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The impact of revenue-sharing contracts on parallel shipping alliances

Adrián Nerja[a,*,1], Mariola Sánchez[b,2]

[a] Fundamentos del Análisis Económico (FAE), Universidad de Alicante, Campus de Sant Vicent del Raspeig, Sant Vicent del Raspeig, 03071 Alicante, Spain
[b] Métodos Cuantitativos para la Economía y la Empresa, Universidad de Murcia, Campus de Espinardo, Murcia 30100, Murcia, Spain

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ABSTRACT

In this paper, we explore the effect of revenue-sharing contracts between ports and shipping lines to counter the negative effects of parallel shipping alliances. We consider a vertical structure approach formed by port-shipping line chains, where ports are considered the upstream market, while shipping lines are the downstream market. Then, we propose the vertical integration of both chains as a solution to the loss of welfare because of the shipping alliance. We find that when ports may influence the downstream markets, welfare increases, and it is a proper ports response that port horizontal cooperation.

1. Introduction

In January 2023, the three major shipping alliances operate 82.10% of the shipping market in terms of TEU, a figure that has been continuously growing, where in 2014 this figure was of 74% [1]. Before the expansion of shipping alliances, there was a consolidation movement through mergers and acquisitions, leading the share of the top 20 carriers from 48% to 91% between 1996 and 2022; however, today that share remains stable, but consolidation among shipping lines has created monopolies or oligopolies that can abuse their dominant positions, [18]. The first known shipping alliances were formed in the 1970s, but the trend of forming alliances increased in the 1990s, with a great expansion in recent years as an alternative to horizontal consolidation. Shipping companies searched for ways to reduce costs and increase efficiency, and alliances provide a solution by allowing them to share resources and optimize routes [6]. Today, alliances play an important role in the shipping industry, where most major shipping lines are part of one or more alliances. Table 1 displays the market shares of each major alliance, showing that the maritime transport industry is an oligopoly.[3] To ensure healthy competition, the shipping alliances are regulated; however, in recent decades, antitrust exemptions to the shipping alliances have prevailed. Currently, these antitrust exemptions are being eliminated, but still generate serious antitrust concerns for competition authorities and policy makers [17].

This structure of the shipping market causes many ports to choose to compete more actively to maintain their market share. However, a port response to the increasing bargaining power of shipping alliances has been port cooperation instead of cutthroat competition. China has recently led horizontal port integration due to the overcapacity of ports and slow growth in the industry. However, port integration is also frequently observed outside China, such as Tokyo Bay Port in Japan, Los Angeles-Long Beach Port, and New York/New Jersey Port in the United States. Port cooperation may feel like a response to the increasing power of shipping alliances, but its effects and possible results are uncertain. More significantly, the potential monopolistic power resulting from port cooperation could be the most significant concern for society. For example, [21] found that port integration reduces consumer surplus and social welfare. Then, to avoid negative effects of both horizontal integration, shipping alliances, and port integration, we must look for other alternatives.

Our main goal is to analyze the effects of vertical integration between ports and shipping lines to counter the negative effects of shipping alliances. Today, instead of dealing with individual shipping lines, ports now face the collective strength of shipping alliances. Therefore, ports are experiencing a decline in their bargaining power and are losing their dominant position. Thus, the withdrawal of an alliance from a port can deal a fatal blow to its operations, a fact that is happening right now. According to [18], the number of container ports served by regular liner shipping services increased up to early 2019 with 975 ports; however, the

* Corresponding author.
E-mail address: adrian.nerja@ua.es (A. Nerja).
1 0000-0003-3771-8190.
2 0000-0003-0211-3212.
3 i) 2M is formed by Maersk Line and Mediterranean Shipping Company; ii) Ocean is formed by CMA CGM, COSCO Shipping Lines, and Evergreen; iii) THE is formed by Hapag-Lloyd, HMM Co Ltd., Ocean Network Express, and Yang Ming.

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Table 1
Major Shipping Alliances Share. Jan. 2023.
Source: [1].

Alliance	TEU	Share
2M	8,845,340	33,60%
Ocean	7,929,646	30,10%
THEA	4,847,063	18,40%
Total	21,622,049	82,10%

trend reversed and a decline began down to 912 ports in the last 2022, further exacerbated by the ongoing war in Ukraine. Consequently, major ports are forced to make compromises with alliances, sacrificing their own interests to secure the berthing of shippers vessels [9]. As a result, this situation hampers the potential for port development and profitability, limiting their long-term growth prospects. [11] and [5] noted that to succeed, ports must be integrated in the form of a supply chain to face competition. In this way, several papers can be found in the literature that analyze different perspectives of ports and hinterland services integration (e.g., [15,16], or [4]). However, our main objective is to analyze the integration between ports and shipping lines through revenue-sharing contracts. In this line, revenue-sharing contracts can take many forms, such as joint investments or holding stakes. The former consists of investing jointly in terminals in several ways. [25] studies the effects of vertical integration when shipping lines invest in ports' capacity, which leads to an increase in output and consumer surplus, while [3] examines the investment and management of the shipping lines in the terminals. In practice, APM Terminals, a division of Maersk, the largest transport and logistic company in the world, operates 75 terminals.[4] The second way of revenue sharing is holding shares with each other. Today, China is increasingly investing in key European infrastructure, including ports, according to the European Parliamentary Research Service (EPRS). Some operations include the purchase of 24.9% from Tollerort, the company operating the Hamburg container terminal by COSCO in 2022; in Greece, COSCO owns a majority stake in the port of Piraeus terminals; and in Spain, COSCO controls the largest terminals in the ports of Valencia and Bilbao.

In this paper, we theoretically explore whether revenue-sharing contracts can be an effective mechanism to increase welfare and output under parallel shipping alliances. We consider two vertical structures consisting of a port and a shipping line. Both shipping lines offer substitute services and form a parallel shipping alliance. Parallel shipping alliances are those where two firms that offer substitutable services sign an agreement. In addition, we introduce revenue-sharing contracts to form a vertical integration of both chains. Regarding the methodology used, [24] uses a similar model specification, but considering two ports, the feeder and the hub, in the vertical chain instead of one. Furthermore, they consider economies of scale in shipping lines, and their goal is to analyze the response of ports to shipping alliances. [9] analyzes the incentives to form a shipping alliance in a context of a single or monopolistic port and two competing shipping lines or carriers operating there. On the other hand, [19] analyze the incentives to form a vertical agreement in the context of two competitive chains, each formed by a dedicated port and a shipping line. The vertical agreement studied is a revenue-sharing contract specified as in this paper. Then, our contribution mainly remains in two areas. i) Regarding shipping alliances, we consider a partial alliance, a scenario previously studied in the air transport industry [23,10], instead of considering a merger, as the cited papers do, or considering joint profits as [2] and [8]. Lately, [7] have also considered a partial shipping alliance in the maritime transport literature to analyze how shipping alliances affect prices and output under unexpected shocks. Considering partial shipping alliances, we may understand the effects of weak or strong alliances. ii) We consider a vertically integrated structure between ports and shipping lines through a revenue-sharing contract. Under this specification, ports are considered to operate in the upstream market and shipping lines in the downstream market. Thus, port behavior has an important influence on the decisions of shipping lines in this market structure. The revenue sharing contract has also been used by [19], stating that “this (mechanism) appears to be a new area of research in this stream of literature”.

Thus, the main findings of this paper are 1) revenue-sharing contracts offset the negative effects of shipping alliances on traffic and welfare; 2) vertical integration is a better response from ports than horizontal integration, which leads to a more concentrated market structure; and 3) when ports and shipping lines sign an agreement, shipping lines internalize in their decision the profitability and performance of ports, which increases welfare and output. Previously, [24] found that the formation of shipping alliances is a dominant strategy for shipping lines, and that alliances reduce local social welfare. As a response, ports choose horizontal cooperation when substitutability is strong. On the other hand, [19] analyzes the effects of revenue sharing, finding that ports may use the percentage of revenue sharing as a way to increase their own demand, decreasing their rival port demand, as we find. The contribution we make to the previous literature is that we analyze revenue-sharing as a strategy to counter the negative effects of shipping alliances on welfare. In this case, we find that revenue-sharing contracts are a better response than horizontal port cooperation.

The remainder of this paper is organized as follows. The following section sets the benchmark model. Section 3 analyzes the effects of parallel shipping alliances. Section 4 discusses implications of horizontal port cooperation. Section 5 examines vertical integration and how it affects welfare. Finally, Section 6 concludes with some remarks.

2. Benchmark

In this section, we set up a transport network consisting of two ports in the upstream market, with a different shipping line operating in each port in the downstream market. Both shipping lines compete because they offer substitutable services. Thus, the strategic relationship of shipping lines also defines the strategic relationship of ports that are rivals.

2.1. Model description

Consider two ports, *A* and *B*, where each offers substitutable shipping services. In each port operates one and a different shipping line, then there are two port-shipping service pairs competing. Shipping lines provide substitute differentiated services, and they determine their outputs simultaneously. Fig. 1 illustrates the model that shows a vertical relationship between the two markets. The upstream market composed of two ports and the downstream market composed of two shipping lines, *SL*.

The inverse demand system of the transport services, that is the result of the representative shipper's utility maximization,[5] [6] is specified as:

$$p_1 = a - q_1 - dq_2 \tag{1}$$

$$p_2 = a - q_2 - dq_1 \tag{2}$$

For a and d being positive constants. The q_i's represent the output served by the shipping line i on a given origin-destination route. The

[4] You can access their last investments in the next link: https://www.apm-terminals.com/en/about/history.

[5] To obtain the inverse demand system, the representative shipper's utility, that is, $U(q_1, q_2) = a(q_1 + q_2) - \frac{1}{2}(q_1^2 + q_2^2) - dq_1q_2$, is maximized with respect to q_1 and q_2. This system satisfies the usual properties: (i) downward-sloping demand $\frac{\partial p_i}{\partial q_i} = -1 < 0$; (ii) own effects dominate cross effects $\frac{\partial p_1}{\partial q_1}\frac{\partial p_2}{\partial q_2} - \frac{\partial p_1}{\partial q_2}\frac{\partial p_2}{\partial q_1} = 1 - d^2 > 0$.

[6] Shipping lines may differ in the service provided. This could be incorporated into the analysis by assuming different demand intercepts, which would be related to reliability, securing port operations, better departure schedule, priority, etc. The results that follow carry on as long as such differences are not too important.

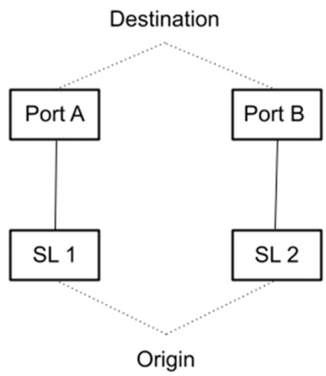


Fig. 1. The cargo network transport.

parameter $d \in (0, 1]$ measures the differentiation of services or the degree of substitutability between the services of the shipping line. When $d = 0$ shipping services are independent, while when $d = 1$ both services are perfect substitutes.

In addition to the inverse demands, p_i ($i = 1, 2$) is the total cost of the shipping companies for each route, including the freight rate of the ship and port charges. Thus:

$$p_1 = f_1 + w_A \tag{3}$$

$$p_2 = f_2 + w_B \tag{4}$$

where f_i are the shipping freight rates for each shipping line $i = 1, 2$, and w_j $\forall$ $j = A, B$ are the port charges paid by the shipping lines. Shipping lines are responsible for the transportation of cargo from its origin to its destination. Their freights include the inland transport parts and the ports' charges. In practice, shipping lines contract inland transportation services, whose freight charges are included in the cost of the shipping lines. Therefore, in this model, f_i are the charges collected by the shipping lines themselves. Finally, the freight rates are the result of solving the equalities in (1) and (2) with (3) and (4), that is:

$$f_1 = a - q_1 - dq_2 - w_A \tag{5}$$

$$f_2 = a - q_2 - dq_1 - w_B \tag{6}$$

The freight rates are levied by the shipping lines; then their profit function, π_i, is composed of the standard operating profits, $(f_i - c)q_i$. The parameter c represents constant marginal costs and is the same for each shipping line, that is, they are symmetric. Then, the shipping lines' profit functions are:

$$\pi_1 = (f_1 - c)q_1 \tag{7}$$

$$\pi_2 = (f_2 - c)q_2 \tag{8}$$

On the other hand, ports' profits depend on the charges paid by shipping lines, which typically include fees for the use of port facilities and equipment, such as wharves, cranes, and loading gear. They may also include fees for services such as berthing, port facilities maintenance, and security. In addition, they can cover government taxes, fees, and tariffs, and agency fees for services such as document management and navigation within the port. Marginal costs have been normalized to zero. Consequently, ports profits functions are:

$$R_A = w_A q_1 \tag{9}$$

$$R_B = w_B q_2 \tag{10}$$

Under this specification, agents make decisions in two stages. In the first stage, each port decides independently and simultaneously on the port charge w_A and w_B to maximize profits. In the second stage, shipping lines compete in quantities. We characterize the subgame perfect Nash equilibrium, solving the game in a standard backward way.

2.2. Second stage: shipping competition in the downstream market

Every shipping line chooses the output independently to maximize its objective function, $\text{Max}_{q_i}\ \pi_i$, $\forall$ $i = 1, 2$. Thus, the outcome per shipping line and total outcome given the degree of cooperation and port charges are the following:

$$q_1^* = \frac{(a - c)(2 - d) - 2w_A + dw_B}{4 - d^2} \tag{11}$$

$$q_2^* = \frac{(a - c)(2 - d) - 2w_B + dw_A}{4 - d^2} \tag{12}$$

$$Q^* = \frac{2(a - c) - w_A - w_B}{2 + d} \tag{13}$$

where the superscript * stands for the equilibrium in the benchmark case. From equations (11) and (12), we see that ports increase the outcome if they reduce their port charge, at the expense of the other port outcome. Then, there is a transference of outcome between ports when they decide to increase/decrease their port charges. This is a competition effect that shows how ports may compete indirectly through port charges.

2.3. First stage: upstream port competition

Ports compete in the sense that their shipping lines offer substitutable services. The ports A and B decide simultaneously and independently about the amount of charges that the shipping alliances must pay, that is, $\text{Max}_{w_j}\ R_j$, $\forall$ $j = A, B$. Then, the ports' charges are:

$$w_A^* = w_B^* = \frac{(a - c)(2 - d)}{4 - d} \tag{14}$$

Then the profits of ports and shipping lines are:

$$\pi_i^* = \frac{4(a - c)^2}{(4 - d)^2(2 + d)^2} \tag{15}$$

$$R_j^* = \frac{2(a - c)^2(2 - d)}{(4 - d)^2(2 + d)} \tag{16}$$

These values are going to be the reference to compare the subsequent cases in the paper.

2.4. Welfare analysis

Following [24], we differentiate between social welfare (SW) and local social welfare (LSW). The difference is that LSW does not include shipping line utilities because they are international firms whose profits are of little concern to policy makers and local governments.

The social welfare is the shippers' total utility net to their marginal cost; whereas the local social welfare is the shippers' total utility net of the payment to the shipping lines. Then:

$$SW^* = U(q_1, q_2) - c(q_1 + q_2) = \frac{4(a - c)^2(7 + (1 - d)d)}{(4 - d)^2(2 + d)^2} \tag{17}$$

$$LSW^* = U(q_1, q_2) - f_1 q_1 - f_2 q_2 = \frac{4(a - c)^2(5 + (1 - d)d)}{(4 - d)^2(2 + d)^2} \tag{18}$$

Social welfare is higher than local social welfare because it includes the welfare of the shipping lines. However, local social welfare is a better indicator of welfare, because shipping lines are relocated firms that do not provide well-being in a specific place.

3. Shipping alliances proliferation

In this section, we analyze the effects of shipping alliances on the maritime transport industry and welfare. As the horizontal consolidation process has entered its mature phase, the significance of alliances has increased significantly. The proportion of global capacity controlled by these alliances has grown by more than 80% since 2015, [18]. Alliance in liner shipping aims to improve cooperative efforts involving liner shipping companies and a strong presence of fleets on certain routes (such as type of vessel, sailing schedules, use of shared terminals, and container coordination) on a global scale, [13]. Furthermore, shipping lines have many incentives to sign alliances among them, which have led to a market structure where more than 80% of traffic is handled by only three shipping alliances; see Table 1. For this reason, in this paper, we consider the existence of a parallel shipping alliance. The purpose of this section is to analyze how shipping alliances impact ports and welfare.

In order to model the shipping alliance, we do not consider a full merger, rather we allow for a partial alliance. Furthermore, we assume that the degree of cooperation between both shipping lines is the same, that is, an equity alliance. [23] stated that 'an equity alliance tends to yield greater firm values, measured in stock returns, than other types of strategic alliances.' Therefore, in the second stage, every shipping line chooses the output maximizing the following expressions:

$$\text{Max}\, q_1 \ \Pi_1 = \pi_1 + \alpha\pi_2 \tag{19}$$

$$\text{Max}\, q_2 \ \Pi_2 = \pi_2 + \alpha\pi_1 \tag{20}$$

When considering a shipping alliance, their objective function changes; now shipping lines maximize their profit plus a weight on their partner's profit. The parameter $\alpha \in [0, 1)$ represents the degree of cooperation. When $\alpha = 0$ there are two fully competing firms in the downstream market, the Cournot case; while when $\alpha = 1$, this represents a merger, where both shipping lines behave as one. The given degree of cooperation, α, is assumed equal for both shipping lines.

3.1. Second stage: downstream shipping competition

Despite forming a parallel alliance, every shipping line chooses the output independently to maximize its objective function, (19) and (20). Thus, the outcome per shipping line and total outcome given the degree of cooperation and port charges are the following:

$$q_1^S = \frac{(a-c)(2-(1+\alpha)d) - 2w_A + (1+\alpha)dw_B}{4-(1+\alpha)^2d^2} \tag{21}$$

$$q_2^S = \frac{(a-c)(2-(1+\alpha)d) - 2w_B + (1+\alpha)dw_A}{4-(1+\alpha)^2d^2} \tag{22}$$

$$Q^S = \frac{2(a-c) - w_A - w_B}{2+(1+\alpha)d} \tag{23}$$

where superscript S stands for the equilibrium of the shipping alliance case.

Proposition 1. Shipping alliances reduce total output, that is, $\frac{\partial Q^S}{\partial \alpha} = -dq^S < 0$.

This is an expected consequence, also found in [9], for instance, because every market concentration reduces output. Analyzing the effect of the degree of cooperation, other things equal, shipping lines increase their freight rates when the degree of cooperation increases, which allows them to raise their profits. This is the main effect of parallel shipping alliances and why they are raising concern.[7]

[7] The consideration of several shipping lines operating at each port would make the analysis more complex while not adding further insights. In fact, [14], for airline alliances, show that the total output of the partners is likely to decrease, while the non-partner output can increase, remain unchanged, or decrease. The user surplus is very likely to fall after a parallel airline alliance. See also the section on alliances in [22].

3.2. First stage: upstream port competition

Ports A and B, as in the benchmark case, decide simultaneously and independently over the charge shipping alliances must pay. Then, the ports' charges are:

$$w_A^S = w_B^S = \frac{(a-c)(2-(1+\alpha)d)}{4-(1+\alpha)d} \tag{24}$$

Then the profits of ports and shipping lines are:

$$\pi_i^S = \frac{4(a-c)^2(1+\alpha d)}{(4-(1+\alpha)d)^2(2+(1+\alpha)d)^2} \tag{25}$$

$$R_j^S = \frac{2(a-c)^2(2-(1+\alpha)d)}{(4-(1+\alpha)d)^2(2+(1+\alpha)d)} \tag{26}$$

Proposition 2. Shipping alliances encourage ports to reduce their charges, $\frac{\partial w_j^S}{\partial \alpha} < 0$, then, as a consequence, their profits decrease, $\frac{\partial R_j^S}{\partial \alpha} < 0$.

To compensate for the loss of output due to the shipping alliance, which reduces the profits of the ports, the ports should decrease the charges, that is, $\frac{\partial w_j^S}{\partial \alpha} < 0$. This fact reduces the profits of ports, then losing bargaining power when negotiating with shipping lines, also stated by [12]. In conclusion, as [9] found, shipping alliances reduce downstream competition, lower port charges, and weaken the monopolistic advantage of the port. That is why ports are looking for ways to recover their starting position in the industry, as well as to mitigate market volatility. On the other hand, shipping lines increase their profits due to alliances, because they increase their market power, becoming a stronger monopolistic position as the alliance gets stronger, which is also found by [24].

3.3. Welfare analysis of shipping alliances

The only agents that benefit from alliances are the shipping lines, then a decrease in local social welfare is expected. However, there are opposite effects on social welfare.

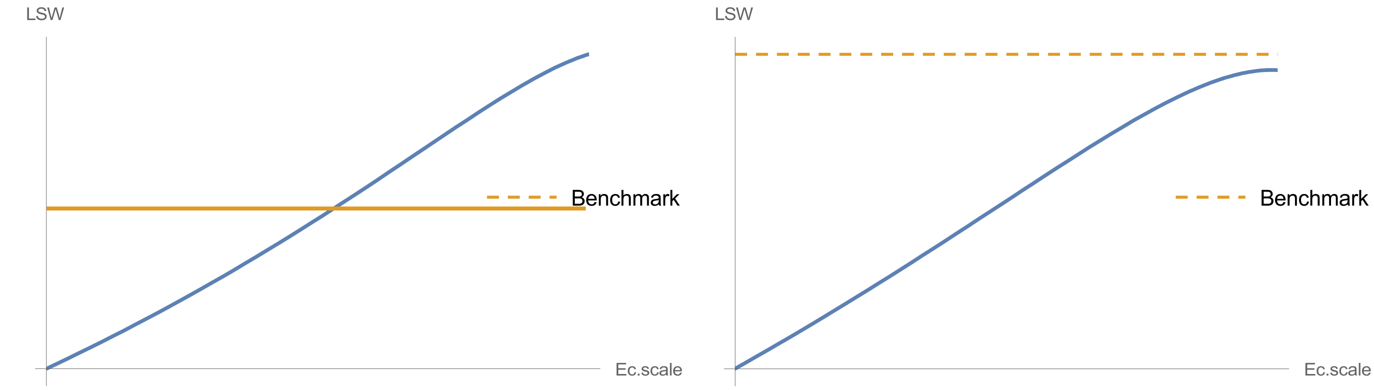
Proposition 3. Shipping alliances reduce LSW, $\frac{\partial LSW^S}{\partial \alpha} < 0$, but SW increases with respect to the benchmark case when the shipping lines are substitutable enough, $d > \frac{2}{2+\alpha}$.

As expected, shipping alliances reduce LSW, also found by [24], raising concern among ports and policy authorities. Regarding SW, it increases with a high enough degree of differentiation, also affected by the level of alliance, α. This is because ports, to palliate the reduction in output due to alliances, reduce the port rate w, with the net effect of the increase on output, then on social welfare. However, ports' profits are always decreasing with the degree of alliance by this fact, the reduction of profits.

The negative effects of shipping alliances are known; however, governments granted antitrust immunity to them because of the high economies of scale that the maritime transport industry has. When analyzing the effects of economies of scale in the downstream market over the benchmark case, we found that they effectively improve the output with the increment on welfare, total, and local. On the other hand, when considering shipping alliances, we have two opposite forces, the positive effects in terms of welfare coming from the economies of scale, and the negative effects from the shipping alliances.

Given that achieving economies of scale is one of the reasons used to justify shipping alliances, we aim to examine their impact on LSW and SW. Fig. 4 illustrates the comparison between LSW in the benchmark scenario (dashed line) and the case of shipping alliances with economies of scale in the downstream market (thick line).[8] In the case of a

[8] To introduce economies of scale, the shipping lines costs are modified: $C_i = cq_i - \frac{\lambda q_i^2}{2}$, where $\lambda > 0$ represents the economies of scale.



(a) Weak alliance (b) Strong alliance

Fig. 2. Local social welfare: shipping alliances with economies of scale vs. benchmark.

weak alliance, that is, low values of α as shown in Fig. 2a, the positive effect of economies of scale outweighs the negative effect of shipping alliances. On the other hand, when economies of scale are high enough and there is a strong alliance, i.e., high values of α, LSW with shipping alliances exceeds the benchmark level. However, if the shipping alliance is strong enough, as depicted in Fig. 2b, the positive impact of economies of scale never exceeds the negative effects of shipping alliances. Additionally, it also influences the degree of substitutability, d, implying that as long as d increases, the scenario depicted in Fig. 2b becomes more likely. This result is supported by [8], which states that "the often deified economies of scale of mega-ships are not, but a chimera unless their capacity can be fully utilized".

Shipping alliances offer advantages in terms of both scale and scope economies. Within these alliances, shipping lines can distribute investment risks and, by utilizing increasingly larger vessels, achieve economies of scale that lead to reduced shipping costs per container and improved fleet utilization. By forming shipping alliances in complementary regions, they can provide customers with more extensive and interconnected networks. On the other hand, regulatory authorities emphasize the importance of ensuring that the cost savings gained by carriers are passed on to clients. One of the most significant factors influencing maritime freight rates and charges is competition. Empirical evidence demonstrates that as the number of carriers increases, there is a higher likelihood that cost savings will be transferred to clients. Competition authorities consistently strive to maximize options among competing shipping lines and services while actively monitoring any anticompetitive behavior or unjustifiable fees and charges. That is why shipping alliances have raised serious antitrust concerns, a phenomenon that has increased significantly during the COVID-19 pandemic. The shipping alliances are strengthening, in an industry with a high degree of service substitutability, leaving a situation similar to Fig. 2b, where the benchmark case in terms of welfare is worsened. Policy makers are regulating shipping alliances to increase competition in the downstream market. In the next section, we analyze a measure in which ports mergers are encouraged to get back bargaining power against shipping lines. However, this creates a vertical monopoly that over-concentrates the market. Then, in Section 5 we propose vertical integration through a revenue sharing contract to involve shipping lines in port decisions and welfare.

4. Ports horizontal cooperation to balance bargaining power with shipping lines

Ports have experienced how their bargaining power and profits are declining due to global shipping alliances. A natural response of ports is to compete; however, as we have already seen, with shipping alliances, port competition leads to results of competitive markets. Then, instead of cut-throat competition, the response of close ports has been to cooperate. One of the main reasons to cooperate is the overcapacity of ports, which is usual in China, but also in other countries around the world [21]. The rapid development in the shipping industry triggered, during several decades, a huge investment in port infrastructures. This strategy is widespread worldwide and takes a variety of forms, from relatively weak collaboration, such as capital penetration, to the most integrated one, a merger, [20].

In this section, we consider a complete integration. When considering horizontal cooperation of ports, in the first stage, ports maximize port charges through the maximization of joint profits, that is, they $\text{Max}_{w_A, w_B}\, R_A + R_B$. This is the only change to the previous section. Now, let us see which are the main effects of horizontal cooperation in the upstream market in the case of shipping alliances.

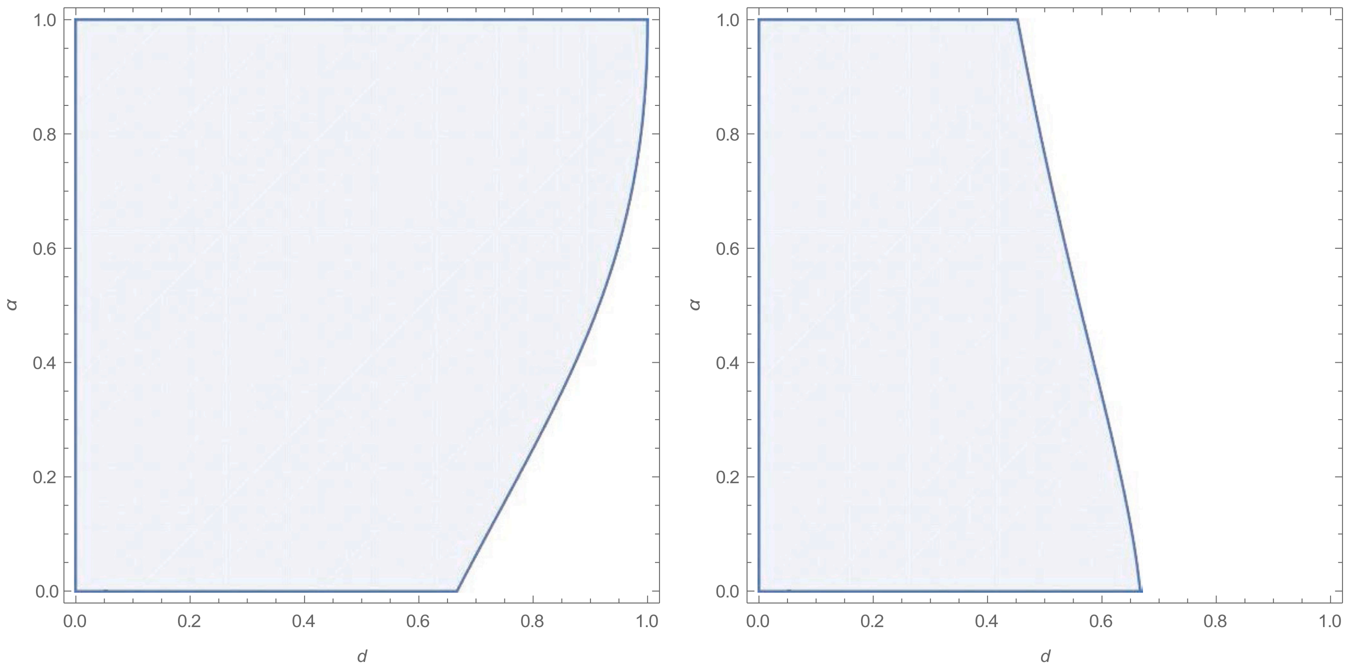
Proposition 4. When ports respond to shipping alliances with a horizontal cooperation strategy, ports increase their bargaining power, which enables them to rise ports' charges and then their profits. However, as a direct result, transportation output and shipping line profits fall. As a result, social welfare drops.

When two ports are horizontally integrated, it generates a monopoly situation in the upstream market, leaving a situation where ports compensate the losses induced by shipping alliances. First, ports behave as a single firm, imposing monopoly port charges on shipping lines. As a response, shipping lines reduce their traffic due to the increase of their operating costs. Therefore, port cooperation only benefits the ports themselves, generating welfare losses, which is one of the main concerns from the perspective of society. Thus, we can say that port cooperation may not be a good strategy to minimize the negative effects of parallel shipping alliances because what we get is a vertical chain with two non-competitive markets.

In consequence, even though ports' horizontal cooperation allows solving the overcapacity problem, there are other alternatives that increase traffic, and welfare. The alternative we analyze is revenue-sharing contracts with shipping alliances. The main effect is that the output increases, so this fact would partially or totally solve overcapacity problems. Last but not least, ports get back bargaining power, which enhances competition, then the increment of social welfare.

5. Effects of vertical integration on shipping alliances

Over recent decades, the bargaining position of shipping lines has been strengthened in four ways, according to [18]: '1) Individual carriers have been able to increase their market shares. 2) Carriers have a greater choice of ports, to reach the same inland transport markets or, as a result of better trade facilitation, improved transit, and common transport markets in neighboring countries. 3) Through vertical integration, major carriers have become both clients and tenants and



(a) $R_j^R > R_j^S$ (b) $R_j^R > R_j^*$

Fig. 3. Ports profits comparison.

have acquired greater negotiating power. 4) As members of alliances, shipping lines have been able to create concentrated buyer markets oligopolies.' Then, the growing negotiating power of shipping alliances leads ports to decide on new forms to ensure long-term existence and competitiveness. One way is through some kind of revenue-sharing contract, where shipping lines are also involved in the performance of ports, whereas shipping alliances keep running in the chosen ports over time. From a welfare perspective, ports decisions may influence the downstream market, and then a vertical agreement could head to a situation where shipping alliances also look at the output growth instead of imposing a most monopolistic situation. Thus, in this section, we propose a solution to counter the adverse effects of shipping alliances, and as an alternative to ports horizontal cooperation. In this case, ports and shipping lines form a vertically integrated structure through a sharing-revenue contract, forming a market structure with two vertically integrated chains. Then, each vertical structure maximizes joint profits, where each shipping line maintains a proportion of joint profits r_j, and each port the rest, $(1 - r_j)$. Therefore, shipping lines and ports profits when they sign a revenue-sharing contract are:

$$\pi_1 = r_A(a - c - q_1 - dq_2)q_1; \;\; R_A = (1 - r_A)(a - c - q_1 - dq_2)q_1 \tag{27}$$

$$\pi_2 = r_B(a - c - q_2 - dq_1)q_2; \;\; R_B = (1 - r_B)(a - c - q_2 - dq_1)q_2 \tag{28}$$

In this new setting, in the first stage the ports decide on the share proportion r_j, while in the second stage the shipping lines that form an alliance choose their output. The change from the previous setting is that instead of the port charge, now each vertical structure shares a proportion of joint profits. Thus, ports decide on the share proportion in the first stage. Furthermore, to motivate and ensure that shipping lines sign the contract, the port proposes a 'take it or leave it' contract where shipping lines make at least the same profits as in the case of shipping alliances without vertical agreement.

In the second stage, every shipping line chooses the output independently to maximize its objective function, as in (19) and (20). Therefore, the outcome per shipping line and the total outcome depend on the degree of cooperation and the proportions of sharing. Ports could use the sharing proportions to compete with each other. An increase in the sharing proportion increases its own output, but reduces their rival output.

5.1. First stage: revenue-sharing contract

In addition to the decisions of the shipping lines on output, the ports must decide the proportions of the revenue-sharing contract. Once again, to make shipping lines sign the contract, they must at least make the same profits as in (25). Thus, the optimization problem that ports face is $\text{Max}\, r_j\; R_j,\;\; s.\,t.\;\; \pi^R \geq \pi^S$, where the superscript R represents the case of revenue sharing contracts. Then, the sharing proportions and revenues of every agent are:

$$r_j^R = \frac{4}{(4 - (1+\alpha)d)^2} \tag{29}$$

$$R_j^R = \frac{(a-c)^2(1+d\alpha)(6-(1+\alpha)d)(2-(1+\alpha)d)}{(4-(1+\alpha)d)^2(2+(1+\alpha)d)^2} \tag{30}$$

$$\pi_i^R = \pi_i^S \tag{31}$$

Shipping lines keep the same level of profit that finally depends on the proportion of sharing determined by the degree of substitutability of services, d, and the degree of alliance, α. Regarding the profits of ports, Proposition 3 showed how the shipping alliances decrease them. Fig. 3 illustrates when port profits are higher (shaded area) compared to shipping alliances and benchmark scenarios, for different levels of product differentiation and degree of alliance, d and α, respectively. When considering revenue sharing, the shadowed area in Fig. 3a shows when port profits are higher with respect to the shipping alliance case, which is always the case as long as $d \longrightarrow 1$ and $\alpha \longrightarrow 1$. Nevertheless, lower levels in the degree of cooperation between shipping lines open the door to prefer a scenario of shipping alliances in the market. On the other hand, Fig. 3b offers the case where port profits are higher than the benchmark ones. It can be seen how ports regain bargaining power under the existence of a revenue-sharing contract mechanism, which means higher profits.

5.2. Welfare analysis of revenue-sharing

In this subsection, we discuss the implications of vertical integration facilitated by revenue-sharing on overall welfare. Furthermore, we

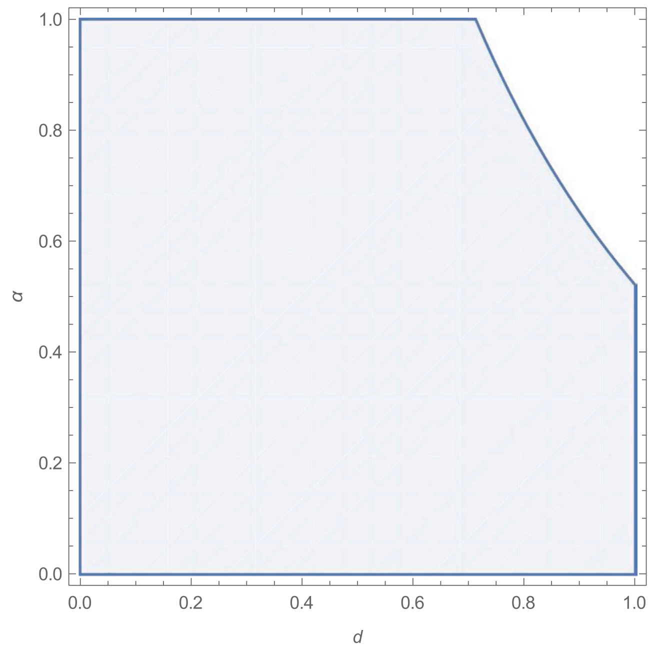


Fig. 4. LSW^R vs LSW^*.

compare the results with the cases examined previously to gain valuable insights into the effects of this kind of contract.

Proposition 5. Revenue-sharing contracts increase social welfare and local social welfare with respect to the shipping alliance case, $SW^R > SW^S$ and $LSW^R > LSW^S$.

One of the main issues of shipping alliances is the loss of welfare, which causes policy concerns. When considering revenue sharing, shipping lines are involved in port performance, which directly impacts local social welfare. Ports are the infrastructure that allows maritime transport. The capacity of ports is fixed, so they rely on the optimization of their capacity to improve their performance and profits. Revenue sharing expands production, improving even the benchmark case, $Q^R > Q^*$. When looking at social welfare, the same result is obtained, that is, revenue sharing further increases social welfare with respect to the benchmark, $SW^R > SW^*$. The shadowed area in Fig. 4 shows when $LSW^R > LSW^*$. It can be seen that LSW is improved mainly in any combination of d and α, except when the alliance is very strong and the services very similar. In this case, the sharing proportion increases to compensate for the negative effect of alliances, and then the ports reduce their profit to levels below the benchmark.

When attending vertical integration, ports can point to the establishment as a transshipment hub. In that way, it transforms into a fully vertical company in a hub port. An illustrative example is the concession of the Piraeus port in Greece to COSCO (China), one of the top five global liner shipping companies. Through this concession, COSCO brought its own services and cargo, resulting in a significant increase in volume and connectivity, both within the hinterland and with overseas ports and markets it serves, [18]. However, achieving that situation is not easy in the sense that the process of expanding capacity or constructing new ports is often time consuming and takes years, if not decades, to complete. This lengthy time frame is due to various factors that must be considered, including the establishment of efficient inland connections and the management of environmental concerns. On the contrary, shipping lines have the advantage of adaptability and agility. Although it may take a few years to acquire new ships, they can quickly utilize idle vessels or improve service speeds to handle additional cargo in the meantime.

6. Concluding remarks

Nowadays, the maritime transport sector is a concentrated and oligopolistic market due to two main events: a horizontal consolidation process with a result of 91% of the market share of the top 20 carriers in 2022, and shipping alliances where the shipping market is mainly governed by only three global alliances; see Table 1. At first, shipping alliances have been agreed upon by authorities in order to exploit economies of both scale and scope, fulfilling the increasing demand for shipping services around the world. Additionally, shipping alliances have the ability to distribute investment risks, potentially leading to cost reductions, while also capitalizing on the benefits of enhanced networks through the utilization of complementary regions. Authorities and regulators face the challenge of striking a balance between promoting competition through effective regulation of shipping alliances and capitalizing on cost reductions that should be passed on to clients. Competition authorities should include shipping alliances in their assessments to ensure fair competition. It is crucial that authorities provide clear guidelines on what alliances are legally allowed to do, including the ability to negotiate jointly with other partners in the supply chain. By conducting comprehensive analyses of the impact on competition, service quality, and efficiency, authorities can identify potential concerns and apply suitable remedies. Another possible approach is to enforce reporting requirements to enhance transparency and accountability within these collaborations. However, the widespread adoption of shipping alliances has placed ports in a position of reduced negotiating power vis-à-vis shipping lines. Consequently, ports are now seeking greater stability and profitability, prompting them to explore avenues of horizontal collaboration among themselves. Although this approach helps mitigate the adverse effects of shipping alliances on ports, it also leads to a more concentrated market characterized by higher prices, ultimately resulting in decreased production and welfare.

Another venue involves vertical integration between ports and shipping alliances. Ports are encouraged to establish vertical engagement with shipping alliances to prevent alliances from seeking alternative ports. There are several ways of vertical integration, such as terminal investments or holding shares, which we call the model revenue-sharing contracts. In such cases, shipping lines become involved in the performance and financial goals of ports. This alignment allows the entire shipping industry to work towards a shared goal of maintaining a stable and steadily growing market, where competition drives the improvement of all involved stakeholders. In the process of allowing vertical integration, collaboration between sector regulators, competition authorities, and port authorities is vital to effectively address any competition concerns that may arise. This collaboration ensures the promotion of fair competition and improves the overall competitiveness of this crucial segment within the supply chain.

In this paper, we demonstrate how vertical integration between ports and shipping lines can be a potential solution, employing a basic model that incorporates shipping alliances in the downstream market and a revenue-sharing contract. While there are various other factors that may impact the overall findings, the fundamental concept remains intact. Consequently, this study enables us to derive policy implications. Given the increasing market power of shipping alliances over time, it becomes imperative to identify mechanisms that can effectively redistribute the surplus generated by shippers to other affected agents. Therefore, authorities must promote vertical agreements between ports and shipping lines, avoiding the counterfactual effects of horizontal integration in both the upstream and downstream markets. Vertical integration can play a significant role in the modernization of facilities and the improvement of services within the port industry. However, it can also pose challenges, such as limited access or discriminatory treatment toward competing users of port facilities. Although vertical integration offers benefits, it is essential to address these potential issues to ensure fair and equitable access for all users and foster healthy competition within the port sector.

This is a new stream in the maritime transport literature. Many aspects of vertical cooperation between ports and shipping lines must then be investigated. For example, we have proposed a study in which both agents sign an agreement; however, for future research, we will analyze the incentives for each agent to sign that agreement. Furthermore, it must be seen how other relevant aspects, such as port congestion or economies of scale, influence vertical chain competition, shipping alliances, and port cooperation.

Data availability

No data was used for the research described in the article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

A.1. Payoffs

In Table 2 the payoffs for the four cases exposed in the paper can be found:

A.2. Proofs

Proof of Proposition 1

$\frac{\partial Q^*}{\partial \alpha} = -dq^* < 0$ is proofed by inspection.

Proof of Proposition 2

Regarding port charges, $\frac{\partial w_j^S}{\partial \alpha} = -\frac{2(a-c)d}{(4-(1+\alpha)d)^2} < 0$, which is true because every element in the quotient is positive.

With respect to ports' profits, $\frac{\partial R_j^S}{\partial \alpha} = -\frac{4(a-c)^2 d(4-(1+\alpha)d(2-(1+\alpha)d)}{(4-(1+\alpha)d)^3(2+(1+\alpha)d)^2} < 0$. This is true because every term in the quotient is positive. The only term to prove because it is hard to see by inspection is $(4-(1+\alpha)d(2-(1+\alpha)d) > 0$, where $(1+\alpha)d(2-(1+\alpha)d < 4$, which is true because both terms on the left are fewer than two: $(1+\alpha)d < 2$ and $(2-(1+\alpha)d < 2$.

Proof of Proposition 3

Regarding LSW, $\frac{\partial LSW^S}{\partial \alpha} = -\frac{8d(a-c)^2(10-d(2\alpha+(1+\alpha)d(2-(1+\alpha)^2 d)}{(4-(1+\alpha)d)^3(2+(1+\alpha)d)^3} < 0$, because the quotient is positive.

However, with respect to SW, $\frac{\partial SW^S}{\partial \alpha} = -\frac{8d(a-c)^2(1-(1+\alpha)d)(6+2d\alpha-(1+\alpha)^2 d^2)}{(4-(1+\alpha)d)^3(2+(1+\alpha)d)^3}$. In this case, there are conditions imposed by $-(6+2d\alpha-(1+\alpha)^2 d^2)$, and after arithmetical manipulation we obtain that $\frac{\partial SW^S}{\partial \alpha} < 0$ if $d < \frac{1}{1+\alpha}$, and $\frac{\partial SW^S}{\partial \alpha} > 0$ otherwise.

Proof of Proposition 4

We are going to verify Proposition 4 by comparing the results of the port cooperation versus the benchmark case:

- Port charges:

Table 2
Optimal solutions, profits, and welfare.

	Benchmark	Shipping Alliances	Port Cooperation	Revenue Sharing
w_i	$\frac{(a-c)(2-d)}{4-d}$	$\frac{(a-c)(2-(1+\alpha)d)}{4-(1+\alpha)d}$	$\frac{a-c}{2}$	
r_i				$\frac{4}{(4-(1+\alpha)d)^2}$
p_i	$\frac{a(6-d^2)+2c(1+d)}{(4-d)(2+d)}$	$\frac{a(6+2d\alpha-(1+\alpha)^2 d^2)+2c(1+d)}{(4-(1+\alpha)d)(2+(1+\alpha)d)}$	$\frac{a(3+(1+2\alpha)d)+c(1+d)}{2(2+(1+\alpha)d)}$	$\frac{a(1+d\alpha)+c(1+d)}{2(1+\alpha)d}$
f_i	$\frac{2a+c(6+(2-d)d}{(4-d)(2+d)}$	$\frac{2\alpha(1+d\alpha)+c(6+d(2-(1+\alpha)^2 d))}{(4-(1+\alpha)d)(2+(1+\alpha)d)}$	$\frac{\alpha(1+d\alpha)+c(3+(2+\alpha)d)}{2(2+(1+\alpha)d)}$	$p_i - w_i$
Q	$\frac{4(a-c)}{(4-d)(2+d)}$	$\frac{4(a-c)}{(4-(1+\alpha)d)(2+(1+\alpha)d)}$	$\frac{(a-c)}{2+(1+\alpha)d}$	$\frac{2(a-c)}{2+(1+\alpha)d}$
π_i	$\frac{4(a-c)^2}{(4-d)^2(2+d)^2}$	$\frac{4(a-c)^2(1+d\alpha)}{(4-(1+\alpha)d)^2(2+(1+\alpha)d)^2}$	$\frac{(a-c)^2(1+d\alpha)}{4(2+(1+\alpha)d)^2}$	$\frac{4(a-c)^2(1+d\alpha)}{(4-(1+\alpha)d)^2(2+(1+\alpha)d)^2}$
R_j	$\frac{2(a-c)^2(2-d)}{(4-d)^2(2+d)}$	$\frac{2(a-c)^2(2-(1+\alpha)d)}{(4-(1+\alpha)d)^2(2+(1+\alpha)d)}$	$\frac{(a-c)^2}{4(2+(1+\alpha)d)}$	$\frac{(a-c)^2(1+d\alpha)(6-(1+\alpha)d)(2-(1+\alpha)d)}{(4-(1+\alpha)d)^2(2+(1+\alpha)d)^2}$
$R_j + \pi_i$	$\frac{2(a-c)^2(6-d^2)}{(4-d)^2(2+d)^2}$	$\frac{2(a-c)^2(6+2d\alpha-(1+\alpha)^2 d^2)}{(4-(1+\alpha)d)^2(2+(1+\alpha)d)^2}$	$\frac{(a-c)^2(3+(1+2\alpha)d)}{4(2+(1+\alpha)d)^2}$	$\frac{(a-c)^2(1+d\alpha)}{(2+(1+\alpha)d)^2}$
SW	$\frac{4(a-c)^2(7+(1-d)d)}{(4-d)^2(2+d)^2}$	$\frac{4(a-c)^2(7+(1+2\alpha-(1+\alpha)^2 d)d)}{(4-(1+\alpha)d)^2(2+(1+\alpha)d)^2}$	$\frac{(a-c)^2(7+(3+4\alpha)d)}{4(2+(1+\alpha)d)^2}$	$\frac{(a-c)^2(3+(1+2\alpha)d)}{(2+(1+\alpha)d)^2}$
LSW	$\frac{4(a-c)^2(5+(1-d)d)}{(4-d)^2(2+d)^2}$	$\frac{4(a-c)^2(5+(1-(1+\alpha)^2 d)d)}{(4-(1+\alpha)d)^2(2+(1+\alpha)d)^2}$	$\frac{(a-c)^2(5+(3+2\alpha)d)}{4(2+(1+\alpha)d)^2}$	$\frac{(a-c)^2(40-d(8+(5+13\alpha-(1+\alpha)(1+2\alpha)d)(1+\alpha)d))}{(4-(1+\alpha)d)^2(2+(1+\alpha)d)^2}$

$$\frac{a-c}{2} - \frac{(a-c)(2-(1+\alpha)d}{4-(1+\alpha)d} = \frac{(a-c)d(1+\alpha)}{2(4-(1+\alpha)d)} > 0$$

- Port profits: $\frac{(a-c)^2}{4(2+(1+\alpha)d)} - \frac{2(a-c)^2(2-(1+\alpha)d)}{(4-(1+\alpha)d)^2(2+(1+\alpha)d)^2} = \frac{(a-c)^2d^2(1+\alpha)^2}{4(4-(1+\alpha)d)^2(2+(1+\alpha)d)} > 0$
- Output: $\frac{2(a-c)}{4+2d(1+\alpha)} - \frac{4(a-c)}{(4-(1+\alpha)d)(2+(1+\alpha)d)} = -\frac{(a-c)d(1+\alpha)}{(4-(1+\alpha)d)(2+(1+\alpha)d)} < 0$
- Shipping line profits: $\frac{(a-c)^2(1+d\alpha)}{4(2+(1+\alpha)d)^2} - \frac{4(a-c)^2(1+d\alpha)}{(4-(1+\alpha)d)^2(2+(1+\alpha)d)^2} = -\frac{(a-c)^2d(1+\alpha)(1+d\alpha)(8-(1+\alpha)d)}{4(4-(1+\alpha)d)^2(2+(1+\alpha)d)^2} < 0$
- Social welfare: $\frac{(a-c)^2(7+(3+4\alpha)d)}{4(2+(1+\alpha)d)^2} - \frac{4(a-c)^2(7+d(1+2\alpha)-(1+\alpha)^2d^2}{(4-(1+\alpha)d)^2(2+(1+\alpha)d)^2} = -\frac{(a-c)^2d(1+\alpha)(24+d(1+9\alpha-d(1+\alpha)(3+4\alpha)))}{4(4-(1+\alpha)d)^2(2+(1+\alpha)d)^2} < 0$

Proof of Proposition 5

Regarding social welfare, we have to prove that $SW^R > SW^S$ and $LSW^R > LSW^S$, that is, $SW^R - SW^S > 0$ and $LSW^R - LSW^S > 0$, then: $SW^R - SW^S = LSW^R - LSW^S = \frac{(a-c)^2(2-(1+\alpha)d)(10-(1-5\alpha)d-(1+\alpha)(1+2\alpha)d^2)}{(4-(1+\alpha)d)^2(2+(1+\alpha)d)^2} > 0$

By inspection, every term is positive. The third term in brackets in the numerator is also positive, because $10 + 5d\alpha > d + (1+\alpha)(1+2\alpha)d$, and the maximum sum of the terms in the right place of the inequality is 7, which is fewer than 10.

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