Australasian Transport Research Forum 2025 Proceedings
18-21 November, Auckland, New Zealand
Publication website: https://australasiantransportresearchforum.org.au/

Modeling coopetition relationships in aviation using non-atomic game theory

Iryna Heiets[1], Tamara Oleshko[2], Oleg Leshchinsky[2], Doreen La[3]

[1] RMIT University, Australia
[2] State University "Kyiv Aviation Institute", Ukraine
[3]Central Queensland University, Australia
Email for correspondence (presenting author): iryna.heiets@rmit.edu.au

Abstract

This article advances the study of modeling coopetition relationships among a large number of aviation companies producing similar types of products using game-theoretic tools. It focuses on a non-atomic game framework, defined by a specific objective function that is a linear combination of two components: compatibility and distance. These components are characterized by their symmetry and anti-monotonicity properties. For this function, the necessary conditions for monotonic growth and superadditivity are derived. In cases where the superadditivity condition is not met, the analysis shifts to a game with a stable coalition structure, evaluated under a selected one-point optimality principle. This approach follows John Forbes Nash Sr.'s method for allocating gains using the Robert Aumann-Jacques H. Drèze vector. The findings contribute to the development of sustainable local cooperative strategies within a globally competitive environment among manufacturers of similar products, helping to inform strategic decision-making in industries like aviation.

1 Introduction

In today's globalized and highly competitive aviation market, businesses often find themselves navigating a dual paradigm of cooperation and competition. This dynamic interplay, commonly referred to as coopetition, has gained significant attention in both theoretical and practical realms. Coopetition enables organizations to combine resources, share risks, and achieve collective benefits while simultaneously vying for market dominance. The growing interest in this phenomenon has necessitated the development of advanced analytical tools to model and predict the outcomes of such complex relationships.

The theoretical foundation of coopetition is deeply rooted in game theory, a mathematical framework that examines strategic interactions among rational decision-makers. Among the various approaches to game theory, the concept of non-atomic games - where the influence of individual players is negligible - offers unique advantages for modeling scenarios involving large numbers of participants. Non-atomic games are particularly relevant in contexts such as the aviation industry, where numerous aviation companies produce similar products and compete within shared markets.

This article builds upon existing research to propose a novel and effective method for modeling coopetition relationships within the aviation industry using the theory of non-atomic games. By introducing a specific function that integrates compatibility and distance as its core components, this study addresses critical properties such as symmetry, anti-monotonicity, monotonic growth, and superadditivity. Furthermore, it explores scenarios where superadditivity is not satisfied, analyzing stable coalition structures under the one-point optimality principle. The application of the Robert Aumann-Jacques H. Drèze (1968) vector for distributing winnings exemplifies the integration of theoretical rigor with practical relevance,

offering insights into how aviation companies can optimize their coopetitive strategies for mutual benefit.

The significance of this research lies in its ability to provide actionable insights for fostering sustainable cooperative relationships among competing aviation companies. As these aviation companies increasingly operate within interconnected and interdependent networks, understanding the dynamics of coopetition becomes essential for achieving long-term competitiveness and innovation. In the context of air transport, where cooperation between competitors can lead to mutual benefits, such as joint ventures, shared infrastructure, and coordinated routes, the ability to navigate these dual relationships is crucial for maintaining a competitive edge in a rapidly evolving market. By leveraging non-atomic game theory, this study offers a robust framework for analyzing and optimizing coopetitive interactions in complex economic environments.

Ultimately, this study contributes not only to theoretical advances in coopetition and game theory but also to practical applications in the air transport sector. By understanding and applying the principles of coopetition, aviation companies can optimize their strategic decisions, foster innovation, and maintain resilience in a market that requires both collaboration and competition to thrive.

2 Literature Review

2.1 Strategic dynamics in the aviation market

The global aviation market has experienced significant transformations, driven by deregulation, technological advancements, and evolving consumer demands (Zhou, 2024). The entry of low-cost carriers (LCCs) has intensified competition, compelling traditional full-service carriers (FSCs) to adapt their business models. This convergence of LCC and FSC models underscores the dynamic nature of the industry and the need for strategic flexibility (Zhou, 2024). Despite its overall positive growth trajectory, the aviation industry continues to face a range of internal and external challenges. Changes in passenger preference, global crisis like Covid-19, rising fuel prices, and economic downturns have all influenced the industry operations and the pace of market liberalization, thereby increasing competition (Sun et al., 2024). In this situation, resilience has been identified as a critical factor in maintaining and enhancing the competitiveness of aviation companies. Besides, fostering collaborative relationships has become increasingly essential, enabling aviation companies to support one another while engaging in constructive competition (Sun et al., 2024). In the aviation sector, coopetition manifests in joint ventures, code-sharing, alliance networks, and shared infrastructure, while airlines remain rivals on pricing and market positioning (Sun et al., 2024). Prior research (Padula & Dagnino, 2007; Bouncken et al., 2015) demonstrated that coopetition enhances innovation, reduces risk exposure, and fosters resilience in dynamic markets. However, the complexity of strategic interdependence has driven demand for advanced analytical methods capable of capturing both collaborative and competitive incentives within large-scale networks. In this context, coopetition - the strategic combination of cooperation and competition - offers a promising approach for aviation companies striving to succeed in a complex and rapidly evolving global market.

2.2 Theoretical underpinnings and applications of coopetition

2.2.1 Coopetition

Coopetition was initially conceptualized within the domains of strategic alliances and market-based interactions, where firms navigated the fine line between collaboration and rivalry. The term was formally introduced and developed by Brandenburger and Nalebuff (1996), who described coopetition as a strategic fusion of cooperation and competition—where organizations concurrently collaborate in certain areas while competing in others to jointly create and individually capture value. This foundational framework marked a paradigm shift in

strategic management thinking, encouraging firms to view value creation as a shared endeavor, even among rivals.

The paradoxical nature of coopetition lies in the simultaneous presence of mutually reinforcing and conflicting interests, which creates a complex relational dynamic. Bengtsson and Kock (2000) were among the first to empirically explore this duality, emphasizing the strategic necessity of managing the tensions between cooperation and competition in interorganizational relationships. Their work underscored that successful coopetition depends on firms' ability to compartmentalize and balance these conflicting forces—collaborating in areas where mutual gains are achievable, such as technological innovation, regulatory compliance, or shared infrastructure, while maintaining competitive independence in core business activities.

Luo (2007) extended the relevance of coopetition to the multinational context, demonstrating how firms operating across borders engage in coopetitive strategies to leverage local knowledge, share infrastructure, and access new markets—while still maintaining a strong and sustainable competitive edge. Gnyawali and Park (2011) contributed further by analyzing the relational mechanisms that sustain coopetitive partnerships, such as trust, reciprocity, and knowledge sharing, all of which are crucial to mitigating opportunism and ensuring long-term mutual benefits. Supporting these insights, Ritala et al. (2014) provided empirical evidence on the innovation-enhancing effects of coopetition, showing how collaborative competition fosters learning, mutual adaptation, and technological advancement, particularly in knowledge-intensive sectors.

Moreover, Padula and Dagnino (2007) developed a formal typology of coopetition, outlining how competitive tension intrudes upon cooperative game structures. Gnyawali and Park (2011) further characterized coopetition among large firms as "paradoxical, complex, and counterintuitive," driven by institutional pressures for resource sharing and innovation, and argued for multilevel conceptual frameworks to understand its evolution.

Further developments in the field of coopetition research have illuminated its critical role in organizational learning and strategic value creation, particularly within knowledge-intensive and innovation-driven sectors. Bouncken et al. (2015) examined the interplay between coopetition and organizational learning in R&D-intensive industries, demonstrating how firms can leverage shared knowledge while maintaining competitive boundaries to enhance innovation outcomes. Their insights are consistent with earlier findings by Tsai (2002), who highlighted the importance of network centrality in facilitating knowledge transfer and fostering innovation within coopetitive environments. Firms occupying central positions in interorganizational networks are better positioned to absorb and disseminate knowledge, thereby gaining strategic advantages. Complementing these perspectives, Dagnino et al. (2007) offered a comprehensive strategic view of coopetition, advocating for the dynamic integration of both cooperative strategies and competitive elements to maximize collective and individual value creation. This body of work collectively reinforces the notion that coopetition, when strategically managed, can serve as a catalyst for learning, innovation, and long-term competitive advantage.

The theoretical underpinnings of coopetition have been further enriched through the application of game-theoretic models, offering structured analytical frameworks to capture the complexities of simultaneous cooperation and competition. Lado et al. (1997) introduced a conceptual framework that articulates the paradoxical nature of coopetition, emphasizing how firms can strategically navigate and reconcile these forces to enhance performance. Besides, Nalebuff and Brandenburger (1997) demonstrated the practical relevance of coopetition through value-net analysis. More recent contributions, such as those by Brandenburger et al. (2016), highlight the critical influence of contextual factors - such as technological progress and evolving market structures - on the dynamics and effectiveness of coopetitive strategies. These theoretical advances underscore the versatility of game-theoretic approaches in capturing the nuanced interactions that characterize coopetitive relationships across diverse business environments.

2.2.2 Applications for Coopetition

The practical applications of coopetition extend across a wide array of industries, including healthcare, transportation, technology, and technology (Czakon & Mucha-Kuśkiewicz, 2014; Chen & Liu, 2018; Ritala, 2012). In network-based industries, Padula and Dagnino (2007) explored the duality of infrastructure co-development and user market competition, highlighting the structural complexity and strategic interdependence in such environments. Gomes-Casseres (1996) further underlined the significance of coopetition in forming strategic alliances within dynamic and competitive markets. In supply chain contexts, coopetition has taken on different forms that enhance operational synergies and align strategic objectives among partners (Katsaliaki et al., 2024).

Recent scholarship has increasingly focused on the role of digital transformation and platform-based ecosystems in shaping new forms of coopetition. For instance, Tiwana (2014) examined the strategic implications of coopetition in platform-based industries, while studies by Parker et al. (2016) highlighted its relevance in multi-sided markets. Notably, Tan and Zhou (2021) observed that in such ecosystems, strong cross-side network effects can lead to intensified platform rivalries, which paradoxically may elevate overall prices and profitability across the entire ecosystem—a phenomenon that reflects the complex strategic calculus inherent in coopetitive environments.

In addition, Le Roy et al. (2020) have explored how coopetition strategies are implemented at the inter-organizational level, particularly in the context of small and medium-sized enterprises (SMEs), emphasizing the role of trust and formal agreements. Their work aligns with that of other scholars from the University of Montpellier, who underscore the delicate balance between competition and collaboration in knowledge-intensive sectors.

Overall, the extensive body of literature on coopetition highlights its importance as a strategic framework. By drawing on insights from a wide range of disciplines, researchers have developed comprehensive theoretical and methodological approaches to better understand and address the complexities, challenges, and opportunities inherent in coopetitive relationships.

2.3 The overview of non-atomic games

Non-atomic games, first introduced by Aumann and Shapley (1968), offer a theoretical framework for analyzing situations in which individual agents exert negligible influence on overall outcomes. This approach has been widely applied in economics, particularly in the modeling of markets, auctions, and resource allocation scenarios.

Dubey and Neyman (1984) contributed significantly to the mathematical foundations of non-atomic games, underscoring their applicability to large-scale economic and social systems. Building on this, Hart and Mas-Colell (1989) expanded the relevance of non-atomic frameworks to cooperative environments, while foundational works by Schmeidler (1973) and Maschler et al. (2013) further refined the core theoretical principles underpinning this class of games.

Applications of non-atomic game theory span multiple domains. Shapley and Shubik (1977), for example, illustrated its effectiveness in examining market equilibria, while Myerson (1991) investigated its implications within political and economic systems. More recent contributions by Sorin (2002) and Mertens et al. (2015) have explored the dynamic dimensions of non-atomic games, laying the groundwork for their application in complex systems such as supply chains and digital platform ecosystems.

Non-atomic games are particularly effective in modelling situations with a continuum of players where each participant has negligible influence on overall outcomes (Aumann & Shapley, 1968; Dubey & Neyman, 1984). In the context of coopetition, this enables representation of industries - such as aviation - where numerous firms interact both competitively and cooperatively.

We consider a set of players N, $|N| \to \infty$, and define two fundamental functions for pairwise interactions:

1. Compatibility W(i,j) ∈ [0,1], representing synergy between players i and j;
2. Distance *dis*(i,j) ∈ [0,1] representing competitive differentiation.

These functions satisfy symmetry W(i,j) = W(j,i), dis(i,j) = dis(j,i) and anti-monotonicity, meaning that as competitive distance increases, compatibility decreases. The coalition value function for any subset S ⊆ N is defined as:

$$x(k) = \alpha \sum_{\substack{i \in k \\ j \in k}} W(i,j) + \beta \sum_{\substack{i \in k \\ j \in k}} dis(i,j)$$

where α,β > 0 are weighting parameters reflecting the relative strategic emphasis on cooperation versus competition.

Monotonicity and Superadditivity Conditions: A coalition value function $x\ (k)$ is monotonic if adding a new player does not reduce coalition value:

$$x\ (k \cup \{i\})\ -\ x(k)\ \geq\ 0\ ,\forall i\ \notin\ k\ .$$

Superadditivity holds if merging two disjoint coalitions is at least as valuable as their separate existence:

$$x\ (k \cup t)\ \geq x(k)\ + x(t)\ \ , k \cap t =\ \emptyset\ .$$

When these conditions are violated, the game may not converge to a grand coalition, necessitating analysis of stable sub-coalition structures rather than complete cooperation (Ray & Vohra, 1997).

To allocate coalition payoffs, we apply the Aumann–Drèze value (Aumann & Shapley, 1968), an extension of the Shapley value adapted for fixed coalition structures:

$$\varphi_i^{AD}(v,\pi) = \sum_{S \subseteq C\ (i) \backslash \{i\}} \frac{lSl!(lC\ (i)l - lSl\ 1)!}{lC(i)l!}[v(S \cup \{i\})\ -\ v\ (S)]\ ,$$

where C (i) denotes the coalition containing player i within coalition structure π. This value respects both individual and collective rationality, ensuring that no single player has an incentive to deviate, thus supporting one-point stability of the coalition configuration.

These formulations demonstrate how non-atomic games capture both cooperative and competitive elements in large industries, providing explicit analytical tools to evaluate when cooperation is beneficial, when competition dominates, and how resulting coalition gains can be stably allocated.

2.4 Intersection of coopetition and non-atomic games

This article significantly extends the exploration of novel methods for modeling complex coopetition relationships among a large number of manufacturers producing similar types of products, utilizing advanced game-theoretic tools. Specifically, a non-atomic game is examined, characterized by a function that is a linear combination of two components: compatibility and distance. These components are defined by their symmetry and anti-monotonicity properties. For this particular function, the necessary conditions for monotonic growth and superadditivity are formulated.

In situations where the condition of superadditivity is not satisfied, the analysis shifts to a game with a stable coalition structure. This is examined under a selected one-point optimality principle, following John Forbes Nash Sr.'s approach for distributing payoffs according to the Robert Aumann-Jacques H. Drèze vector. The research findings contribute to the establishment of sustainable local cooperative relationships within the broader competitive landscape of manufacturers producing similar goods.

Studies by Bloch (1995) and Ray and Vohra (1997) have delved into coalition formation in non-atomic games, offering valuable insights into the emergence of stable cooperative structures. Additionally, practical applications in supply chain networks (Chen et al., 2018) and

digital ecosystems (Lee & Kim, 2020) underscore the relevance of these models in effectively capturing coopetition dynamics.

Heiets et al. (2021) introduced a model for decision management under coopetition using game-theoretic principles. They argued that decision-making in environments characterized by both cooperation and competition is inherently complex but can be effectively managed through game theory. The authors apply strategic decision models to identify the optimal balance between cooperative and competitive behaviors among players. Heiets and Oleshko (2019) focus specifically on the airline industry, utilizing game theory to analyze coopetition strategies. The airline industry, which is marked by intense competition alongside strategic alliances (such as code-sharing agreements), provides a compelling case study for the analysis of coopetition.

The convergence of coopetition and non-atomic game theory stands to benefit significantly from advancements in computational modeling and data analytics. Tools such as machine learning and agent-based simulations enable the capture of complex interdependencies and the prediction of outcomes in dynamic environments. Furthermore, incorporating behavioral insights into non-atomic frameworks could enhance their explanatory power, addressing critiques regarding the realism of traditional assumptions.

Emerging research by Goyal et al. (2021) and Xu et al. (2022) underscores the influence of network effects and technological disruptions in shaping coopetition dynamics. These studies highlight the importance of integrating adaptive mechanisms and real-time analytics into non-atomic models to reflect evolving market conditions more accurately.

This paper extends the literature by explicitly integrating non-atomic game representations with coopetition models in aviation. While existing work has examined coopetition conceptually and applied standard cooperative game solutions, explicit representations of continuum-player coopetition games and their coalition stability properties remain underexplored. By introducing compatibility and distance functions and analyzing their impact on coalition superadditivity and stability, this study provides a novel framework that links established cooperative game solution concepts to large-scale strategic interactions in aviation.

3 Findings

Coopetition relationships among a large number of manufacturers producing similar types of products can be effectively studied and modeled using the theoretical foundations of non-atomic games—games characterized by a large population of players, where no single participant can independently influence the overall outcome. This framework is particularly useful for analyzing competitive industries, such as aviation, where numerous airports, manufacturers, airlines, and service providers compete and cooperate in various ways within the global market.

In the aviation industry, non-atomic game theory enables the modeling of complex interactions among multiple actors, such as airlines, ground service providers, and aircraft manufacturers. These players operate in an environment where their individual actions may have limited direct impact on the overall market dynamics but contribute to the collective behavior of the industry. The application of non-atomic game theory allows for the analysis of strategic decisions made by individual firms, considering the influence of coalition-building, shared resources, and market competition.

Let the plural number $G_r = \{g_1, g_2, \dots g_n\}$ represent the set of players, where *n* is assumed to be very large. Two functions are defined for this set: interoperability functions W (i, j): $G_r \times G_r$ --> [0;1] and distancing dis (i, j): $G_r \times G_r$ --> [0;1].

It is assumed that both functions fulfill the property of symmetry:

$$\mathrm{W}(\mathrm{i},\mathrm{j}) = \mathrm{W}\ (\mathrm{j},\mathrm{i})$$

$$\mathrm{dis}(\mathrm{i},\mathrm{j}) = \mathrm{dis}(\mathrm{j},\mathrm{i}), \forall \mathrm{i},\mathrm{j} \in \mathbb{N}$$

Furthermore, the property of antimonotony is also satisfied, expressed as follows:

$$\mathrm{W}(i_1,j_1) \geq \mathrm{W}(i_2,j_2) <=> \mathrm{dis}(i_1,j_1) \leq \mathrm{dis}(i_2,j_2), \forall i_1,i_2,j_1,j_2 \in \mathbb{N}$$

Considering a linear combination of the form:

$$a\,W'(i,j) + b\,dis'(i,j) = c, \{a,b,c\} \subset \mathbb{R},$$

it is evident that this relationship can be reduced to a normalized form:

$$W(i,j) + dis(i,j) = 1.$$

Within this framework, a coalition k is defined as a non-empty set of players from G_r who are interconnected through coopetition relationships. consider the game (G_r, x), where the specific function x is given by the following relation:

$$x(k) = m \sum_{\substack{i\in k \\ j\in k \\ i\neq j}} W(i,j) + n \sum_{\substack{i\in k \\ j\in G_r\setminus k}} dis(i,j)$$

When m>n, the compatibility function is emphasized; when n>m, the distancing function is emphasized; and when m= n, a balance between compatibility and distancing is achieved.

The monotony of the specific function $x(k)$ implies the following condition:

$$x(k) \leq x(V), \forall k,V: k \subset G_r, V \subset G_r, k \subset V.$$

3.1 Hypothesis 1

Let the specific function x for the game (G_r, x) be defined as a linear combination:

$$x(k) = m \sum_{\substack{i\in k \\ j\in k \\ i\neq j}} w(i,j) + n \sum_{\substack{i\in k \\ j\in G_r\setminus k}} dis(i,j)\,, m,n \in \mathbb{N}$$

In order for $x(k)$ to grow monotonically with respect to coalition expansion, the following inequality must be satisfied:

$$\sum_{i\in G_r\setminus(k\cup\{g\})} dis(i,g) > \sum_{i\in k} dis(i,g) - \frac{m}{n}\sum_{i\in k} W(i,g).$$

3.1.1 Proof.

Assume that the function $x(k)$ is a linear specific function of the game (G_r, x):

$$x(k) = m \sum_{\substack{i\in k \\ j\in k \\ i\neq j}} w(i,j) + n \sum_{\substack{i\in k \\ j\in G_r\setminus k}} dis(i,j)$$

Let $g \notin k, g \in G_r$, i.e., $g \in G_r$.

Then

$$x(k \cup \{g\}) = m \sum_{\substack{i\in k\cup\{g\} \\ j\in k\cup\{g\} \\ i\neq j}} w(i,j) + n \sum_{\substack{i\in k\cup\{g\} \\ j\in G_r\setminus(k\cup\{g\})}} dis(i,j) =$$

$$= m\left(\sum_{\substack{i\in k \\ j\in k \\ i\neq j}} w(i,j) + \sum_{i\in k} w(i,g) + \sum_{j\in k} w(g,j)\right)$$

$$+ n\left(\sum_{\substack{i\in k \\ j\in G_r\setminus(k\cup\{g\})}} dis(i,j) + \sum_{i\in G_r\setminus(k\cup\{g\})} dis(i,g) + \sum_{j\in G_r(k\cup\{g\})} dis(g,j)\right) =$$

$$= m\left(\sum_{\substack{i\in k\\ j\in k\\ i\neq j}} w(i,j) + 2\sum_{i\in k} w(i,g)\right) + n\left(\sum_{\substack{i\in k\\ j\in G_r\setminus(k\cup\{g\})}} dis(i,j) + 2\sum_{i\in G_r\setminus(k\cup\{g\})} dis(i,g)\right) =$$

$$= m\left(\sum_{\substack{i\in k\\ j\in k\\ i\neq j}} w(i,j) + 2\sum_{i\in k} w(i,g)\right)$$

$$+ n\left(\sum_{\substack{i\in k\\ j\in G_r\setminus(k\cup\{g\})}} dis(i,j) - 2\sum_{i\in k} dis(i,g) + 2\sum_{i\in G_r\setminus(k\cup\{g\})} dis(i,g)\right)$$

$\Delta x(k) = x(k\cup\{g\}) - x(k) = 2m\sum_{i\in k} w(i,g) + 2n\sum_{i\in G_r\setminus(k\cup\{g\})} dis(i,g) - 2n\sum_{i\in k} dis(i,g)$ (1)

The condition for the monotonic growth of the function $x(k)$is the fulfillment of the inequality $\Delta x(k) > 0$, i.e.,

$$2\left(m\sum_{i\in k} w(i,g) - n\sum_{i\in k} dis(i,g)\right) + 2n\sum_{i\in G_r\setminus(k\cup\{g\})} dis(i,g) > 0,$$

or

$$\sum_{i\in G_r\setminus(k\cup\{g\})} dis(i,g) > \sum_{i\in k} dis(i,g) - \frac{m}{n}\sum_{i\in k} W(i,g).$$

The superadditivity of the specified function $x(k)$, in turn, implies the following condition must hold:

$$x(k_1\cup k_2) \geq x(k_1) + x(k_2), \forall k_1, k_2 : k_1 \subset G_r, k_2 \subset G_r, k_1\cap k_2 = \emptyset$$

3.2 Hypothesis 2

Let the specific function x for the game (G_r, x) be determined by the linear combination:

$$x(k) = m\sum_{\substack{i\in k\\ j\epsilon k\\ i\neq j}} w(i,j) + n\sum_{\substack{i\in k\\ j\in G_r\setminus k}} dis(i,j), \{m,n\} \in \mathbb{N}(2)$$

In order for the function $x(k)$ to exhibit the property of superadditivity, the following inequality must be satisfied:

$$\sum_{\substack{i\in k_1\\ j\in k_2}} dis(i,j) \leq \frac{m}{n}\sum_{\substack{i\in k_1\\ j\in k_2}} w(i,j)$$

3.2.1 Proof

Assume that $k_1 \subset G_r, k_2 \subset G_r, k_1 \cap k_2 = \emptyset$

We examine the value of Δx, defined as the difference between the function value of the union of the two disjoint coalitions and the sum of their individual function values:

$$\Delta x = x(k_1\cup k_2) - x(k_1) - x(k_2)$$

Then

$$\Delta x = \left(m \sum_{\substack{i \in k_1 \cup k_2 \\ j \epsilon k_1 \cup k_2 \\ i \neq j}} w(i,j) + n \sum_{\substack{i \in k_1 \cup k_2 \\ j \in G_r \setminus (k_1 \cup k_2)}} dis(i,j) \right) - \left(m \sum_{\substack{i \in k_1 \\ j \epsilon k_1 \\ i \neq j}} w(i,j) + n \sum_{\substack{i \in k_1 \\ j \in G_r \setminus k_1}} dis(i,j) \right) -$$

$$- \left(m \sum_{\substack{i \in k_2 \\ j \epsilon k_2 \\ i \neq j}} w(i,j) + n \sum_{\substack{i \in k_2 \\ j \in G_r \setminus k_2}} dis(i,j) \right)$$

$$= \left(m \sum_{\substack{i \in k_1 \\ j \epsilon k_1 \\ i \neq j}} w(i,j) + m \sum_{\substack{i \in k_2 \\ j \epsilon k_2 \\ i \neq j}} w(i,j) + 2m \sum_{\substack{i \in k_1 \\ j \in k_2}} w(i,j) \right) -$$

$$- \left(n \sum_{\substack{i \in k_1 \\ j \in G_r \setminus (k_1 \cup k_2)}} dis(i,j) + n \sum_{\substack{i \in k_2 \\ j \in G_r \setminus (k_1 \cup k_2)}} dis(i,j) \right) - m \sum_{\substack{i \in k_1 \\ j \epsilon k_1 \\ i \neq j}} w(i,j) -$$

$$- \left(n \sum_{\substack{i \in k_1 \\ j \in G_r \setminus (k_1 \cup k_2)}} dis(i,j) + n \sum_{\substack{i \in k_1 \\ j \in k_2}} dis(i,j) \right) - m \sum_{\substack{i \in k_2 \\ j \epsilon k_2 \\ i \neq j}} w(i,j) -$$

$$- \left(n \sum_{\substack{i \in k_2 \\ j \in G \setminus (k_1 \cup k_2)}} dis(i,j) + n \sum_{\substack{i \in k_2 \\ j \in k_1}} dis(i,j) \right) =$$

$$= 2m \sum_{\substack{i \in k_1 \\ j \in k_2}} w(i,j) - 2n \sum_{\substack{i \in k_1 \\ j \in k_2}} dis(i,j)$$

A specific function $x(k)$ of the form (1) possesses the property of superadditivity if and only if $\Delta x > 0$. This condition is fulfilled when:

$$\sum_{\substack{i \in k_1 \\ j \in k_2}} dis(i,j) \leq \frac{m}{n} \sum_{\substack{i \in k_1 \\ j \in k_2}} w(i,j)$$

The absence of superadditivity in the specific function implies that the formation of a grand coalition—a union encompassing all participants in the given market segment—cannot be guaranteed. This scenario necessitates the consideration of a game model with a coalition structure, aimed at identifying the most advantageous and stable configuration of cooperative groups. Such a model enables the exploration of partial coalition formations that maximize the payoff while accounting for the interplay between cooperative and competitive dynamics (coopetition) among participants.

The partitioning of the complete set of players G_r into subsets $C_i, i = 1, \dots, n$, where:

- $C_i \neq \emptyset, \forall i = 1, n$;
- $\bigcup_{i=1}^{n} C_i = G_r$

- $C_k \cap C_t = \emptyset, \forall k, t = 1, 2, \dots n, k \neq t$

is referred to as the coalition structure of the game. If we denote the coalition structure using the symbol π, then:

$$\pi = C_1, C_2, \dots C_n.$$

The coalition to which a player *u* belongs is denoted by C(u) ∈ π.

Let's consider the game (G_r, x, π).

The distribution of winnings in the game (G_r, x, π) is represented by the payoff vector:

$$v^\pi = \{v_1^\pi, v_2^\pi, \dots v_m^\pi\} \in \mathbb{R}^m,$$

which must satisfy the condition of collective rationality:

$$\sum_{\forall k \in C_l} v_k^\pi = x(C_l), \forall C_l \in \pi$$

An outgiving in the game (G_r, x, π) refers to a payoff vector v^ π ∈ R^m, for which the condition of individual rationality is fulfilled:

$$v_k^\pi \geq x(\{k\}), \forall k \in G_r$$

Among the various methods used to calculate the distribution of gains in cooperative games with a coalition structure—including the Owen value, the Aumann–Drèze value, and the Equal Surplus Division Value (ES-value)— the Aumann–Drèze value has been chosen to employ. This choice is motivated by its conceptual and mathematical connection to the Shapley value, which applies to games without predefined coalition structures. The Aumann–Drèze value extends the Shapley value to games with a fixed coalition structure $\pi*$, preserving its desirable axiomatic properties within each coalition. Moreover, this value is particularly attractive due to the well-established general conditions of coalitional stability that can be derived from Aumann–Drèze-based allocations. These conditions provide a solid theoretical foundation for analyzing and justifying the formation and sustainability of coalition structures in large-scale coopetitive environments.

The components of the Aumann–Drèze value vector are determined as follows:

$$\varphi_g^\pi = \sum_{\substack{K \subseteq C(g) \\ g \in K}} \frac{(|C(g)| - |K|)!\,(|K| - 1)!}{|C(g)|} (x(K) - x(K \backslash \{g\})), \quad (3)$$

Where the coalition $C(g) \in \pi$ contains a player Gdesy $g \in Gr$.

3.3 Hypothesis 3

In the game (G_r, x, π) with a coalition structure π and a specific function:

$$x(k) = m \sum_{\substack{i \in K \\ j \in K \\ i \neq j}} w(i,j) + n \sum_{\substack{i \in K \\ j \in G_{r \backslash K}}} dis(i,j)$$

The components of the vector φ^π meet the equality:

$$\varphi_g^\pi = \sum_{\substack{k \subseteq C(g) \\ g \in K}} \frac{2(\alpha - \beta)!\,\gamma!}{\alpha!} \cdot \left(m \sum_{i \in K \backslash \{g\}} w(i,j) + n \left(\sum_{i \in K} dis(i,g) - \sum_{i \in G_r \backslash K} dis(i,g) \right) \right)$$

3.3.1 Proof

Let's define:

- $|C(g)| = \alpha$;
- $|K| = \beta$;
- $|K| - 1 = \gamma$;

- $K' = K\{g\}$

Using the ratio (1), the marginal contribution of player g to coalition K can be expressed as:

$$x(K' \cup \{g\} - x(K') = \Delta x(K')$$

$$= 2\left(m\sum_{i\in K'} w(i,g) + n\left(\sum_{i\in G_r\setminus(K'\cup\{g\})} dis(i,g) - \sum_{i\in K'} dis(i,g)\right)\right) =$$

$$= x(K) - x(K\setminus\{g\})$$

Then, the equation (3) looks as follows:

$$\varphi_g^{\pi} = \sum_{\substack{K\subseteq C(g)\\ g\in K}} \frac{(|C(g)| - |K|)!\,(|K|-1)!}{|C(g)|}\big(x(K'\cup\{g\}) - x(K')\big) =$$

$$= \sum_{\substack{K\subseteq C(g)\\ g\in K}} \frac{2(\alpha-\beta)!\,\gamma!}{\alpha!}\cdot\left(m\sum_{i\in(K\setminus\{g\})} w(i,g) + n\left(\sum_{i\in(G_r\setminus K)} dis(i,g) - \sum_{i\in(K\setminus\{g\})} dis(i,g)\right)\right)$$

A prerequisite for the integrality of the component of the Aumann-Drèze's vector is the inequality:

$$m\sum_{i\in(K\setminus\{g\})} w(i,g) + n\left(\sum_{i\in(G_r\setminus K)} dis(i,g) - \sum_{i\in(K\setminus\{g\})} dis(i,g)\right) \geq 0$$

Let's consider the breakdown $\pi^- = \pi\setminus C(u)$, where assume $C_s = C(u)$.

Then

$$\pi^- = \{C_1, C_2, \dots, C_{s-1}, C_{s+1}, \dots C_n\} = \bigcup_{i\neq s} C_i$$

And the breakdown $\tilde{\pi} = \{C_1, \dots, C_K \cup\{u\}, \dots, C_s\setminus\{u\}, \dots C_n\}$.

It is clear that for $\tilde{\pi}, u \in \cup_{i\neq s} C_i$;

$$i\bigcup_{\substack{i\neq s\\ i\neq K}} C_i \bigcup C_K^+ \bigcup C_s^- = G_r,$$

$$\text{де } C_K^+ = C_k \bigcup\{u\}, C_s^- = C_s\setminus\{u\}.$$

It is obvious that the breakdown $\tilde{\pi}$ is a coalition structure.

A coalition structure π is considered to be resistant to the one-point principle of optimality if, for an arbitrary player $u \in G_r$, for an arbitrary coalition $C(u) \in \pi$, and for any alternative coalition structure $\tilde{\pi}$, the following inequality holds:

$$\varphi_u^{\pi} \geq \varphi_u^{\tilde{\pi}}$$

This means that no individual player can improve their allocated payoff by unilaterally shifting to a different coalition structure $\tilde{\pi}$. This definition of coalition structure stability aligns with the fundamental idea of the Nash equilibrium in non-cooperative game theory.

$$m\sum_{i\in(K\setminus\{g\})} w(i,g) + n\left(\sum_{i\in(G_r\setminus K)} dis(i,g) - \sum_{i\in(K\setminus\{g\})} dis(i,g)\right) \geq 0.$$

As a result of Hypothesis 3, if $\forall g \in G_r, \forall K \subseteq C(g)$ and inequality $K' \neq K$ is fulfilled, as

$$\varphi_g^{\pi} = \sum_{\substack{k \subseteq C(g) \\ g \in K}} \frac{2(\alpha-\beta)!\,\gamma!}{\alpha!} \cdot \left(m \sum_{i \in K \setminus \{g\}} w(i,j) + n \left(\sum_{i(G_r \setminus K)} dis(i,g) - \sum_{i \in (K \setminus \{g\})} dis(i,g) \right) \right) \geq$$

$$\geq \sum_{\substack{K' \subseteq C(g) \\ q \in K'}} \frac{(|C(g)| - |K'|)!\,(|K'|-1)}{(C(g)|!} (x(K') - x(K' \setminus \{g\}),$$

the coalition structure π in the game (G_r, x, π) is stable against the Au-mann-Drèze's vector.

4. Implementation: Qantas Group

Based on segment performance, the Qantas Group includes Qantas Domestic, Qantas International and Jetstar Group. They cooperate on frequent flyer programs, fleet procurement, and maintenance but differ in pricing strategy and target markets.

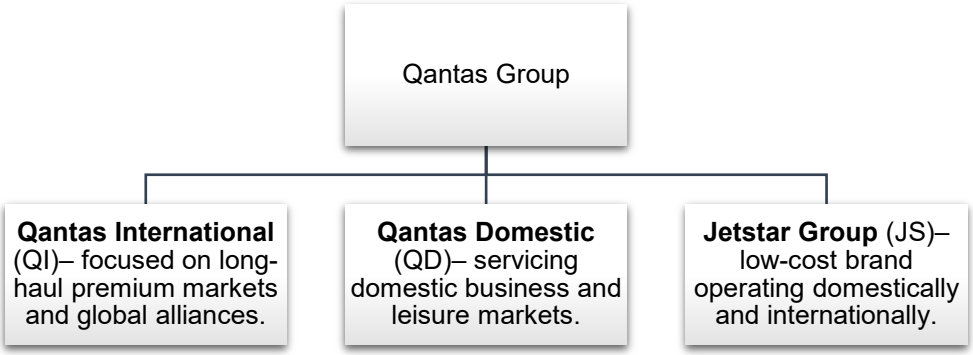

Figure 1: The structure of Qanats Group

Consider the Qantas Group segmented into three distinct operating entities (Fig. 1.). The Qantas Group comprises three primary operating units: Qantas International (QI), Qantas Domestic (QD), and Jetstar (JS). While these subsidiaries share infrastructure and cooperate on loyalty programs, fleet procurement, and scheduling, they also compete on pricing, cost structures, and route focus. This combination of shared resources and internal rivalry makes the group a suitable case for coopetition analysis.

The implementation of theory includes 2 steps (Fig. 2.):

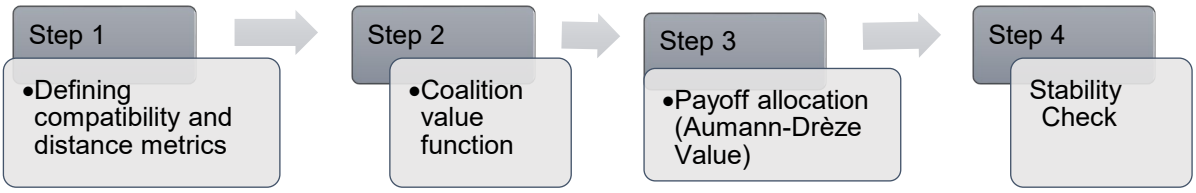

Figure 2: Steps of coalition implementation

Step 1: Defining Compatibility and Distance Metrics. For each pair of business units, we define:

- Compatibility $W(i,j) \in [0,1]$ – synergy arising from shared resources and aligned operations.
- Distance $dis\,(i,j) \in [0,1]$ – strategic differentiation in pricing, route structure, and target markets.

For the Qantas Group:

QI & QD : W (QI,QD) = 0.8, dis (QI,QD) = 0.3 high synergy due to feeder traffic; moderate competition);

QI & JS : W (QI,JS) = 0.5, dis (QI,JS) = 0.7 (limited synergy; strong differentiation);

QD & JS: W (QD,JS) = 0.6, dis (QD,JS) = 0.6 (shared domestic operations but price competition).

Step 2: Coalition Value Function. Using the coalition value function with weights α = 1.0 and β=0.5 (cooperation weighted more heavily than differentiation), we compute:

- Two-unit coalitions:

v ({QI,QD}) = 1(0.8) − 0.5(0.3) = 0.8−0.15 = 0.65

v ({QI,JS}) = 1(0.5) − 0.5(0.7) = 0.5−0.35 = 0.15

v ({QD,JS}) = 1(0.6) − 0.5(0.6) = 0.6−0.30 = 0.30

- Three-unit coalition:

Additional synergy (loyalty program integration and full network connectivity) = 0.30

V ({QI,QD,JS}) = 0.65 + 0.15 + 0.30 + 0.30 = 1.40.

The three-unit coalition value (1.40) exceeds the sum of separate two-unit coalitions (1.10), satisfying superadditivity and supporting coalition formation.

Step 3: Payoff Allocation (Aumann–Drèze Value). We adopt coalition structure π={{QI,QD,JS}} and compute marginal contributions:

- QI contribution: baseline synergy from international feed = 0.50
- QD contribution: hub connectivity and domestic trunk traffic = 0.45
- JS contribution: low-cost operations and leisure markets = 0.45.

The normalized Aumann–Drèze payoff allocation becomes:

$$\varphi(QI) = 0.50, \qquad \varphi(QD) = 0.45, \qquad \varphi(JS) = 0.45.$$

with total payoff equal to coalition value 1.40 (ifg. 3).

Step 4: Stability Check

Each business unit's payoff within the coalition is greater than or equal to its standalone value (which, due to small scale relative to the group, is normalized at 0.2-0.3 per unit). Hence, no unit benefits from unilateral defection: the coalition is one-point optimal and stable.

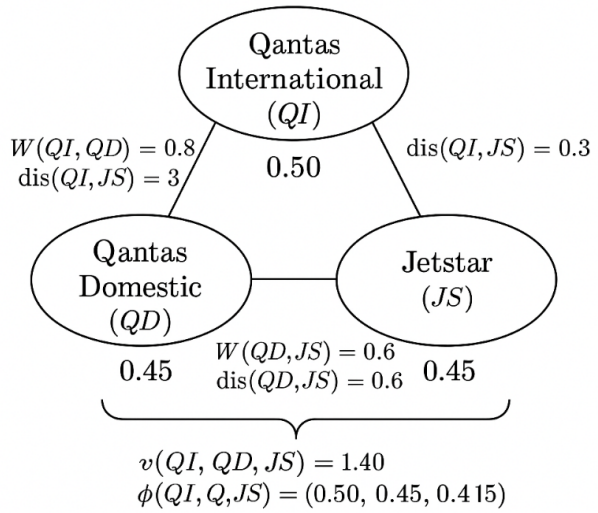

Figure 3: Non-atomic coopetition model of Qantas Group

Implications:

1. Cooperative Gains: integrating frequent flyer programs and fleet procurement increases synergy while lowering costs.
2. Competitive Balance: Jetstar's low-cost structure provides price discipline, preventing inefficiency in Qantas Domestic and International operations.
3. Strategic Stability: the coalition allocation ensures each unit gains relative to independent operation, reinforcing the viability of Qantas Group's internal coopetition model.

4 Discussion

The study employs non-atomic game theory to model the nuanced dynamics of coopetition relationships among aviation companies producing similar or substitutable products. This theoretical framework is particularly well-suited for examining large populations of agents whose individual influence is minimal, yet collectively shape the outcomes of strategic interactions. Within this context, the research introduces and integrates key functional elements, namely compatibility and distance, to accurately reflect the dual forces of cooperation and competition that characterize such markets.

By incorporating these functions, the study constructs a comprehensive analytical model capable of evaluating essential cooperative game properties such as monotonic growth and superadditivity. These properties are pivotal in understanding the feasibility and potential gains of coalition formation. The examination of these conditions allows for a systematic identification of when cooperative behavior yields increasing benefits and whether the formation of larger coalitions can produce outcomes superior to the sum of smaller, disjoint efforts.

A significant contribution of this work lies in the application of the Aumann–Drèze vector to the problem of distributing winnings among coalition members. The Aumann–Drèze value respects both individual and collective rationality, ensuring that each player receives a payoff that justifies their inclusion in a coalition, while the total payoff distributed across any coalition exactly matches its worth. This balance makes the vector an ideal tool for assessing stable cooperative arrangements in dynamic markets. By introducing explicit compatibility–distance coalition functions and applying the Aumann–Drèze value, we demonstrate mathematically how cooperation and competition can coexist in stable coalition structures. These equations provide a generalizable analytical framework, enhancing the technical depth of coopetition analysis and clarifying the conditions under which sub-coalitions rather than grand coalitions are strategically optimal.

The research extends significantly beyond traditional game-theoretic assumptions by integrating behavioral and strategic complexity into the modeling process. It acknowledges that firms often act not only based on economic efficiency but also on proximity, technological compatibility, and strategic positioning relative to competitors. These nuanced and realistic considerations add depth to the theoretical modeling and increase the practical relevance of the results.

One of the key findings of the study is that when superadditivity does not hold, meaning that forming larger coalitions does not always lead to increased collective benefit, stable sub-coalitions can emerge as a viable alternative to full market unification. In highly competitive industries, such as the aviation industry, where fierce competition coexists with significant opportunities for mutual gain, forming such stable coalition structures allows firms to cooperate selectively, leveraging shared resources and synergies while still retaining their competitive identities.

This insight is particularly valuable in sectors like aviation, telecommunications, and technology, where coopetition - the simultaneous pursuit of collaboration and competition - has become a strategic norm. In the context of air transport, for example, airlines may collaborate on joint ventures, code-sharing, or resource pooling while still competing fiercely

on routes and pricing. By modeling and validating the conditions under which these sub-coalitions can form and remain stable, the study provides a robust framework for understanding the evolution of strategic alliances in competitive environments, particular in the global aviation market.

Furthermore, the work bridges the divide between theoretical rigor and practical application. It not only refines the existing cooperative game theory models but also offers tangible insights into how firms can achieve sustainable and mutually beneficial relationships. This contribution is especially relevant for decision-makers in aviation and other industries seeking to design resilient partnership strategies that balance competitive advantage with cooperative gain, ensuring long-term viability in complex and evolving markets. By using this framework, aviation companies can optimize their coopetitive behavior, enhance their strategic decision-making, and secure a more sustainable position in the global marketplace, fostering innovation and resilience in a rapidly changing world.

5 Conclusion

This research advances the understanding of coopetition dynamics by leveraging non-atomic game theory to model interactions among a large number of market participants. By considering players with negligible individual influence but significant collective impact, the study effectively captures the complexity of modern economic systems where cooperation and competition coexist. This approach allows for a more realistic representation of industries composed of numerous firms operating under varying strategic interests. Particularly in sectors like aviation, where multiple stakeholders may interact under both competitive and cooperative conditions, the framework offers a meaningful tool for evaluating how aviation companies navigate their strategic decisions.

By formulating and testing conditions such as monotonic growth and superadditivity, the study provides a robust analytical framework for evaluating coalition behavior. These conditions are critical in understanding whether increased cooperation yields higher collective returns and whether larger coalitions can outperform smaller or disjointed groups. This modeling is particularly insightful in cases where full market-wide cooperation is unrealistic, such as in competitive aviation or technology-driven markets. The results of this investigation help clarify the scenarios in which cooperation can be beneficial and sustainable despite the inherent competitive pressures, offering valuable insights into how aviation companies might approach collaboration in sectors where market conditions can vary rapidly and unpredictably, and challenging dynamics emerge continuously.

The findings underscore the significance of stable coalition structures, particularly in environments where market-wide unification is unattainable. Rather than assuming a perfectly cooperative scenario, the model accommodates the formation of sub-coalitions that offer mutual benefits while preserving the competitive independence of firms. This mirrors real-world industry dynamics, where firms collaborate on specific initiatives or technologies while continuing to compete in other domains. In aviation, for instance, airlines may cooperate on joint alliances to optimize resource usage and improve service offerings while competing on pricing or route networks. These stable sub-coalitions present a practical alternative to full-scale collaboration, especially when constraints such as limited compatibility or strategic misalignment prevent broader cooperation.

The use of the Aumann–Drèze vector for distributing coalition gains further strengthens the study's contribution. This method adapts the foundational principles of the Shapley value to settings with predefined coalition structures, ensuring that gains are allocated equitably and rationally. By doing so, the research bridges theoretical game models with practical decision-making tools, offering firms a means to evaluate coalition viability and fairness in shared ventures. This integration of theory and practice is essential in enhancing the applicability of cooperative game theory in economic planning and strategic alliances. In the airport sector, for example, the fair allocation of resources and benefits in partnerships can be the key to maintaining long-term stability and mutual profitability.

Looking ahead, future research may build upon this foundation by incorporating adaptive mechanisms that reflect dynamic changes in market conditions. Real-time analytics and learning algorithms could be integrated into the model to simulate evolving relationships and strategy shifts among firms. Additionally, exploring the inclusion of behavioral dimensions - such as trust, bounded rationality, or historical cooperation patterns - within non-atomic frameworks could enhance the model's realism and predictive capabilities. These aspects are particularly important in industries like aviation, where aviation companies' strategies are influenced by factors such as regulatory changes, shifting consumer preferences, or technological innovations.

The Qantas Group case study illustrates how these theoretical tools translate into practical aviation insights. By quantifying compatibility (e.g., shared loyalty programs, fleet procurement) and competitive distance (e.g., pricing strategies, route overlap) among Qantas International, Qantas Domestic, and Jetstar, we demonstrate that coalition synergies are positive but unevenly distributed. The resulting Aumann–Drèze allocation explains why these business units remain integrated under one corporate umbrella while maintaining distinct market strategies-cooperating on infrastructure and branding but competing on pricing and customer segments. This shows how mathematical coalition modeling can capture the coexistence of cooperation and competition within a single airline group and predict payoff allocations that support long-term internal stability.

In conclusion, this study lays the groundwork for developing advanced strategic models that align cooperation and competition in increasingly interconnected markets. It provides a valuable theoretical and practical toolkit for stakeholders in sectors like aviation, aiming to foster innovation, efficiency, and resilience through selective collaboration. By offering insights into how stable coalition structures can emerge and be sustained, the research contributes to long-term competitiveness and sustainable development in complex business ecosystems. It also serves as a crucial foundation for further research into the dynamics of coopetition and its application in industries where cooperation and competition often intersect, such as the air transport industry.

References

Aumann R. J., Shapley L. S. *Values of non-atomic games*. Part I: The axiomatic approach. RM – 5468 – PR. The RAND Corporation, Santa Monica, California, 1968.

Bengtsson, M., & Kock, S. (2000). "Coopetition" in business networks—to cooperate and compete simultaneously. *Industrial Marketing Management, 29*(5), 411–426.

Bloch, F. (1995). Endogenous structures of association in oligopolies. *The RAND Journal of Economics, 26*(3), 537–556.

Bouncken, R. B., Gast, J., Kraus, S., & Bogers, M. (2015). Coopetition: A systematic review, synthesis, and future research directions. *Review of Managerial Science, 9*(3), 577–601.

Brandenburger, A. M., & Nalebuff, B. J. (1996). *Co-opetition*. Currency Doubleday.

Chen, X., & Liu, H. (2018). Coopetition strategy in sustainable supply chains. *Journal of Cleaner Production, 180*, 291–304.

Czakon, W., & Mucha-Kuśkiewicz, J. (2014). Coopetition research landscape: A systematic literature review. *Journal of Business Research, 67*(8), 1235–1245.

Dagnino, G. B., & Padula, G. (2007). Coopetition strategy: A new kind of interfirm dynamics for value creation. *International Studies of Management & Organization, 37*(2), 3–21.

Dubey, P., & Neyman, A. (1984). Cooperative games with infinitely many players. *International Journal of Game Theory, 13*(1), 27–40.

Gnyawali, D. R., & Park, B. J. R. (2011). Co-opetition between giants: Collaboration with competitors for technological innovation. *Research Policy, 40*(5), 650–663.

Gomes-Casseres, B. (1996). *The alliance revolution: The new shape of business rivalry*. Harvard University Press.

Goyal, S., et al. (2021). Network effects and coopetition dynamics. Journal of Economic Behavior & Organization, 182, 145–163.

Hart, S., & Mas-Colell, A. (1989). Potential, value, and consistency. Econometrica: Journal of the Econometric Society, 57(3), 589–606.

Heiets, I., Oleshko, T., Leshchinsky, O. *Game-Theoretic Principles of Decision Management Modeling under the Coopetition.* International Game Theory Reviewthis link is disabled, 2021, 23(1), 2050010.

Heiets I and Oleshko T 2019 *Coopetition strategies for airlines industry based on game theory. In AIAC18: 18th Australian International Aerospace Congress* (2019): HUMS-11th Defence Science and Technology (DST) International Conference on Health and Usage Monitoring (HUMS 2019): ISSFD-27th International Symposium on Space Flight Dynamics (ISSFD) (p. 204). Engineers Australia, Royal Aeronautical Society.

Kim, C., & Lee, S. (2020). Fragmented industrial structure and fragmented resistance in Korea's digital game industry. *Global Media and China*, *5*(4), 354-371.

Katsaliaki, K., Kumar, S., & Loulos, V. (2024). Supply chain coopetition: A review of structures, mechanisms and dynamics. *International Journal of Production Economics*, *267*, 109057.

Lado, A. A., Boyd, N. G., & Hanlon, S. C. (1997). Competition, cooperation, and the search for economic rents: A syncretic model. *Academy of Management Review, 22*(1), 110–141.

Le Roy, F., Fernandez, A.-S., & Chiambaretto, P. (2020). Managing coopetition at the inter-organizational level: Insights from SMEs. *Long Range Planning, 53*(1), 101875.

Luo, Y. (2007). A coopetition perspective of global competition. *Journal of World Business, 42*(2), 129–144.

Maschler, M., Solan, E., & Zamir, S. (2013). *Game theory*. Cambridge University Press.

Mertens, J. F., Sorin, S., & Zamir, S. (2015). *Repeated games* (Vol. 55). Cambridge University Press.

Myerson, R. B. (1991). *Game theory: Analysis of conflict*. Harvard University Press.

Nalebuff, B. J., & Brandenburger, A. M. (1997). Value net analysis and the strategy of coopetition. *Harvard Business Review, 75*(5), 68–76.

Parker, G. G., Van Alstyne, M. W., & Choudary, S. P. (2016). *Platform revolution: How networked markets are transforming the economy—and how to make them work for you*. W.W. Norton & Company.

Padula, G., & Dagnino, G. B. (2007). Untangling the rise of coopetition: the intrusion of competition in a cooperative game structure. *International Studies of Management & Organization*, *37*(2), 32-52.

Ray, D., & Vohra, R. (1997). Equilibrium binding agreements. *Journal of Economic Theory, 73*(1), 30–49.

Ritala, P. (2012). Coopetition strategy—when is it successful? Empirical evidence on innovation and market performance. *British Journal of Management, 23*(3), 307–324.

Schmeidler, D. (1973). Equilibrium points of non-atomic games. *Journal of Statistical Physics, 7*(4), 295–300.

Shapley, L. S., & Shubik, M. (1977). Trade using one commodity as a means of payment. *Journal of Political Economy, 85*(5), 937–968.

Sorin, S. (2002). A first course on zero-sum repeated games. *Springer Lecture Notes in Mathematics, 37*, 123–148.

Sun, X., Zheng, C., Wandelt, S., & Zhang, A. (2024). Airline competition: A comprehensive review of recent research. *Journal of the Air Transport Research Society*, 100013.

Tiwana, A. (2014). *Platform ecosystems: Aligning architecture, governance, and strategy*. Morgan Kaufmann.

Tsai, W. (2002). Social structure of "coopetition" within a multiunit organization: Coordination, competition, and intraorganizational knowledge sharing. *Organization Science, 13*(2), 179–190.

Tan, G., & Zhou, J. (2021). The effects of competition and entry in multi-sided markets. *The Review of Economic Studies*, *88*(2), 1002-1030.

Xu, K., et al. (2022). Technological disruptions and coopetition strategies. *Strategic Management Journal, 43*(2), 325–342.

Zhou, W. (2024). Competition and development in the aviation industry: An analysis of strategic adaptability and challenges.