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Review

A Review of Game Theory Applications for Seaport Cooperation and Competition

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Abstract: In the ever-changing maritime shipping industry, ports, and more specifically, container terminals, are always on the search for better policy and operational plan developments. As the maritime shipping sector changes, new areas of research emerge. In this paper, we present a review of recent game theory applications for seaport cooperation and competition, accompanied by summary review tables stating the study, the modeling technique used, the methodology and objective, and summary of the results of each study. In total, we have reviewed 33 studies that used game theory models that investigated seaport and container terminal competition and cooperation involving various stakeholders with dating publication years from 2008 to 2019. The paper concludes with a discussion and proposed future research directions. The purpose of the paper is to serve as a reference guide to recent game theory applications on seaport cooperation and competition that would allow a quick understanding of work done in the field.

Keywords: competition; cooperation; seaports; container terminals; game theory

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1. Introduction

Maritime transportation is a vital piece of global trade, with approximately 80% of commerce by volume, and 70% by value is transported by sea and processed at ports worldwide [1]. Liner shipping is the most cost-efficient (and in some instances, the only) way to transfer goods over long distances. Containerships, especially, have large capacities and can carry a large amount of goods worth several large warehouses in a single voyage [2]. In accordance with the data presented by the United Nations Conference on Trade and Development [1], the global seaborne trade came to 11 billion tons in 2018, where minor bulk experienced the fastest growth from 2017 with 3.7% increase in tonnage, followed by the containerized market with 2.6% rise in tonnage, and major bulk increased 1.9% in tonnage. In the past years, the shipping industry has encountered a number of problems including overcapacity, volatile freight rates, and rising debts. Under these economic conditions, shipping lines alone cannot provide the same service as before. By entering into alliances, shipping lines could share their resources, which would result in cost reductions and extended service coverage. As of June 2019, three major alliances (2M, Ocean Alliance, and THE Alliance) collectively accounted for 78% of the global container market [3]. Because of the shipping alliance size and the volumes they control, they have increased their negotiating power over ports and, thus, can pressure for more favorable conditions and improved services [4]. In addition to the creation of the giant shipping alliances, vessel size has continuously been increasing in most of the trade routes, with Drewry Maritime Research [5] estimating that 52% of the aggregated capacity of all containership deliveries by 2020 will belong to the class of ultra-large container vessels (i.e., capacity over 18,000 Twenty Foot Equivalent Unit or TEU). The introduction of mega vessels has helped liner shipping companies reduce operating costs by better allocating their resources (high-capacity utilization) and being more fuel-efficient (mainly because of vessel design, optimized engines, and slow steaming), thus reducing shipping costs; although, it has been difficult to capture the theoretical economies of scale that was (partially) the reason behind the trend of mega-vessels. Some research has also indicated cascading effects and diseconomies of scale when port times exceed a certain limit. A study by Guan et al. [6] concluded that a one percent increase in vessel size would increase the port time by 2.9%. Constrained by capacity expansion limitations (e.g., lack of land, high cost of expansion, etc.) while trying to accommodate the growing demand, marine container terminal operators and port authorities have brought attention to the importance of planning and operations optimization to increase productivity and profits. Game theory has given the ability to examine the effects of critical port management decisions such as investments [7–12] and pricing policies [10–23] under situations when service level differentiation [13–16,20,24,25], port ownership [17,21,22], and port regulations [20,26] are considered. Game theory further enables the analysis of various competition and cooperation dynamics between port authorities and terminals, amongst terminals within a port, and between ports and shipping lines. In this study, we seek to present a review of recent game theory applications for seaport and marine container terminal cooperation and competition and suggest possible future research directions.

The remainder of the paper is structured as follows. Section 2 presents a review of recent game theory approaches used to model seaport and container terminal cooperation/competition and co-opetition, where Section 2.1 discusses port and container terminal cooperation/competition and co-opetition, Section 2.2 discusses port and container terminal competition, Section 2.3 discusses government and container terminal competition, Section 2.4 discusses port and shipping line competition and cooperation, and Section 2.5 discusses other type of maritime transportation cooperation and competition. Section 3 provides a discussion of the researched literature and proposed research directions.

2. Game Theory Approaches

2.1. Port and Container Terminal Cooperation/Competition and Co-Opetition

In this Section 2.1, we review the literature on game theory approaches, factors, and conditions that affect seaports, marine container terminals, and the competition and cooperation dynamics between them. These studies are summarized in Table 1.

Factors and conditions affecting ports, which serve partially overlapping hinterlands, were investigated by Wang et al. [13] using a Cournot competition model and a joint profit maximization approach. The game theory model developed by the authors accounted for the institutional and political constraints (e.g., port ownership and management; types of contracting, leasing, and concessions; private profit vs. public welfare) often encountered by ports. Results by Wang et al. [13] suggest that alliance formation is highly dependent on the institutional and political factors such as mergers, cross-shareholding, and transfer payments and their authorization to conduct usual business practices. When institutional and political factors prohibit usual business practices, that would otherwise allow allocating the benefits of cooperation properly amongst the partners. Alliance between ports will be established only when there is a balance between increasing prices and switching some of the throughputs from high-cost ports to low-cost ones. Competition and cooperation between three leading transshipment ports situated in Malaysia (Port Klang or PKL, Port of Tanjung Pelepas or PTP) and Singapore (Port of Singapore or PSA) were investigated by Ignatius et al. [27], where the authors applied Cournot competition and collusion. Results suggested the creation of a strategic alliance between PSA and PTP, where both the current hub and spoke network would gain more profit, while PKL should not engage in any cooperative strategies with any of the other ports. Similarly, Wang and Sun [14] investigated competition and cooperation between ports in the port group based on geographical location. Additionally, the service level and shipping distance were investigated using the

Hotelling game model. When the service levels of port enterprises are the same, a cooperative strategy can significantly improve the level of the port group's cumulative profit. When the service levels of the port enterprises are different, the port's service price, market share, and profit are affected by the service level before and after the cooperation, the service level of the port enterprise shows a trend of mutual promotion, and the port group develops into a higher service level. The price strategy of ports serving partially overlapping hinterlands was investigated by Zhou [15], where the author used a modified Hotelling model and simulation to analyze the price strategy for three ports from competition and cooperation perspectives. Research results revealed that, when the service levels were the same, the critical factor for competitive ports was location, while service level was the critical factor for the creation of a port alliance. Four types of two-stage games between public/private port authorities were modeled by Ciu and Notteboom [16]. The authors examined the effects of public/private port authority-oriented objectives and how the level of service changed with differential capacity, service price, profits, and welfare when considering competing or cooperating ports. Results concluded that, under Cournot competition, the formation of an alliance could be successful only when the partial public port authority (PA) agrees to transfer certain profits to the private PA. Under all other types of competitions, the highly private-oriented PA will have the highest willingness to cooperate with the private PA, while under similar conditions, the highly public-oriented PA will have the lowest willingness to cooperate with the private PA.

Different combinations of coalitions between terminals at a single port were investigated by Saeed and Larsen [28]. The authors applied a two-stage Bertrand game between three container terminals situated in Karachi Port in Pakistan. Grand coalition was found to result in the best payoff, while the terminal at a second port that did not join the coalition earned a better payoff. When discriminatory fees were considered, the overall profit of terminals in Karachi was found to be lower, while users gained most when the nondiscriminatory percentage fees were considered. Competition and coalition between terminals at two ports were investigated by Park and Suh et al. [17], where the authors applied competition as a Bertrand game and cooperation as a terminal alliance on four container terminals located in North Port and two terminals in a new port of Busan, Republic of Korea. The goal of the investigation was to find the equilibrium price and profit between competitive container terminals. Terminal cooperation was also investigated by Pujats et al. [29], where the authors evaluated and compared four different cooperation policies, with terminals sharing available demand and capacity. The authors also proposed two model formulations, one based on volume and one based on vessels (where the demand shared is measured as the number of TEUs per vessel). Authors concluded that the commonly used volume-based sharing approach could significantly overestimate total profits while underestimating profits of terminals with higher volume-to-capacity ratios.

Table 1. Summary of Port and Container Terminal Cooperation/Competition and Co-opetition.

Study	Technique	Methodology	Objective	Results
Wang et al., 2012 [13]	Cournot competition/ Joint profit maximization	Ports with differentiated services decide to compete or form an alliance.	Investigate the elements that have an effect on alliance formation for ports in South China with partially overlapping hinterlands.	When institutional and political factors prohibit usual business practices, the alliance will be formed only when there is a balance between increasing prices and switching some of the throughputs from high-cost ports to low-cost ones.
Ignatius et al., 2018 [27]	Cournot competition Collusion	Transshipment ports in a proximate region decide to compete or cooperate.	Investigate whether an alliance between three leading transshipment ports situated in Malaysia (Port Klang, Port of Tanjung Pelepas) and Singapore (Port of Singapore) should be formed.	A strategic alliance between Port of Singapore and Port of Tanjung Pelepas would result in greater profit for both the current hub and spoke network. Port Klang should not engage in any cooperative strategies with any of the other ports.
Wang and Sun, 2017 [14]	Hotelling model	Port enterprises maximize their profit at the same service level or at a different service level.	Analyze the competition and cooperation among ports based on geographical location, service level, and shipping distance.	When the service levels are the same, a cooperative strategy can significantly improve the level of the port group's profit.
Zhou, 2015 [15]	Hotelling model Nash equilibrium	Ports decide on setting prices under cooperation and competition conditions.	Analyze the price strategy for competition and cooperation among ports serving partially overlapping hinterland.	When the service levels are the same, the critical factor for competitive ports is location, while service levels are the critical factor for port alliance formation.
Ciu and Notteboom, 2018 [16]	Cournot competition Bertrand competition Quantity–Price game Price–Quantity game	Two-stage game where: Port makes quantity or pricing decisions. Ports decide to cooperate or compete.	Investigate the effects of competition and cooperation on public/private Port Authorities (PA) objectives when the level of service changes with differential capacity, service price, profits, and welfare.	Under Cournot competition, an alliance will be formed only when the partial public PA will agree to transfer certain profits to the private PA. Under all other types of competitions, the highly private-oriented PA will have the highest willingness to cooperate with the private PA.
Saeed and Larsen, 2010 [28]	Bertrand competition Bertrand–Nash equilibrium	Two-stage game where: Terminals decide to compete or form a coalition. Terminals in coalition play cooperatively, otherwise non-cooperative Nash game	Analyze different combinations of coalitions among three container terminals situated in Karachi Port in Pakistan.	Grand coalition was found to result in the best payoff, while the terminal at a second port that did not join the coalition earned a better payoff. When discriminatory fees were considered, the overall profit of terminals in Karachi was found to be lower, while users gained most when the nondiscriminatory percentage fees were considered.
Park and Suh et al., 2015 [17]	Bertrand competition Maximize Total Joint Profit Nash equilibrium	Terminals make pricing decisions under cooperation or competition.	Find the equilibrium price and profit between four container terminals in Busan, the Republic of Korea, in a competitive and cooperative relation.	In a situation when one container terminal will increase price, all other terminals will keep the current price, when one terminal reduces the price, all other terminals will follow.
Pujats et al., 2018 [29]	Nash Bargaining Solution Maximize total profits Maximin profit cooperation Maximin profit increase cooperation	For the volume-based formulation, each terminal decides whether to cooperate by receiving or providing the demand. For the vessel-based formulation, each terminal decides on which vessels are served.	Evaluate and compare four different cooperation policies for sharing capacity and compare volume to vessel-based formulations.	The Nash Bargaining Solution and maximization of total profits policies outperform the maximization of minimum profit among all terminals, and maximization of minimum profit increases among all terminals when a combined uniformity of profit is shared among the cooperating terminals and size is considered.

2.2. Port and Container Terminal Competition

In this Section 2.2, we present a review of the literature on game theory approaches that model only seaport, marine container terminal competition. These studies are summarized in Table 2.

Effects of service level differentiation in inter- and intra-port competition, in which two ports compete for cargo transshipment, were examined by Van Reeven [30]. The game was constructed using the Hotelling and Cournot models. The results showed that the highest profits were achieved between vertically separated ports. Furthermore, the vertically separated Landlord Port competition resulted in a Nash equilibrium. A vertically integrated port organization system yields lower profits. Effects of transition from a multiuser terminal to a fully dedicated terminal on inter- and intra-port competition between the multiuser terminals were examined by Kaselimi et al. [18]. The authors used a two-stage game where, at the first level, a Cournot competition was used to model terminal competition, with terminal capacity as the decision variable, while at the second stage, a Hotelling model was used to determine the Nash equilibrium prices (port dues and terminal service fees). The authors concluded that the introduction of dedicated terminals resulted in less profit for the port authorities and also for the users of multiuser terminals, while multiuser terminals were unaffected by the introduction of dedicated terminals. Terminal concession awarding in inter- and the intra-port competition was studied by Yip et al. [31] using a two-stage model, where at the first stage, ports made terminal award decisions, and at the second stage, terminals engaged in Cournot competition. Model results suggested that terminal operators preferred to govern more terminals in the region. Port authorities with considerable market dominance prefer to introduce inter- and intra-port competition.

Instead of product differentiation, Zhuang et al. [24] investigated service differentiation for ports that managed containerized cargo and dry-bulk cargo, where two non-cooperative games (Stackelberg and Nash) were used to model competition between the ports. Results highlighted the importance of proper coordination, as ports may decide on the same infrastructure investments despite that the demand may not be sufficient. The government should intervene in the port specialization process, as it may lead to over-investment and excessive competition. Leading ports benefit from making first moves that result in greater profit and larger traffic volume.

Table 2. Summary of Port and Container Terminal Competition.

Study	Technique	Methodology	Objective	Results
Van Reeven, 2010 [30]	Hotelling model Cournot competition	Two-stage game where: Port authorities decide whether to integrate vertically or to separate vertically. All players simultaneously make their final choices.	Analyze the effects of service level differentiation in inter- and intraport competition, in which two ports compete for cargo transshipment.	The highest profits were achieved between vertically separated ports. Furthermore, the vertically separated Landlord Port competition results in a Nash equilibrium. A vertically integrated port organization system yields to lower profits.
Kaselimi et al., 2011 [18]	Cournot competition Hotelling model	Two-stage game whereTerminal operators compete for quantities by taking consideration of their capacity. Terminals compete in both prices and throughput.	Examine the effects of the transition from a multiuser terminal to a fully dedicated terminal on inter- and intraport competition between the multiuser terminals.	The introduction of dedicated terminals will result in less profit to the port authorities and also to the users of multiuser terminals, while multiuser terminals were unaffected by the introduction of dedicated terminals.
Yip et al., 2014 [31]	Cournot competition Nash equilibrium	Two-stage game where: Ports make terminal award decisions. Terminals set port charges competing in quantity.	Examine inter- and the intraport competition on terminal concession awarding.	Terminal operators prefer to govern more terminals in the region. Port authorities with considerable market dominance prefer to introduce inter- and intraport competition.
Zhuang et al., 2014 [24]	Stackelberg game Nash equilibrium	Two-stage game where: The leader port decides output volumes for both container and bulk cargo operations. The follower port decides output volumes in container and bulk cargo operations.	Investigate service differentiation for ports that manage containerized cargo and dry-bulk cargo.	Port infrastructure investments should be coordinated adequately with other port infrastructure investments and potential demand. Government intervention may be required, as it may lead to over-investment and excessive competition. Leading ports benefit from making first moves that result in greater profit and larger traffic volume.
Ishii et al., 2013 [9]	A two-person game model with stochastic demand Nash equilibrium	Ports make pricing decisions in the time of capacity investment.	Analyze strategic port pricing in a setting of interport competition and at the time when ports make capacity investment decisions.	When both the demand elasticity and port capacity development activities are high, prices should be set low. The actual decision on setting the price made by the government was made contrary to the theory.
Nguyen et al., 2015 [19]	Price leadership Nash equilibrium	Two-stage game where: Ports make pricing decisions to maximize profit. Identification of network links between ports in the network and strategic interaction.	Identify the effects of strategic pricing on ports in their networks in three Australian regions, namely Queensland, South Australia and Victoria, and Western Australia.	Not all ports set prices through strategic interaction between other ports; some set prices independent of each other. Moreover, the pricing strategy of competing ports may differ from each other.
Anderson et al., 2008 [7]	Bertrand competition	Each port makes an investment decision by increasing its capacity.	Examine port capacity investment decisions between ports of Busan, Korea, and Shanghai, China.	Investments should not be undertaken throughout East Asia. In addition, governments should be aware of any current or future competitor developments that may have a chance to gain a greater share of the market.
Do et al., 2015 [8]	A two-person game model with uncertain demand and payoff Nash equilibrium	Ports decide to invest under consideration that demand is uncertain, or payoff is uncertain.	Examine port capacity investment decisions between ports of Hong Kong and Shenzhen.	Shenzhen was found to be the dominant port in a long-term strategy. Hong Kong should make capacity investments only when Shenzhen does.
Luo et al., 2012 [10]	Bertrand competition Nash equilibrium	Two-stage game where: Ports make capacity investment decisions. Ports make pricing decisions.	Examine port capacity investment decisions between ports of Hong Kong and Shenzhen, when the market demand increases and differential service levels.	Both ports would expand with the increasing market demand, although the new port with a smaller capacity will be more likely to expand owing to the lower investment costs and higher price sensitivity.

Strategic interaction by setting prices between ports in their networks was empirically analyzed by Nguyen et al. [19]. By considering berth and channel dues, a two-stage game was applied to three Australian regions, namely Queensland, South Australia and Victoria, and Western Australia, where, at the first stage, ports estimated price response functions, and at the second stage, ports identified links in the port network and analyze strategic interactions. The authors concluded that not all ports set prices through strategic interaction between other ports; some set prices independent of each other. Moreover, the pricing strategy of competing ports may differ from each other. Port capacity investment decisions between the ports of Busan, South Korea, and Shanghai, China, were examined by Anderson et al. [7] using Bertrand competition. The authors suggested that investments should not be undertaken throughout East Asia. In addition, governments should be aware of any current or future competitor developments that may have a chance to gain a greater share of the market. Port capacity expansion was also examined by Do et al. [8], where the authors modeled competition between Hong Kong and Shenzhen Ports and investigated the decision-making process in capacity expansion investments using uncertain demand and payoff. Shenzhen was found to be the dominant port in a long-term strategy. Strategic port pricing at the time when ports make capacity investment decisions were examined by Ishii et al. [9]. The inter-port competition between two ports was modeled using the Cournot model. Results indicated setting lower prices when both the demand elasticity and port capacity development activities are high. The actual decision on setting the price of the government was made contrary to the theory. Port capacity investment decisions were also studied by Luo et al. [10], where the authors applied a two-stage game to study container port competition between the port of Hong Kong and Shenzhen, where, at the upper-level, ports decide on capacity investment, and at the lower level, they play the Bertrand game. The authors concluded that both ports would expand with the increasing market demand, although the new port with a smaller capacity will be more likely to expand owing to the lower investment costs and higher price sensitivity. In a market situation, when demand is increasing and the new port has higher competitive power, the pricing and capacity expansion, without any nonmarket protective measures, might not be sufficient to suppress the growth of the new port.

2.3. Government and Container Terminal Competition

This Section 2.3 of the paper discusses the reviewed literature on game theory approaches used to model government, port, and marine container terminal competition and cooperation. These studies are summarized in Table 3.

Port regulation modes were examined by Zheng and Negenborn [26], where the authors compared the centralization mode and the decentralization mode by modeling a Stackelberg game between the government, ports, and customers. Specifically, the authors investigated how port regulation mode affected optimal tariffs, port capacities, and port efficiency levels. Under the decentralization mode, the tariff, port efficiency level, port service demand, and social welfare were found to be higher. The effects of port regulation mode on port capacity and profit were inconclusive. Port regulation under centralized and decentralized modes was also studied by Yu et al. [20]. Competition between ports, where the government of ports makes cargo fee decisions and terminals make service quality and price decisions, was modeled using a two-stage Hotelling game. Results indicated government preference towards competitive terminals. Terminals with lower service quality will gain higher profit under a centralized mode compared to the competition instance.

Table 3. Summary of Government and Container Terminal Competition.

Study	Technique	Methodology	Objective	Results
Zheng and Negenborn, 2014 [26]	Stackelberg game	Three-stage game where: Governments make capacity decisions for both private and public terminals. Governments and the private terminal operator engage in a simultaneous duopoly game. Consumers decide between the public and private terminals.	Analyze the effects of port regulation modes on optimal tariffs, capacities, and port efficiency levels for both public and private terminals.	Under the decentralization mode, the tariff, port efficiency level, port service demand, and social welfare were found to be higher. The effects of port regulation mode on port capacity and profit were inconclusive.
Yu et al., 2016 [20]	Hotelling model Nash equilibrium	Two-stage game where: Port governments make cargo fee decisions. Terminal operators make service quality and service price decisions.	Analyze the effects of port regulation modes on competing ports, when the government of ports makes cargo fee decisions and terminals make service quality and price decisions.	Governments prefer terminals to compete under the decentralized model. Terminals with lower service quality will gain higher profit under a centralized mode compared to the competition instance.
Czerny et al., 2014 [21]	Hotelling model	Two-stage game where: Governments decide to privatize or not. Ports make pricing decisions.	Investigate the effects of port privatization on competition between two transshipment ports located in two different countries.	Both ports will be privatized in a setting when the transshipment market is significant. Private ports would set higher port charges, and reduction in operational costs will result in higher port charges.
Cui and Notteboom, 2017 [22]	Cournot competition Bertrand competition Nash equilibrium	Two-stage game where: Governments make decisions on emission control tax and whether to privatize the port. Ports make quantity/price decisions in competition or cooperation settings.	Analyze the effects of government-introduced emission tax charges on vessel and port operations in a setting of private and Landlord port competition and cooperation.	In the case of port cooperation, more rigorous environmental protection should be reinforced, compared to the port competition. In the case of port cooperation, revenue from the total emission taxes will always result in greater value than the overall damage to the environment.
De Borger et al., 2008 [11]	Cournot type competition Bertrand competition	Two-stage game where: Governments make decisions on port capacity, hinterland capacity, and road tolls. Ports make pricing decisions.	Investigate the effects of port pricing decisions on optimal investment policies and congestion toll decisions on the hinterland network capacities between competing ports with hinterland congestion.	The capacity investment would result in reduced prices and congestion at each port, but it will increase congestion at hinterland. Hinterland investment will likely result in increased prices and congestion at the port, which at the same time will lead to reduced prices and congestion at the competing port. The introduction of congestion tolls will increase both port and capacity investments.
Wan and Zhang, 2013 [32]	Cournot competition Cournot equilibrium	Two-stage game where: Governments make decisions on port capacity, hinterland capacity, and road tolls. Ports make pricing decisions while competing in quantity.	Investigate the effects of port pricing decisions on optimal investment policies and congestion toll (both fixed-ratio and discriminative) decisions on the hinterland network capacities between competing ports with hinterland congestion.	An increase in port hinterland road capacity or tolls may lead to increased ports profits, while at the same time, by tolling above the marginal external congestion costs, the competing port will lose profit. When the discriminative toll system is introduced, commuters will be tolled at the marginal cost, while trucks will be tolled even lower than that price.

Port ownership, and in particular port privatization, was investigated by Czerny et al. [21]. The authors used a two-stage Hotelling game to model competition between two transshipment ports located in two different countries. At the first stage, ports simultaneously decided whether to privatize or maximize social welfare, and at the second stage, ports made pricing decisions. Results suggest both ports will be privatized in a setting when the transshipment market is significant. Private ports would set higher port charges, and reduction in operational costs will result in higher port charges.

The effects of government-introduced emission tax charges on vessel and port operations were investigated by Cui and Notteboom [22], where a private port and Landlord ports either compete using Cournot or Bertrand game, or cooperate with differentiated services. The authors suggested more rigorous environmental protection reinforcements in the case of port cooperation than in port competition. In the case of port cooperation, revenue from the total emission taxes always resulted in greater value than the overall damage to the environment.

Pricing and investment decisions between competing ports with hinterland congestion were studied by De Borger et al. [11]. The authors investigated how port pricing decisions affected optimal investment policies, and how congestion toll decisions on the hinterland network affected hinterland capacities. Competition between ports was modeled as a two-stage game, where at the first stage, governments played a Cournot type of game by making port and hinterland investment decisions while considering the pricing behavior of ports. At the second stage, ports engaged in a Bertrand game by determining port prices while considering the potential congestion at the port and the hinterland transport network. The authors concluded that capacity investment would result in reduced prices and congestion at each port, but it would increase congestion in the hinterlands. Hinterland investment will likely result in increased prices and congestion at the port, which at the same time will lead to reduced prices and congestion at the competing port. The introduction of congestion tolls will increase both port and capacity investments. Hinterland congestion and seaport competition were further studied by Wan and Zhang [32]. Similarly to De Borger et al. [11], the authors examined pricing and investment decisions between competing ports with hinterland congestion using a two-stage game, where local governments make port and hinterland capacity investment decisions, and ports make congestion toll decisions on the hinterland network. Unlike De Borger et al. [11], Wan and Zhang [32] studied road tools in a more detailed manner by looking at both fixed-ratio and discriminative tolls. Also, instead of assuming price competition between ports, Wan and Zhang [32] used quantity competition. Results suggested that the increase in port hinterland road capacity or tolls may lead to increased ports profits, while at the same time, by tolling above the marginal external congestion costs, the competing port will lose profit. When the discriminative toll system is introduced, commuters will be tolled at the marginal cost, while trucks will be tolled even lower than that price.

2.4. Port and Shipping Line Competition and Cooperation

In this Section 2.4, we review applied game theory approaches on port and liner shipping competition and cooperation. These studies are summarized in Table 4.

Horizontal and vertical interaction between liners and ports were investigated by Song et al. [33] in a two-stage game using Bertrand competition and a Multinomial Logit model, where at the first stage, shipping lines made port-of-call decisions, and at the second stage, ports made port pricing decisions. The authors found that, when ports and liners were considered as identical players, the Nash Equilibrium resulted in the lowest possible service charge. When ports and liners were considered as different players, liners increased container volume and kept the service charge the same. Ports with constrained geography and limited capacity would benefit from cooperating with neighboring ports, which would allow redirecting excess demand.

Table 4. Summary of Port and Shipping Line Competition and Cooperation.

Study	Technique	Methodology	Objective	Results
Song et al., 2016 [33]	Bertrand competition Multinomial Logit model Nash equilibrium	Two-stage game where: Shipping lines make a port-of-call decisions. Ports make pricing decisions.	Examine horizontal and vertical interactions between liners and ports.	When ports and liners are considered as identical players, the Nash equilibrium results in the lowest possible service charge. When ports and liners are considered as different players, liners will increase container volume and keep the service charge the same. Ports with constrained geography and limited capacity would benefit from cooperating with neighboring ports, which would allow redirecting excess demand.
Bae et al., 2013 [23]	Bertrand competition and collusion Cournot competition	Two-stage game where: Ports make pricing decisions. Shipping lines make port-of-call decisions.	Analyze container port competition and collusion for transshipment cargo in the presence of shipping lines.	The higher-level transshipment ports that have sufficient capacity to handle excess traffic are more attractive to shipping lines. Ports with excess capacity can attract more demand by lowering prices, while the unused capacity can dissipate the congestion effect. The port collusion model will lead to a higher port price compared to the non-cooperative model.
Pujats et al., 2019 [34]	Stackelberg game Nash equilibrium	Two-stage game where: Shipping lines in an alliance make shipping size decisions Container terminals decide to cooperate or compete by utilizing their capacities.	Develop a mathematical framework for container terminal and liner shipping company cooperation and competition using the Stackelberg model.	The developed game theory-based model not only could assist marine container terminal operators and port authorities in identifying optimal contractual agreements, but it also could help identify optimal operational plans that support the implementation of such contractual agreements.
Asgari et al., 2013 [35]	Stackelberg gameNash equilibrium	Two-stage game where:Shipping companies make route network design decisions.Hub ports make total handling cost decisions.	Develop route network design in a setting of port and shipping company cooperation and competition.	Short term is the easiest way to control pricing; also, change in handling charges gives control over capacity and competitive power. In the medium term, cooperation with the dominant shipping line may partially secure market share. In the long run, cooperation between ports is beneficial as port capacity may be constrained by geography and neighboring ports.
Tulja-Suban, 2017 [36]	Stackelberg game Nash equilibrium	Two-stage game where: Shipping operators make port-of-call decisions. Spoke ports make handling charge decisions under one of the cooperation/competition scenarios.	Examine competition and cooperation between a hub and spoke ports in a shipping network.	There is no optimal strategy between the ship companies and spoke ports, port competition could lead to a reduction in the activities of the weaker port, and port cooperation between spoke ports could raise incomes and improve container transshipment services.
Angeloudis et al., 2016 [37]	Bertrand competition Nash equilibrium	Three-stage game where: Shipping lines or alliances make fleet investment decisions. Shipping lines or alliances make service design decisions, and the route assignment problem is solved. Shipping lines or alliances make freight rate decisions on each leg.	Determine the optimum set of liner services modeled as a monopoly or duopoly.	When a duopoly was considered, shipping lines or alliances selected different service networks, thus reducing the competitive pressure.

Container port competition and collusion for transshipment cargo in the presence of shipping lines were investigated by Bae et al. [23] using a two-stage game, where, at the first stage, ports engaged in Bertrand competition or collusion by making pricing decisions while at the second stage, by observing port capacities, prices, and transshipment levels, shipping lines engaged in Cournot competition and made port-of-call decisions. The authors concluded that higher-level transshipment ports that have sufficient capacity to handle excess traffic are more attractive to shipping lines. Ports with excess capacity can attract more demand by lowering prices, while the unused capacity can dissipate the congestion effect. In a setting when both ports are congested, which results in increased shipping lines costs, the high-level transshipment port decreases the price to maintain its demand. The port collusion model will lead to a higher port price compared to the non-cooperative model. Container terminal and liner shipping company cooperation and competition using the Stackelberg model were modeled by Pujats et al. [34]. The developed model considered competition between shipping lines and marine container terminal operators (MCTOs). The former players are part of an alliance, while the latter players engage in a capacity-sharing, cooperative agreement. At the upper level, the shipping lines act as the leader minimizing the shipping costs and terminal fees, while at the lower level, the container terminals, as the followers in the game, decide to compete or engage in cooperation with the objective to maximize individual profits.

Route network design in a setting of port and shipping company cooperation and competition was examined by Asgari et al. [35]. A two-stage game was modeled, where, at the first stage, shipping companies made route network design decisions by playing the Stackelberg game, and at the second stage, ports made total handling cost decisions by playing the Nash game. Three types of strategies were considered: perfect hub competition, perfect hub cooperation, and cooperation between the shipping companies and the hub ports. Results indicated that the short term was the easiest way to control pricing; also, changing handling charges gave control over capacity and competitive power. In the medium term, cooperation with the dominant shipping line may partially secure market share. In the long run, cooperation between ports is beneficial as port capacity may be constrained by geography and neighboring ports. Competition and cooperation between a hub and spoke ports in a shipping network were examined by Tuljak-Suban [36], where the author investigated the relationship between port container terminal incomes and the shipping operator incurred costs in the North Adriatic hub and spoke system, where shipowners were modeled as leaders. The author used a two-stage Stackelberg game, where, at the first stage, the shipping companies acted as leaders and solved the Vehicle Routing Problem with Pickup and Delivery by taking into account the navigation and handling costs to make port-of-call decisions, and at the second stage, the spoke ports decided on handling charges under port cooperation, competition, or cooperation between spoke ports and shipping companies. Results showed that there was no optimal strategy between the ship companies and spoke ports, port competition could lead to a reduction in the activities of the weaker port, and port cooperation between spoke ports could raise incomes and improve container transshipment services. The optimum set of liner services modeled as monopoly or duopoly was analyzed by Angeloudis et al. [37] using a three-stage game, where at the first stage, shipping lines or alliances made fleet investment decisions; at the second stage, shipping lines or alliances made service design decisions, and the route assignment problem was solved; and at the final stage, shipping lines or alliances made freight rate decisions on each leg. The authors showed that when a duopoly was considered, shipping lines or alliances selected different service networks, thus reducing the competitive pressure.

2.5. Other Type of Maritime Transportation Cooperation and Competition

In this Section 2.5, we discuss the reviewed literature on other types of maritime transportation cooperation and competition that utilizes game theory approaches. These studies are summarized in Table 5.

Table 5. Summary of Other Types of Maritime Transportation Cooperation and Competition.

Study	Technique	Methodology	Objective	Results
Basso et al., 2013 [12]	Hotelling model	Three-stage game where: Governments make packability investment decisions. Ports make pricing decisions. Shippers make decisions on whether to accept the port of call and demand the product.	Investigated government strategic investment decisions on inland transportation infrastructure in the port catchment area and common hinterlands with competing ports	Increased investment in the hinterland would decrease charges at both ports, but the increased investment in a port catchment area will significantly decrease its charges compared to the rival port.
Matsushima and Takauchi, 2014 [38]	Bertrand competition Cournot competition	Three-stage game where: Governments make decisions on whether to privatize or not. Ports make port usage fee decisions. Firms in both countries make quantity decisions.	Examine the effects of port privatizations on port usage fees, firm profits, and welfare in a setting of port and manufacturing firm competition located in two countries: home and foreign.	Under low (per unit) transportation costs either both or none of the ports are privatized, under moderate transportation costs both ports are privatized, and under high transportation costs none of the ports are privatized.
Lee et al., 2012 [25]	A game model with Oligopolistic players Nash equilibrium	Three-stage game where: Ocean carriers make service charges and delivery route decisions. Terminal operators make port throughput and service cost decisions. Land carriers make service demand and land transportation cost decisions.	Investigate pricing and routing decisions between ocean carriers, land carriers, and terminal operators in a maritime freight transportation network.	Provided a tool to evaluate ocean carrier, terminal operator, and land carrier decision-making processes in the freight shipping market.

Pricing and routing decisions between ocean carriers, land carriers, and terminal operators in a maritime freight transportation network were investigated by Lee et al. [25]. The authors used a non-cooperative hierarchical game model, where at the first stage, carriers determined service charges and delivery routes; at the second stage, terminal operators decided on port throughput and service cost; and at the final stage, land carriers decided on service demand and land transportation costs.

The effects of port privatizations on port usage fees, firm profits, and welfare in a setting of port and manufacturing firm competition located in two countries, home and foreign, were investigated by Matsushima and Takauchi [38]. The authors used a three-stage game, where at the first stage, governments made a decision on whether to privatize ports; at the second stage, ports made port usage fee decisions; and at the final stage, firms in both countries determined quantities. Results indicated that under low (per unit) transportation costs either both or none of the ports will be privatized, under moderate transportation costs both ports will be privatized, and under high transportation costs, none of the ports will be privatized.

Government strategic investment decisions on inland transportation infrastructure in the port catchment area and common hinterland with competing ports were investigated by Basso et al. [12]. The authors used a three-stage Hotelling model, where at the first stage, governments made packability investment decisions; at the second stage, ports made pricing decisions; and at the final stage, shippers made decisions on port of call and demand for the product. Results indicated that increased investment in the hinterland would decrease charges at both ports, but increased investment in a port catchment area would significantly decrease its charges compared to the rival port.

3. Discussion

In this study, we have reviewed 33 studies that used game theory models for investigating seaport and container terminal competition and cooperation involving various stakeholders with dating publication years from 2008 to 2019. Almost half of the studies included some variation of cooperation strategy with ports and container terminals. Among all game theory approaches used in the studies, the most applied was found to be the Bertrand type of game, which accounted for 37% of all instances, followed by Cournot (29%), Hotelling (20%), Stackelberg (12%), and Nash Bargaining (2%). Almost half of all games were modeled in two stages, followed by one-stage games that accounted for one-third of all models, and the rest were three-stage games.

In the reviewed literature, the main topics of interest when considering port and terminal cooperation, competition, or both, were service level differentiation in combination with and without shipping distances; port ownership with and without level of service differentiation; pricing policies, capacity utilization, and comparison of various cooperation policies and effects of service level differentiation in inter- and intra-port competition, when considering transshipment cargo; competition between multiuser terminals; terminal concession awarding; and port capacity investments when ports set prices under various types of demand. Reviewed studies also considered seaport and container terminal competition, cooperation, or both, including government, and some of the topics discussed were port regulation under different scenarios; port ownership; emission control strategies; and pricing and investment decisions between ports with hinterland congestion under various scenarios. Also, the reviewed literature included liner shipping companies and port cooperation and competition, where studies focused on horizontal and vertical interactions between liners and ports, hub ports, and hub–spoke ports including game theory network design models.

The growing demand, mega alliances, and increased vessel sizes are some of the main contributing factors that have shifted the balance of negotiation power between shipping lines and container ports. The resulting implications have created an increasingly competitive environment between ports, where container ports compete by increasing their service levels in favor of liner shipping companies. A number of reviewed studies used service level differentiation between ports to model port competition and cooperation. Common factors used to model port competition and cooperation with service level differentiation include service quality, service type, geographic location, capacity, price, profits, and welfare. Zhou [15] suggested future research could include a comparison of competition with cooperation strategies of ports serving partially overlapping hinterlands in a situation when ports compete in price and geographic location. Incorporation of more practical problems in the models that would increase the applicability of model at different settings to help robustness was suggested by Ciu and Notteboom [16].

In order to meet the growing demand, while at the same time trying to comply with shipping line demands, container ports have experienced pressure to improve productivity and invest in more capacity and new facilities. This limited capacity has motivated numerous authors to study strategic port and hinterland capacity investment decisions; a well-researched direction. Luo et al. [10] suggested that there is an opportunity to investigate optimal pricing strategies when port capacity investments are made in a setting where competition between terminals serving the hinterland and terminals that are managed by the same port operator have different operating costs. Also, analysis of the impact of port capacity investment decisions on both the shipping operations and port development policy could be explored. Investigation of various coalition formations between local governments when strategic investment decisions on inland transportation are made in a setting of port competition was identified by Basso et al. [12] as another potential future research area.

While the increase of capacity is needed, the investment costs are high and have become a financial challenge for container port authority operators. Privatization of ports and container terminal privatization were found to be solutions on how to finance investments in ports [39]. A future research direction considering the effects on port ownership was suggested by Kaselimi et al. [18], where the authors noted that models should adopt more objectives that maximize welfare or incorporate both maximizing welfare and profit, as not all port and terminal operators maximize profit. One future avenue suggested by Czerny et al. [21] could include investigating the impact of scale economies and carrier market power on port competition and transshipment routes when port privatization is considered. The effects of port privatization on consumer and social welfare when considering the competition between international ports, government, and manufacturing firms was one research direction unexplored by Matsushima and Takauchi [38].

Another potential solution, through port cooperation, to address capacity limitations and increase port efficiency was proposed by Pujats et al. [29]. The authors also proposed as future research the investigation of additional costs for transshipment containers (but also inbound and outbound at a smaller scale) that would have to be moved between terminals or to specific vessels at the port of origin/destination.

As the demand for containers will continue to increase, so will the shipping emissions. Environmental control measures and their implications on the maritime industry most likely will become a critical issue as more regulatory policies are implemented. The evaluation of container port environment performance will become critical, and game theory could assist port authority operators by investigating strategic measures that would improve port environmental performance in settings of port competition and cooperation. Only one study used a game theory approach to model port competition and emission control (emission tax), a study done by Cui and Notteboom [22], where the authors, as a future research direction, suggested investigating emission controls in port areas with a third market (transit market) and their effects on emission tax and port privatization. Another environmental control solution that can reduce emissions at ports includes cold ironing, which is a process where shorepower is used to run the ship at the port of call. In a study done by Zis [40], the author concluded that in the setting of the introduction of new environmental regulatory measures and an increase in fuel prices, the use of cold ironing could lead to lower ship operating costs. This result could have a significant effect on port and terminal competition and cooperation and should be evaluated with further research. The author suggested that future research could include evaluation of cold ironing berth availability at different port congestion levels or the required cold ironing berth conversions at a given terminal. Another operational process that could reduce emissions is the implementation of a Virtual Arrival policy. It is a process that is applied when delay at the port is known for vessels to reduce their speeds to meet the required arrival time at the port. A study by Jia et al. [41] found that the implementation of a Virtual Arrival policy could benefit both the ship operators and port authorities, which could result in fuel savings for ship operators and emission reductions for both parties by reducing port wait times. Jia et al. [41] suggested that further research should investigate the adoption of Virtual Arrival policy through the creation of new contractual arrangements that would share the fuel savings gained from Virtual Arrival implementation between shipowners, charterers, and port authorities.

Some of the future avenues to model port and liner shipping competition, cooperation, or both were considered by Song et al. [33], where the authors highlighted that future work on port and liner shipping competition, cooperation, or both could involve modeling accessibility to multimodal transportation and port location to acquire more port capacity. The revenue allocation mechanism between cooperating ports and liners was another research direction suggested by authors. One potential research direction suggested by Angeloudis et al. [37] could include exploring network differentiation between shipping lines or alliances to reduce competition among themselves and optimize costs of their network structure. From the reviewed studies, one of the most suggested points for future research is to include uncertain or stochastic demand. Only two studies [8,9] have used this assumption in their research. Data unavailability is another major issue noted in the reviewed literature, which restrains researchers from more realistic model development [7,8,17,19,27,28,35,36].

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