4	3.1	19	3.0	4.0	34	3.0	3.2	49	2.3	3.0
5	2.3	3.3	20	3.3	3.3	35	3.1	3.5	50	3.3	3.5
6	2.5	3.5	21	4.0	3.5	36	3.3	3.3	51	3.5	3.8
7	3.8	3.5	22	2.5	3.8	37	4.0	3.5	52	3.0	3.5
8	3.5	2.8	23	2.8	3.9	38	2.0	3.5	53	3.2	3.0
9	1.8	3.2	24	2.5	2.5	39	3.0	3.6	54	2.7	3.5
10	2.5	3.3	25	3.0	2.3	40	3.2	4.0	55	2.4	4.0
11	3.5	3.6	26	3.3	3.3	41	3.5	3.5	56	2.5	3.8
12	3.3	3.0	27	2.3	4.3	42	3.3	3.5	57	3.2	3.5
13	2.5	2.5	28	3.0	3.0	43	3.0	3.6	58	2.9	3.8
14	1.8	3.5	29	3.8	3.3	44	3.3	3.4	59	2.8	3.5
15	3.3	3.7	30	3.0	4.0	45	4.5	4.5	60	2.6	3.8

Strict data privacy and confidentiality agreements were enforced throughout the study to safeguard sensitive business information. Customer feedback and company-specific data were anonymized and referred to by company labels. This ensured a secure, ethical, and transparent approach to data management, maintaining integrity in the analysis. Table 4 summarizes the customer feedback ratings, including the average KPIQpP values, standard deviation, and value co-creation gain (VCG) during both periods.

Table 4. Summary of customer feedback ratings and value co-creation gain (VCG) assessment.

Feedback Ratings	KPIQpP (Average)	Standard Deviation	Feedbacks Received
Best Practices KPIQpP(BP)	3.01	0.57	351
Coopetition Practices KPIQpP(CP)	3.41	0.43	393
Value Co-creation Gain (VCG)	13.4%	24.3%	-

Increase in Average Product Quality—the average KPIQpP improved from 3.01 (BP) to 3.41 (CP), representing a 13.4% increase in the perceived product quality.

Enhanced Consistency in Quality Ratings—the standard deviation decreased from 0.57 to 0.43, indicating a 24.3% reduction in variability, reflecting greater product quality consistency.

Higher Customer Engagement—the number of feedback responses increased from 351 (BP) to 393 (CP), suggesting increased customer engagement during the coopetition phase.

The comparative analysis between BP and CP demonstrates that integrating a technology-driven coopetition network enhances the perceived product quality and reduces variability. The 13.4% improvement in KPIQpP, coupled with a 24.3% gain in consistency, highlights the effectiveness of coopetition networks in value co-creation within the Portuguese ornamental stone sector.

These findings support the hypothesis that transitioning to a technology-driven coopetition network significantly improves the customer-perceived quality, consistency, and overall value co-creation outcomes.

6.3. Results and Discussion

The feedback collected during both phases came from customers interacting with the companies in the respective periods. While some customers may have participated in both phases, others may not have, and all the responses were anonymous, preventing the direct pairing of customer assessments over time. This introduces a potential limitation in comparing individual perceptions but does not diminish the results' overall observed trends and statistical significance.

The experiment's results support the hypothesis that transitioning to a technology-driven coopetition network enhances the customer-perceived product quality, facilitating value co-creation. Figure 3 illustrates the daily average customer feedback trend recorded during the CP phase.

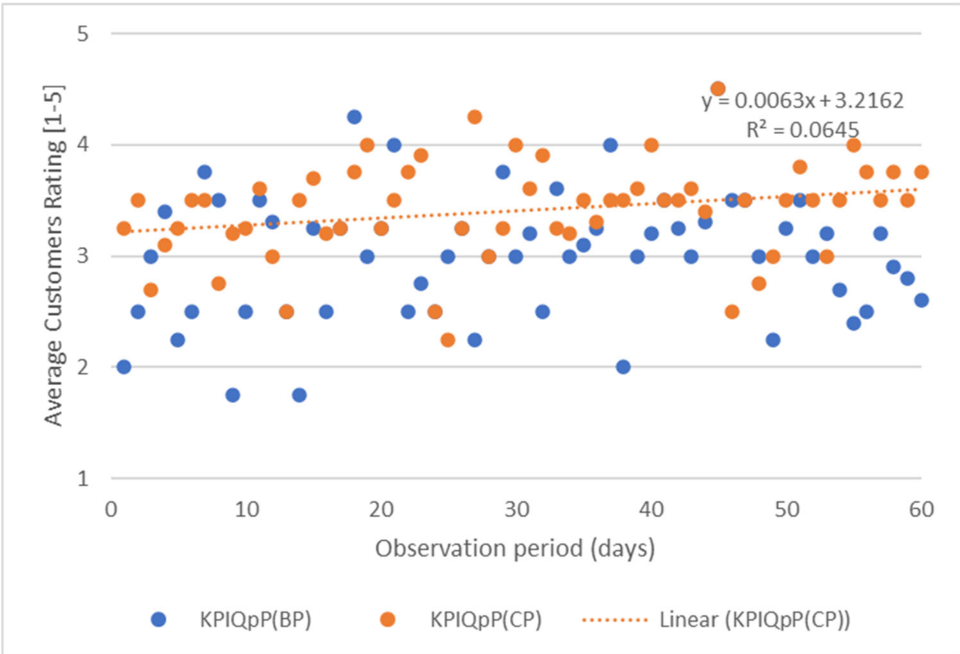

Figure 3. Daily average customer feedback evolution.

The positive slope of the trend line (0.0063) indicates a consistent upward trajectory in the perceived product quality under coopetition practices. While the immediate numerical increase in ratings may seem marginal, the sustained improvement trend suggests long-term operational and quality gains driven by technology-enabled coopetition.

An econometric analysis of the trend line further reveals an R^2 value of 0.0645, suggesting that while time contributes to KPIQpP improvements, other factors—such as resource sharing, technological integration, and enhanced operational coordination—also play a crucial role in driving performance gains.

The increase in customer responses during the CP phase suggests that the participating companies handled higher order volumes, likely indicating expanded production capacity. Importantly, this increase in production did not lead to a proportional rise in defects, underscoring the collective benefits of coopetition, such as optimized resource utilization, shared expertise, and improved operational efficiency.

A paired t-test was conducted to compare the mean KPIQpP ratings between BP and CP to validate the hypothesis statistically. The paired t-test results were as follows: (1) the mean KPIQpP increased from 3.0067 (BP) to 3.4092 (CP), reflecting a 13.4% improvement in the perceived product quality; (2) the calculated t-statistic (−4.5099) exceeded the critical value (2.0010) for a two-tailed test at a 95% confidence level, confirming statistical significance; and (3) the p-value (3.14×10^{-5}) was significantly lower than the 0.05 threshold, providing strong evidence to reject the null hypothesis of no difference in perceived quality.

These results provide robust statistical confirmation that the technology-driven coopetition model significantly improves the perceived product quality.

The findings highlight several important takeaways: (1) Improved Perceived Product Quality—the 13.4% increase in KPIQpP validates the hypothesis that coopetition enhances customer satisfaction through better resource allocation and process optimization; (2) Greater Consistency in Quality Outcomes—the variance reduction (from 0.3309 to 0.1894) suggests improved coordination and more predictable quality levels, enhancing customer trust and reliability; and (3) Sustained Quality Gains Over Time—the positive trend line slope reinforces the idea that coopetition networks support continuous improvements, rather than just short-term gains.

These results underscore the value of technology-driven coopetition as a strategic tool for fostering operational synergies, leveraging shared resources, and enhancing collective capabilities. By allowing firms to distribute tasks based on expertise and capacity, coopetition networks enable companies to meet or exceed customer expectations more effectively, resulting in higher perceived product quality and sustained value co-creation.

7. Conclusions, Limitations, and Future Research Directions

The findings affirm that coopetition networks, facilitated by technological integration, significantly improve the customer-perceived quality. Notably, KPIQpP increased by 13.4%, rising from an average score of 3.01 under BP to 3.41 under CP. This improvement was accompanied by a reduction in variability, with the standard deviation decreasing from 0.57 to 0.43, reflecting greater consistency in quality delivery.

These results underscore the potential of coopetition frameworks to enable firms to leverage shared resources, distribute tasks more effectively, and consistently meet customer expectations. Furthermore, the positive trend observed over the experimental period suggests the potential for long-term quality improvements when companies adopt IoT-enabled coopetition frameworks.

This study highlights that the proposed framework—rooted in the S-D Logic perspective—offers a robust foundation for value co-creation. By fostering seamless resource integration and enhancing operational efficiency, technology-driven collaboration networks empower firms to deliver higher-quality products and promote sustainable value co-creation processes.

However, the study also reveals several risks and limitations that must be addressed. A key challenge is that many firms declined to participate in the experiment due to concerns over confidentiality breaches and the potential misuse of proprietary information. These concerns highlight the need for robust institutional safeguards, such as binding confidentiality agreements, to build trust and enable secure collaboration within coopetition frameworks. Another limitation is collecting customer feedback, which, although collected anonymously to ensure ethical data practices, made it impossible to track specific changes in individual customer perceptions over time. Consequently, the study could not provide insights into how individual customer experiences evolved across the experimental phases.

The small sample size also constrained the scope of the experiment, as only six firms from the Portuguese ornamental stone sector participated. This limited sample restricts the generalizability of the findings to other industries and contexts. Additionally, data collection was conducted over two 60-day intervals, offering insights into the short-term effects of coopetition networks but leaving such frameworks' long-term dynamics and sustainability unexamined. Lastly, the study's focus on a single industry introduces another limitation, as the framework's applicability to sectors with varying technological capacities or operational challenges remains unexplored.

Building on the findings of this study, future research should address these limitations and further explore the potential of technology-driven coopetition networks. Expanding the scope and scale of the framework by testing it across multiple industries and regions with larger and more diverse sample sizes would help validate its generalizability and adaptability. Longitudinal studies would be particularly valuable in understanding the sustainability of coopetition networks and their long-term contributions to value co-creation. To address confidentiality concerns, future research could explore the development of more sophisticated data-sharing protocols and institutional safeguards, which would enhance trust and encourage broader participation. Integrating emerging technologies such as artificial intelligence (AI) and blockchain could improve resource transparency, operational integration, and customer-perceived quality.

Another important avenue for future research is to examine the influence of external factors, such as market conditions and resource variability, on the effectiveness of coopetition networks. This would provide a deeper understanding of how these frameworks adapt to dynamic environments. Future studies can refine and expand the proposed framework by addressing these areas, making it more robust and widely applicable. Ultimately, these efforts will unlock the full potential of technology-driven coopetition networks as a powerful mechanism for fostering value co-creation across diverse industries and market contexts.

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