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ABSTRACT

There are many industries in which potentially competitive segments require services provided by natural–monopoly bottlenecks (essential facilities). Since it is difficult to regulate these facilities, developing countries are using Demsetz auctions, where the facility is awarded to the firm that bids the lowest user fee. In this paper we show that when underhand agreements between the monopoly bottleneck and downstream firms are possible, Demsetz auctions need floors on bids, since otherwise welfare can be lower than with an unregulated monopoly.

We model an underhand agreement using a standard hidden–information model. The essential facility is an uninformed principal randomly matched to a downstream company, which observes its costs after closing the underhand agreement. When the essential facility prefers the option of vertical separation, there is downstream competition, which implies that only low cost firms survive.

We find that a sufficiently high floor on bids promotes vertical separation, yielding higher welfare than either an unregulated or a vertically integrated monopoly. Moreover, prohibiting *open* vertical integration means this floor can be lower, thus enhancing welfare. The incentive compatibility constraints required by underhand agreements imply rent sharing and production distortions that make vertical integration less attractive.

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1 Introduction

There are many industries where a potentially competitive segment requires the services provided by natural–monopoly bottlenecks, the so-called *essential facilities*.[1] Regulating these facilities is difficult in general, even more so for the weak regulatory institutions common in developing countries. Hence, some countries have turned to Demsetz auctions, where the facility is awarded to the firm that bids the lowest user fee.[2] Demsetz (1968) showed that this simultaneously achieves ex post rent extraction and second-best efficient pricing.[3] This paper shows, however, that if the monopoly is allowed to integrate vertically, a Demsetz auction may be even worse than no regulation at all on the bottleneck monopoly. In those circumstances, having a floor on the fee that can be bid and prohibiting (open) vertical integration can raise welfare.

The central tradeoff in this paper is that a minimum bid above average costs can foster competition and productive efficiency under asymmetric information, even though it distorts the downstream market. We can use this tradeoff to motivate the model and provide the main intuition behind the results. Consider first the case of an unregulated bottleneck monopoly, which can charge monopoly fees to downstream firms. As is well known (see Spengler (1950)), if the downstream market is competitive and in the absence of economies of scope, there are no incentives for vertical integration, since the monopoly fee for the use of the essential facility extracts all rents from the downstream market. At the other extreme, suppose that the essential facility is regulated perfectly (in prices) so that it makes no rents ex post but is allowed to integrate downstream. If quality of service is supervised imperfectly, the integrated firm has an incentive to exclude rivals by worsening the service quality, thus effectively extending its monopoly power to the unregulated downstream market.[4] Assume there is uncertainty about the costs of operating in the downstream market. Hence welfare is lower under vertical integration than under an unregulated essential facility, because the expected downstream costs of the integrated bottleneck monopoly are higher than those of the downstream firms that survive in a competitive market.

The standard policy recommendation against service quality discrimination is to ban the bottleneck monopoly from operating in the downstream market. The effectiveness of such prohibitions is

[1] For example, electric transmission and distribution are essential facilities for competitive power generators and suppliers; so is the last mile in telecomms for competitive internet service providers or long distance carriers; and seaports and airports for transportation companies.

[2] This is sometimes known as "competition for the field" (instead of in the field) and goes back at least to Chadwick (1859).

[3] See, however, Williamson (1985) for a critique.

[4] Lower quality may increase the costs of competitors (as, for example, in Economides (1998, 1999)) or reduce the willingness to pay of users for their services.

suspect because they can be circumvented by an (illegal) underhand agreement with a downstream firm. Observe, however, that such agreements introduce an additional source of inefficiency: since there is asymmetric information on the cost parameters of the downstream partner, there is a positive probability of distorted production. Thus underhand agreements further reduce welfare.

On the other hand, the standard incentive-compatibility constraints force the bottleneck monopoly to share rents with its downstream affiliate with positive probability, thus reducing the attractiveness of underhand vertical integration. This implies that there is a wedge between expected profits under underhand and open integration. This wedge can be exploited by setting a floor on user fee bids, inducing the essential facility to operate with a competitive downstream market. The distortions introduced by these fees are relatively small.

Consider first a case where the regulator sets no floor. Since underhand agreements lead to rents for the bottleneck monopoly, competition for the franchise drives fees to zero. If two firms tie their bids at zero, the facility is awarded to the firm that offers to pay the highest sum to the government. Since vertical separation yields *ex post* losses, monopolization through an underground agreement is inevitable. By contrast, suppose that the floor lies above the average cost of the bottleneck. Then a vertically separated essential facility will have rents. Moreover, usage of the facility could be larger than with an underhand agreement because only low-cost companies survive in a competitive market. If the rents received under vertical separation are high enough, the bottleneck monopoly will prefer this option to an underhand agreement. Thus, while a floor above average costs distorts the downstream market, it can foster competition and productive efficiency. This is the central tradeoff we exploit in the paper.

For expositional convenience, henceforth we will talk about "seaports" when we mean essential facilities and "shipping companies" when we have in mind the downstream market.[5] Nevertheless, the results have obvious generalizations to other industries with similar structure. We assume that vertical restrictions are in place so only underhand vertical integration is possible. We also assume that the regulator sets a minimum cargo-handling fee for bids. The port franchise is auctioned to the firm that offers the lowest bid.[6]

We model the underhand vertical integration agreement using a standard hidden–information model. The port is the uninformed principal, randomly matched with a shipping company, which observes whether its constant average cost is high or low after closing the underhand agreement. Another option for the port is to remain vertically separated, allowing shipping companies to com-

[5] See Trujillo and Nombela (2000) for a description of port operations.

[6] If two or more firms offer the floor, the franchise is awarded to the one among them offering the largest up front payment.

pete, so that only low cost shipping companies survive. Clearly, the volume of operations is higher in this case, since first, there is competition rather than monopoly downstream and, second, only low-cost shipping companies operate.

Our main result is that with floors welfare is higher than under both unregulated and vertically integrated monopolies. Moreover, the prohibition of vertical integration plays an important role in ensuring this result, even when underhand integration is feasible. Under such an agreement, the port is forced (by the incentive compatibility constraints) to share rents and distort production decisions, making integration relatively less attractive. For this reason, under restrictions on integration the regulator can set a lower floor than when integration is allowed and still induce the port to choose separation, which provides higher social welfare.

We also show that the regulator must be careful when choosing the floor. If the floor to bids is set too low, then monopolization through an underhand agreement becomes inevitable and welfare is even lower than with an unregulated port monopoly. Because of this, there are compelling reasons to argue that the regulator should be cautious and set the floor "too high" (i.e. higher than the lowest cargo-handling fee that makes the port choose separation) rather than "too low."

Our paper is related to the literature of monopoly regulation via franchising which was pioneered by Chadwick (1859) and Demsetz (1968) (see also Stigler (1968), Posner (1972), Williamson (1976), Riordan and Sappington (1987), Spulber (1989, chap. 9), Laffont and Tirole (1993, chap. 7 and 8), Harstad and Crew (1999) and Engel, Fischer, and Galetovic (1998). We contribute to this literature by studying the interaction between the Demsetz auction and the downstream *ex-post* market structure, allowing for the possibility of underhand vertical integration. We show that departing from second-best pricing and leaving *ex post* rents in the pockets of the monopolist can be welfare increasing when competition in the auction affects *ex post* market structure. Moreover, *ex post* rents need not conflict with full *ex ante* rent extraction.

Our paper is also related to Vickers (1995) who studied vertical integration by a monopoly optimally regulated à la Baron and Myerson (1982) into an industry with symmetric firms under Cournot competition (see also Lee and Hamilton (1999)). We differ from Vickers in that in our model the monopoly is regulated by a Demsetz auction. Moreover, firms are asymmetric in the downstream market, which enables us to consider the selection role of competition. Finally, the downstream market is competitive but can be monopolized by lowering quality to rival firms. We thus study the effects of vertical integration on downstream market structure when quality degradation is a problem, a problem studied by Economides (1998, 1999) in the case of an unregulated monopoly that is vertically integrated with one of many downstream firms competing Cournot (see also Salop and Scheffman (1987)). Finally, note also that Laffont and Tirole (2000, chap. 4) provide a complete analysis of regulation under the standard models of one-way access to an essential facility.

The rest of the paper proceeds as follows. In Section 2 we describe the recent seaport auctions in Chile. This case study motivates some of our assumptions and provides an application of the model; we return to it on various occasions in later sections. In Section 3 we show that vertical separation and asymmetric information on costs force the port to share rents. In Section 4 we study the relation between auction outcomes, downstream market structure and welfare. Section 5 discusses several extensions of the basic model. Section 6 briefly summarizes the results of the Chilean port auction. Finally, several appendices include the main proofs and formalizes extensions.

2 The Chilean seaport auctions[7]

Chile is a country isolated by deserts and mountain ranges from its neighbors. Hence the importance of sea-borne trade, which represents a large fraction of its GDP. The Chilean coastline, while long, offers few sites at which important ports can be built without incurring in large sunk investments in breakwaters. Consequently, there are only three large ports for general cargo (as opposed to bulk cargo).

Traditionally, these ports had been state owned, but in 1981, in response to the inefficiencies of state management, the government allowed private firms to unload, store and customs process cargo. Productivity improved substantially under the new regime. Nevertheless, by the mid-nineties, the main Chilean ports had become congested and the government began to look for alternatives to public funding of additional infrastructure. After consulting with experts, it concluded that further productivity improvements could be achieved only if each individual port was operated by a single firm, which would internalize the benefits of investing in large-scale specialized cranes, of improving the coordination of activities within each port and of investing in other activities with important externalities.[8] The expectation was that efficiency gains could at least double the capacity of the ports without any further investments in basic infrastructure.

To ensure that productivity improvements benefit users, the government designed a competitive auction to award the ports to the firm bidding the lowest cargo handling fee. Nevertheless, regulators feared that if shipping companies won the auction, they would monopolize the port by favoring their own operations and lowering the service quality received by competitors. The advantages of

[7]See Foxley and Mardones (2000) for a description of the Chilean seaport auctions.

[8]For example, Mardones (1999, personal communication) argued that firms did not invest in their worker's human capital because they might be hired away by competitors within the port.

Demsetz auctions would be lost in the process. Even though the regulator sets minimum quality standards, these are difficult to monitor and enforce under the Chilean regulatory and legal system. Thus it is unlikely that quality standards would help avoid monopolization.

This analysis led to restrictions on horizontal and vertical integration that were supposed to prevent monopolization. First, the Antitrust Commission, at the request of the government, established that no single firm could operate all three ports. Second, shipping companies could own not more than 40% of a port operators' equity.[9] In addition, the government fixed a floor for the cargo handling fee. If two or more firms were to bid the floor fee in the auction, the port would be awarded to the firm that offered the highest lump sum payment. [10]

The main Chilean shipping and stevedore companies challenged the restrictions to vertical and horizontal integration in court. They argued that the restrictions would favor foreign operators; and, moreover, that restrictions would be ineffective or unnecessary because a vertically-separated port could easily replicate the integrated outcome by granting a monopoly to one shipping company in exchange for underhand payments. In addition, they argued that two of the main ports (Valparaíso and San Antonio) are less than 60 miles away, and they compete with each other, so there was no danger from monopolization of a port. We will examine these arguments below.

3 Vertical separation and rent sharing

In this section we show that when there is hidden information about the costs of shipping companies, an underhand agreement forces the port to share rents with the shipping company even when there are many potential shipping companies. Thus, prohibiting vertical integration imposes a cost on the port. We start by describing the basic model and then solve the port's optimization problem. In the next section we study the auction of the port franchise.

[9]This restrictions applied to *relevant shipping companies*, that is, those that carry more than 25% of the cargo transferred in the *region* during the previous year (regions are an administrative division of Chile). It is also worth noting that this is a prospective rule, in the sense that it must hold during the life of the franchise. See Foxley and Mardones (2000) for more details.

[10]The floor was fixed so as to cover the rental value of capital invested in the preexisting infrastructure of the port (breakwaters, esplanades, etc). The argument of the regulator was that a lower fee would have prevented the entry of new ports, since they would be unable to compete with franchised ports that need not cover returns on preexisting infrastructure.

3.1 The model

The inverse demand for shipping and handling cargo is $p = D(q)$, with $D' < 0$, where q is the total quantity of cargo handled and p is the price paid by users to shipping companies. We assume that the price p covers all necessary arrangements with the port (see Table 1 for the notation used throughout the paper)

There is a continuum of shipping firms, each with constant average cost of transporting cargo equal to s. A fraction $\lambda \in (0,1)$ of shipping companies has a low average cost of s_ℓ per unit of cargo while the remaining shipping companies have a high average cost $s_h > s_\ell$. The port's average cost of handling a unit of cargo is constant and equal to c. Moreover, we assume that the port is able to lower quality enough to price any shipping company out of the market.

For future reference it is useful to distinguish four possible vertical structures:

Unregulated monopoly with vertical separation: The port is free to choose its fee but is not integrated into the shipping market. There is perfect competition among shipping companies and only low cost firms survive.

Regulated monopoly with vertical separation: In this case, the port charges the fee with which it won the auction. The downstream market works as in the previous case.

Vertical integration: The port is matched at random with a shipper, thus the probability of integrating with a low cost shipper is λ. The port gets to know the shipper's costs after starting operations and excluding other firms. The fee bid in the auction is irrelevant.

Underhand integration: The port establishes an underhand agreement with a randomly chosen shipping company and then discriminates against other shipping companies to exclude them from the market. The shipper learns its costs after starting operations and excluding other firms, while the port does not. Again, the fee bid in the auction is irrelevant.

The key assumption above is that shippers are unaware of their own costs when they operate as monopolies until after they begin operations. This is justified by noting that their previous experience is on a much smaller scale.

We now study the optimal underhand contract.

3.2 Underhand agreements

Suppose that vertical integration is prohibited but the port decides to establish an underhand agreement with a shipping company and degrade the quality to exclude rivals. The only observable

Table 1: The notation used throughout the paper is the following:

SYMBOLS

$D(q)$:	inverse demand for shipping
$q(p)$:	demand for shipping
q:	cargo handled
p:	price paid by users
c:	constant average cost of port operations
s:	shipping company's marginal cost
λ:	fraction of low-cost shipping companies
A:	fixed fee paid by shipping company
r:	per-unit fee paid by shipping company
Π:	port + shipping profits
$\pi(A,r)$:	port profits with underhand agreement
π^v:	port profits with volume operation
W:	welfare
w:	cargo handling fee per unit

SUB AND SUPERSCRIPTS

*:	outcomes with an underhand agreement
ι:	outcomes with a vertically integrated monopoly
v:	volume
ℓ:	low cost
h	high cost

variable that can be used in the underhand contract is the amount of cargo q that is handled through the port. Since the shipping company belongs to one of two types, the port can offer a menu of contracts

$$A_i + r_i q_i,$$

$i = \ell, h$ where A_i is a fixed amount and r_i is a per-unit fee (refer to Table 1 for the notation used in the paper). The revelation principle implies that the port will maximize its rent by using a direct, incentive–compatible mechanism such that $(A_i, r_i)_{i=\ell,h}$ that maximize

$$\lambda[A_\ell + (r_\ell - c)q_\ell] + (1-\lambda)[A_h + (r_h - c)q_h] \tag{1}$$

subject to

$$(p_i - s_i - r_i)q_i - A_i \geq 0, \quad i = h, l \tag{2}$$

$$(p_\ell - s_\ell - r_\ell)q_\ell - A_\ell \geq (p_h - s_\ell - r_h)q_h - A_h, \tag{3}$$

$$(p_h - s_h - r_h)q_h - A_h \geq (p_\ell - s_h - r_\ell)q_\ell - A_\ell, \tag{4}$$

$$(p_i - s_i - r_i) + q_i D_i' = 0, \quad i = h, l, \tag{5}$$

where $D_i' \equiv D'(q_i)$. The first pair of inequalities (2) represents the two standard participation constraints. Since the agreement is illegal, there are no legally binding contracts and the port must ensure the shipping company at least zero profits regardless of the shipping company's cost. The next pair of inequalities, (3) and (4), are standard incentive–compatibility constraints. The last equality (5) appears because the shipping company is free to choose a price that maximizes monopoly profits given it faces costs $s_i + r_i$.

Solving this problem leads to the following result:

Proposition 1 *Let $(A_i^*, r_i^*)_{i=\ell,h}$ be the contract that solves (1)–(5); let $(p_i^*, q_i^*)_{i=\ell,h}$ be the corresponding quantities and prices chosen by the shipping company and $\Pi(q_i^*)$ the combined profits. Moreover, let $(A_i^\iota, r_i^\iota)_{i=\ell,h}$ be the contract that the port would impose if it knew the shipping company's costs, $(p_i^\iota, q_i^\iota)_{i=\ell,h}$ the corresponding prices and quantities and $\Pi(q_i^\iota)$ the corresponding combined profits. Then*

(a) $r_\ell^* = c = r_\ell^\iota$ and $r_h^* = c + \frac{\lambda}{1-\lambda}(s_h - s_\ell) > c = r_h^\iota$;

(b) $p_\ell^* = p_\ell^\iota$ and $p_h^* > p_h^\iota$;

(c) $A_\ell^* < \Pi(q_\ell^*) = \Pi(q_\ell^\iota) = A_\ell^\iota$ and $A_h^* + (r_h^* - c)q_h^* = \Pi(q_h^*) < \Pi(q_h^\iota) = A_h^\iota$.

Proof: See Appendix A. ∎

Note that the full-information contract $(A_i^\iota, r_i^\iota)_{i=\ell,h}$ replicates the outcome of a vertically integrated port. Hence, Proposition 1 shows that the restriction on vertical integration reduces port profits for two reasons. First, the port sets a per-unit charge of $r_h^* > c$, which distorts (optimally) the decisions of the high-cost shipper. Second, the port must transfer an informational rent to the low-cost shipper. Since $s_h > s_\ell$ and $(p_h^* - s_h - r_h^*)q_h^* - A_h^* = 0$, the low-cost shipper makes a profit

$$(p_h^* - s_\ell - r_h^*)q_h^* - A_h^* = (s_h - s_\ell)q_h^* > 0$$

by claiming that its cost is high. This sets a lower bound on the rent that the low-cost shipper receives. We have that the port's expected utility under vertical separation is

$$\mathsf{E}_i\pi(A_i^*, r_i^*) = \lambda A_\ell^* + (1-\lambda)\Pi(q_h^*),$$

where $\pi(A,r)$are the port's profits when establishing an underhand agreement which charges a fixed fee A and a per-unit fee r. These profits are lower than the profits of a vertically integrated port

$$\mathsf{E}_i\pi(A_i^\iota, r_i^\iota) = \mathsf{E}_i\Pi(q_i^\iota) = \lambda\Pi(q_\ell^\iota) + (1-\lambda)\Pi(q_h^\iota),$$

since $A_\ell^* < \Pi(q_\ell^\iota)$ as shown in Proposition 1.

For future reference it is useful to compute aggregate welfare with underhand and vertical integration. Let $\mathrm{W}(q)$ be aggregate welfare when q units of cargo are handled, then

$$\mathsf{E}_i\mathrm{W}(q_i^*) \equiv \lambda \left[\int_0^{q_\ell^\iota} D(q)\mathrm{d}q - (c+s_\ell)q_\ell^\iota\right] + (1-\lambda)\left[\int_0^{q_h^*} D(q)\mathrm{d}q - (c+s_h)q_h^*\right]$$

and

$$\mathsf{E}_i\mathrm{W}(q_i^\iota) \equiv \lambda \left[\int_0^{q_\ell^\iota} D(q)\mathrm{d}q - (c+s_\ell)q_\ell^\iota\right] + (1-\lambda)\left[\int_0^{q_h^\iota} D(q)\mathrm{d}q - (c+s_h)q_h^\iota\right].$$

Clearly $\mathsf{E}_i\mathrm{W}(q_i^*) < \mathsf{E}_i\mathrm{W}(q_i^\iota)$ since $q_h^* < q_h^\iota$. Moreover, if the cost of the shipping company is low, aggregate welfare under vertical integration equals welfare under separation.

4 Auction design

In the previous section we showed that vertical separation reduces the attractiveness of monopolizing the shipping market. In this section we study the interaction between the restrictions on vertical integration and the rules of the auction.

4.1 Timeline

The timing of the game is as follows:

1. The regulator sets a floor $\underline{w}$ for the fee per unit of cargo.

2. Each bidder $i = 1, \ldots, n$ submits a bid $(w_i, G_i) \in \mathrm{IR}^2_+$, where w is the per unit cargo handling fee and G is an up-front payment to the government.

3. If $\min_j w_j > \underline{w}$, the port is awarded to the firm bidding $\min_j w_j$. If $\min_j w_j \leq \underline{w}$ the port is awarded, among the firms that bid $\underline{w}$ or less, to the one that offers the largest G_j.

4. After the franchise is awarded the port chooses one of two strategies. Under the $\mathcal{U}$ (underhand) strategy, it establishes a monopolization agreement with a shipping company chosen at random. Under the $\mathcal{V}$ (volume) strategy, it operates the port so as to maximize the volume of cargo, charging at most $\min_j w_j$ per unit.

5. If the port decides to use the $\mathcal{U}$ strategy then:

   - The port offers the shipping company a take-it-or-leave-it underhand contract.
   - The port lowers service quality to rivals and the market is monopolized.
   - The shipping company learns its cost and the contract is implemented.

6. If the port chooses the $\mathcal{V}$ strategy, there is free competition in the shipping market.

Observe that competition for the franchise leads to rent dissipation. Nevertheless, different cargo handling fees will affect demand and the structure of the shipping market.

4.2 Ex post market structure and welfare

As usual, it is convenient to solve the game by backwards induction. Assume that the outcome of the auction is a cargo handling fee w. The port can choose one of two strategies: operate for volume, $\mathcal{V}$, or underhand integration, $\mathcal{U}$. We begin by analyzing the port's decision and the ensuing market structure. Next we study aggregate welfare in each case.

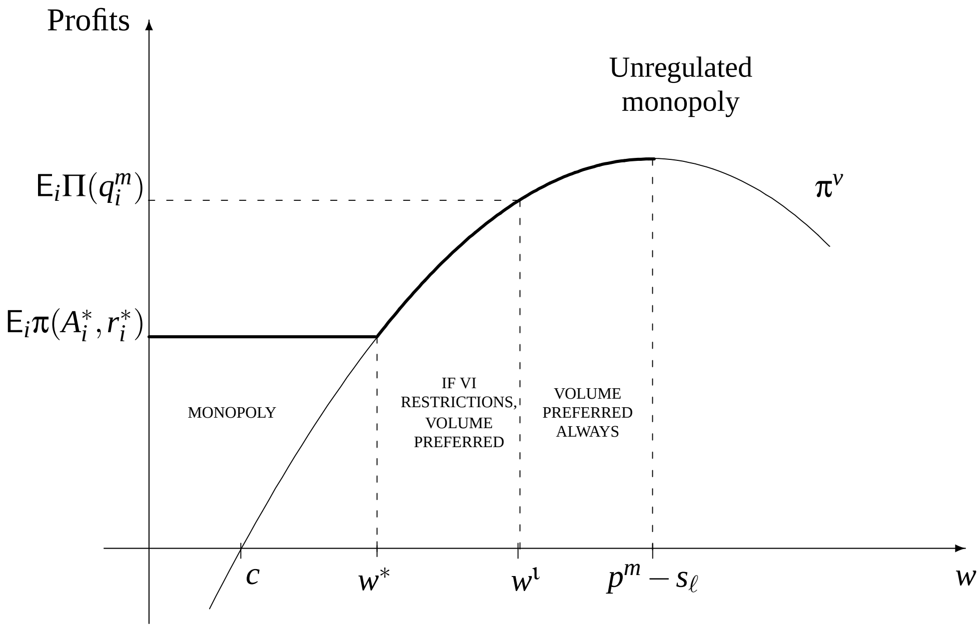

Figure 1: Port profits and market structure

Market structure Consider first the profits of the port using the $\mathcal{V}$ strategy. Call p^v the price paid by users when the port follows strategy $\mathcal{V}$. Since the shipping market is competitive and low-cost shipping companies will drive high-cost shipping companies out of business, the price paid by users will equal the cost of low-cost shipping companies plus the fee for using the port. Thus, in equilibrium

(6) $$p = s_\ell + w \equiv p^v.$$

The total quantity of cargo handled will be $q^v \equiv q(p^v)$ (where $q(p)$ denotes the demand function, i.e., $D^{-1}(p)$ in the notation of Section 3) and the port will make profits equal to

(7) $$\pi^v(w) \equiv (w - c)q(s_\ell + w).$$

Figure 1 plots the profit function (7), which is continuous and strictly increasing in the relevant range if the standard conditions that ensure strict quasiconcavity hold. $\pi^v(w)$ peaks at $w^m \equiv p^m - s_\ell$, where $p^m = \arg\max\ (p - s_\ell - c)q(p)$, the fee that would be set by an unregulated, vertically separated port. As is well known, the port can exploit all its monopoly power by choosing w such that $w + s_\ell = p^m$.

Now, since $\pi^v(c) = 0$, $\pi^v$is increasing in the interval $[c, p^m - s_\ell]$ and there exists $w^* \in (c, p^m - s_\ell)$ such that

$$\pi^v(w^*) = \mathsf{E}_i \pi(A_i^*, r_i^*),$$

that is, w^* is such that profits from the volume and the underhand strategies are the same. There also exists $w^\iota \in (c, p_\ell^m - s_\ell)$ such that

$$\pi^v(w^\iota) = \mathsf{E}_i \Pi(q_i^\iota) \tag{8}$$

with $w^* < w^\iota$, since $\mathsf{E}_i \pi(A_i^*, r_i^*) < \mathsf{E}_i \Pi(q_i^\iota)$ as shown in the previous section. Note also that $\mathsf{E}_i \Pi(q_i^\iota) < \Pi^\eta(w^m)$ because the expected value considers the possibility of integration with a high cost firm. The following results are now apparent from Figure 1:

Result 4.1 *When w is close enough to $p^m - s_\ell$ the port prefers volume operations.*

Result 4.2 *If w is sufficiently low, the port will monopolize the shipping market through an underhand agreement.*

Result 4.3 *Vertical separation makes volume operation relatively more attractive.*

Result 4.1 shows that a competitive shipping market ($\mathcal{V}$) is more attractive when the fee w is high. To see the intuition, assume that $w = p^m - s_\ell$. In this case competition weeds out all inefficient shipping companies and the port makes the same profits as an unregulated monopoly. By contrast, if the port chooses to establish an underhand agreement, it must not only share rents and distort production, but it may also pair up with an inefficient shipping company. This makes an underhand agreement less attractive than operating for volume..

If the cargo handling fee w falls, competition in the shipping market transfers more of the efficiency gains to users via lower prices p, but this lowers profits for the port. There is a value of the fee w^* such that monopolizing the shipping market becomes more attractive, despite the costs of underhand agreements. Interestingly, underhand profits do not depend on w and remain constant at $\mathsf{E}_i \pi(A_i^*, r_i^*)$.

Result 4.3 shows that restrictions on vertical integration enlarge the range of auction outcomes w such that the port chooses the $\mathcal{V}$ strategy and a competitive shipping market results. The reason is quite clear: an underhand integration, even when it cannot be penalized, is not a perfect substitute for legal vertical integration.

Welfare Consider welfare as a function of w. If the port chooses the volume strategy, aggregate welfare is

$$W(q^v) \equiv \int_0^{q^v} D(q)\mathrm{d}q - (c+s_\ell)q^v,$$

i.e., total user surplus minus port and efficient firm shipping costs. Now $d\mathrm{W}(q^v)/dw = [D(q^v) - c - s_\ell]dq^v/dw < 0$ for $w > c$, since $D(q^v) \equiv w + s_\ell > c + s_\ell$ and $dq^v/dw < 0$. On the other hand, with underhand integration, welfare equals $\mathsf{E}_i\mathrm{W}(q_i^*)$. The following proposition compares welfare with competitive and monopolized shipping markets:

Proposition 2 *$W(q^v) > \mathsf{E}_i\mathrm{W}(q_i^\iota) > \mathsf{E}_i\mathrm{W}(q_i^*)$ and $W(q^v) \geq \mathrm{W}(q_i^\iota) \geq \mathrm{W}(q_i^*)$ for $i = \ell, h$. Thus, welfare is always higher when the port chooses a competitive shipping market.*

Proof: Since $d\mathrm{W}(q^v)/dw < 0$ for $w \in [c, p^m - s_\ell]$ and $q^v = q_\ell^\iota$ when $w = p^m - s_\ell$, it follows that welfare with a competitive shipping market is at least equal to $\mathrm{W}(q_\ell^\iota) = \int_0^{q_\ell^\iota} D(q)\mathrm{d}q - (c+s_\ell)q_\ell^\iota$ and generically higher. Now recall that

$$\mathsf{E}_i\mathrm{W}(q_i^\iota) = \lambda\mathrm{W}(q_\ell^\iota) + (1-\lambda)\mathrm{W}(q_h^\iota) > \mathsf{E}_i\mathrm{W}(q_i^*) = \lambda\mathrm{W}(q_\ell^\iota) + (1-\lambda)\mathrm{W}(q_h^*)$$

because $q_\ell^\iota > q_h^*$, from which the result follows. ∎

Proposition 2 implies that vertical and underhand integration reduce welfare. There are three sources of inefficiency when the port chooses underhand integration. First, the standard allocative inefficiency of monopoly, which is also present in an unregulated market (i.e., when the port freely chooses w). Second, underhand integration leads to productive inefficiency, because a high-cost shipping company may be chosen to monopolize the market. And third, the high cost firm faces distorted fees in order to lower the cost of the incentive constraint on the low cost firms.

Figure 2 depicts welfare as a function of the cargo handling fee given the (privately) optimal decision of the port. As long as $w \in [w^*, p^m - s_\ell]$ the port chooses a competitive shipping market when vertical integration is illegal. Welfare increases as we move leftward and w falls; it reaches a maximum when $w = w^*$. The intuition is simple. In that range a lower w leads to a lower shipping fee p and users receive an increasing fraction of the benefits from an efficient shipping market. When the cargo handling fee falls below w^*, the shipping market becomes a monopoly. Welfare jumps down to $\mathsf{E}_i\mathrm{W}(q_i^*)$ and becomes independent of w.

Restrictions on vertical integration have two consequences which differ depending on w. First, they enlarge the range of w's for which the port chooses a competitive shipping market. Obviously, in the interval $[w^*, w^\iota)$ they increase welfare. On the other hand, when the fee is too low, restrictions do not prevent monopolization, so welfare is lower.

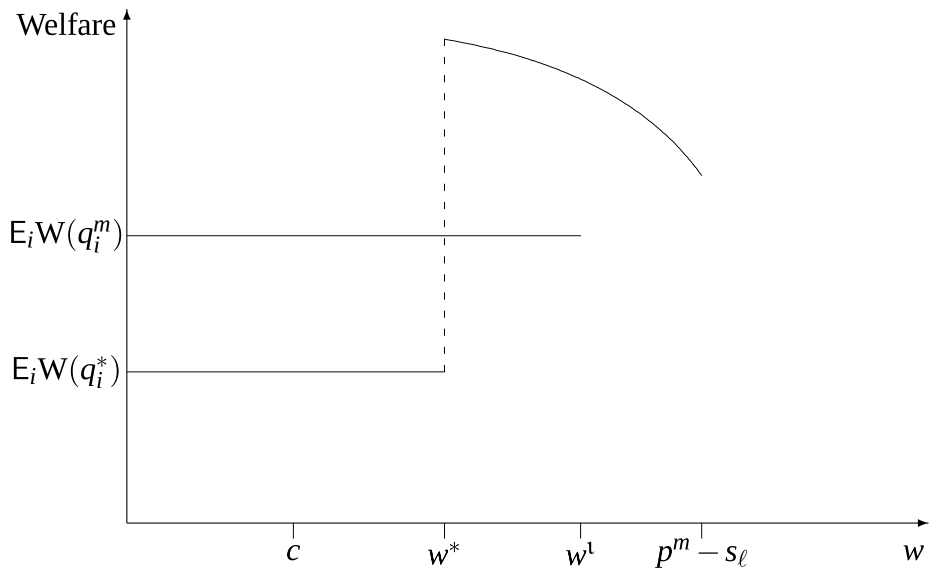

Figure 2: Welfare and market structure

4.3 Auction rules, market structure and welfare

The previous sections have shown how the structure of the shipping market and the welfare impact of the restrictions on vertical integration depend on the fee that wins the auction. In this section we examine the auction for the port franchise.

We begin by considering the case where there is no floor (i.e., $\underline{w} = 0$). In this case, $\min_j w_j > 0$ cannot be an equilibrium, for then it pays to set w slightly below $\min_j w_j$ and receive profits which are at least $\mathsf{E}_i\pi(A_i^*, r_i^*) > 0$ if vertical integration is not allowed and $\mathsf{E}_i\Pi(q_i^\iota) > 0$ if it is. Since neither $\mathsf{E}_i\pi(A_i^*, r_i^*)$ nor $\mathsf{E}_i\Pi(q_i^\iota)$ depend on the fee when w is low enough, competition drives $\min_j w_j$ to zero. Moreover, since monopoly profits do not depend on w, $\max_j G_j < \mathsf{E}_i\pi(A_i^*, r_i^*)$ cannot be an equilibrium either. Hence, we have established the following result:

Result 4.4 *(i) If* $\underline{w} = 0$ *and vertical integration is prohibited then in equilibrium* $\min_j w_j = 0$ *and* $\max_j G_j = \mathsf{E}_i\pi(A_i^*, r_i^*)$*; (ii) if* $\underline{w} = 0$ *and vertical integration is allowed then in equilibrium* $\min_j w_j = 0$ *and* $\max_j G_j = \mathsf{E}_i\Pi(q_i^\iota)$.

Result 4.4 shows that in a precise sense competition for the franchise can be too intense. If there is no floor ($\underline{w} = 0$), competition brings w down to the range where monopolization becomes attractive. When $\underline{w} \in [0, w^*)$, the auction leads to a fee of $\underline{w}$ and underhand agreements ensue.

Thus, the auction inevitably leads to a monopolized shipping market. While ex ante competition for the franchise extracts all expected rents from bidders, Proposition 2 and Result 4.4 imply the following somewhat surprising corollary, which is apparent from Figure 2:

Corollary 1 *If $\underline{w} < w^*$, then (i) welfare is lower than with an unregulated port and (ii) restrictions on vertical integration reduce welfare.*

Simple inspection of Figures 1 and 2 shows that the regulator can do much better by setting a floor $\underline{w} \geq w^*$. Competition for the franchise will drive the cargo handling fee to $\underline{w}$ and the port will choose a competitive shipping market. Any rents that the port may make will be competed away through the lump sum payment G. These facts can be summarized in the following result:

Result 4.5 *(i) If $\underline{w} \geq w^*$ and vertical integration is prohibited then in equilibrium $\min_j w_j = \underline{w}$ and $\max_j G_j = \pi^v(\underline{w})$; (ii) if $\underline{w} \geq w^\iota$ and vertical integration is allowed then in equilibrium $\min_j w_j = \underline{w}$ and $\max_j G_j = \mathsf{E}_i \Pi(q_i^\iota)$.*

Thus, restrictions on vertical integration can be welfare enhancing when combined with a floor $\underline{w} \geq w^*$, since they allow the regulator to set a lower $\underline{w}$ than without the restrictions. Alternatively, for a given $\underline{w}$, restrictions on vertical integration make it less likely that the shipping market will be monopolized. In any case, Result 4.4 suggests that if there is doubt about the true value of w^*, the regulator should err by setting a value of the floor $\underline{w}$ above w^*.

A second implication of the preceding results, which is apparent from Figure 1, is that the government obtains a higher lump sum payment if it sets a floor above w^* than when shipping is monopolized through an underhand agreement. For higher floors to the bid there is a tradeoff between revenue and welfare: a higher floor $\underline{w}$ yields more revenue in the auction but decreases welfare. It follows that the revenue generated in the auction is not necessarily a good indicator of welfare.

5 Extensions

In this section we discuss three extensions which generalize the rent-sharing-cum-inefficiency result on which our results are based. The underlying models are provided in the appendix.

Repetition In the real world, a port that establishes an underhand agreement with an inefficient shipping company will eventually find out the shipping costs and will look for another partner.

However, there is no guarantee that the new shipping company will be efficient, so it is possible that the port establishes consecutive agreements with several shipping companies before eventually finding the right partner. We show in Appendix B that the solution to this multi-period problem is to offer the same menu of underhand agreements as in the one-period game until the port finds a low cost shipping company, at which point it establishes a long term agreement and extracts all the surplus in each following period. Interestingly, there is no ratcheting in this case.

If periods are short, i.e., it is easy to switch to another shipping company, underhand integration becomes more attractive, since the port will find an efficient partner fairly quickly, so it will share only a small fraction of total rents. Restrictions on vertical integration are less effective in this case. By contrast, if replacing shipping companies takes a long time, the one period model is a good approximation and restrictions to vertical integration are an effective means of having a competitive shipping market.

Specific investments and shipping company's opportunism While many port assets are sunk and specific, ships are mobile. Since an underhand agreement is by definition an incomplete contract, the shipping company may hold up the port. In Appendix C, where we abstract from asymmetric information considerations, we consider a model in which the port undertakes sunk investments in equipment that can be used by any shipping company. It is shown that vertical separation reduces rents obtained by the port because it leads to underinvestment, even when the port can extract all *ex ante* rents by making the shipping companies compete to be selected. By contrast, when the shipping market is competitive, a shipping company cannot hold up the port. Hence, vertical separation reduces the relative attractiveness of monopolizing the shipping market.[11]

Oligopoly and collusion As mentioned in Section 2, Chilean shipping companies argued that restrictions on vertical integration were irrelevant because ports would compete with each other. This is doubtful, since ports are few in Chile and therefore collusive agreements are likely. It is shown in Appendix D that vertical separation reduces the rents that ports can make from collusion. That is, any combination of collusive prices that can be sustained with vertical separation can also be sustained under vertical integration, and ports make higher profits in the second case. By making monopolization relatively less attractive, restrictions on vertical integration increase the likelihood that the port chooses the strategy of maximizing volume. The reason is that, as in our previous model, vertical separation forces ports to give shipping companies some informational rents.

[11]Of course, the difference is larger when it is harder to replace the shipping company.

6 Epilogue

In several decisions, the Chilean appellate and supreme courts decided, partly on the basis of the preceding reasoning, that the arguments of the port authority for restrictions on vertical integration were reasonable, i.e., that the limits to vertical integration would make it less likely that the main ports would be operated by monopoly shipping companies. After the delays caused by the injunctions, the port authority was finally able to proceed with the auction of the main ports. There was a satisfactory number of participants in the bidding process (14 for all ports), including domestic and international firms. The domestic shipping lines participated in joint ventures with foreign specialists in port management.

In all three franchises the fees were attained.[12] These were approximately 10% lower than the rates under the private, multi-operator scheme. The three winning bids were offered by a company which was 40% owned by the shipping company who had been the strongest opponent of restrictions on vertical integration. However, by the rules of the bidding process, the port authority awarded one of the ports (Valparaíso) to the runner up. In the end, the government received US$294 million for the three franchises, twice as much as expected (all participants offered an upfront payment).

Whether the government succeeded in preventing the monopolization of the shipping business in Chile's main ports remains an open question that will be answered by a future evaluation of the franchises' performance. However, the analysis has shown that the restrictions on vertical integration plus a minimum per-unit charge for port operations make it less likely that the winners will operate as port monopolies.

[12] A fourth franchise for a less important bulk cargo port was also successful. However, in a second round of auctions for smaller local ports, there was less interest: one was deserted (Arica), while the other had only one bidder (Iquique).

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Appendices

A Proof of Proposition 1

Let $\mathcal{L}$ be the Lagrangian associated to problem (1), and η_i, μ_i and ψ_i, $i = \ell, h$ be the positive multipliers associated with constraints (2), (3–4), (5), respectively.

From the incentive-compatibility constraint (3) and the participation constraint (2) for the high cost shipper it follows that

$$\begin{aligned} (p_\ell - s_\ell - r_\ell)q_\ell - A_\ell &\geq (p_h - s_\ell - r_h)q_h - A_h \\ &> (p_h - s_h - r_h)q_h - A_h \\ &\geq 0. \end{aligned}$$

Hence, the participation constraint of the low-cost shipping company holds with slack and $\eta_\ell = 0$.[13]

Now, from the first order conditions for the A_i, it follows that

$$\frac{\partial \mathcal{L}}{\partial A_\ell} = \lambda - \mu_\ell + \mu_h = 0, \tag{9}$$

$$\frac{\partial \mathcal{L}}{\partial A_h} = (1-\lambda) - \eta_h - \mu_h + \mu_\ell = 0. \tag{10}$$

Solving for λ in (9), then substituting into (10) and rearranging yields $\eta_h = 1$. Hence the participation constraint of the high-cost shipping company binds—all rents are extracted from the high-cost shipping company. Moreover, if $\mu_\ell = 0$ we have $\mu_h = -\lambda < 0$, a contradiction. Hence $\mu_\ell > 0$ and the incentive compatibility constraint for the low-cost firm is binding and the firm is indifferent between behaving as a high- or low-cost firm.

Since η_h and μ_ℓ are strictly positive, we have

$$A_h = (p_h - s_h - r_h)q_h, \tag{11}$$

$$A_\ell = (p_\ell - s_\ell - r_\ell)q_\ell - (s_h - s_\ell)q_h, \tag{12}$$

where $(s_h - s_\ell)q_h$ is the information rent appropriated by the low-cost shipping company.

[13] The strict inequality in the derivation above assumes that $q_h > 0$. As will become clear by the end of the proof, this requires that the shipper's optimal q for $r = c + \frac{\lambda}{1-\lambda}(s_h - s_\ell)$ be positive.

From (11) it follows that (4) is equivalent to

$$A_\ell \geq (p_\ell - s_h - r_\ell)q_\ell,$$

which by (12) is equivalent to

$$(s_h - s_\ell)(q_h - q_\ell) \geq 0$$

and therefore to $q_\ell \geq q_h$. In what follows we ignore this constraint, solve the port's optimization problem and then show that the resulting values of q_ℓ and q_h satisfy the constraint (with strict inequality).

Using (11) and (12) to substitute for A_h and A_ℓ, we can rewrite problem 1 as

$$\max_{(r_\ell, r_h)} \{\lambda[(p_\ell - s_\ell - c)q_\ell - (s_h - s_\ell)q_h] + (1-\lambda)(p_h - s_h - c)q_h\}$$

subject to

$$(p_i - s_i - r_i) + q_i D_i' = 0,$$

$i = \ell, h$. The first order conditions are

$$\frac{\partial \mathcal{L}}{\partial r_\ell} = \lambda[(p_\ell - s_\ell - c) + q_\ell D_\ell'] \frac{\mathrm{d}q_\ell}{\mathrm{d}r_\ell} + \psi_\ell \frac{\partial}{\partial r_\ell}[(p_\ell - s_\ell - r_\ell) + q_\ell D_\ell'] = 0 \tag{13}$$

$$\frac{\partial \mathcal{L}}{\partial r_h} = \left\{(1-\lambda)[(p_h - s_h - c) + q_h D_h'] - \lambda(s_h - s_\ell)\right\} \frac{\mathrm{d}q_h}{\mathrm{d}r_h}$$
$$+\psi_h \frac{\partial}{\partial r_h}[(p_h - s_h - r_h) + q_h D_h'] = 0. \tag{14}$$

Given s_i, the shipping company's first order condition defines q_i as a function of r_i which, by the second order conditions, is strictly decreasing. It follows that we may differentiate with respect to r_i the first order condition to obtain:

$$\frac{\partial}{\partial r_i}\left\{p_i - s_i - r_i + D_i' q_i\right\} \equiv 0.$$

Now $p_\ell - s_\ell - c = p_\ell - s_\ell - r_\ell + (r_\ell - c)$. Hence, one can rewrite (13) as

$$\lambda(r_\ell - c)\frac{\mathrm{d}q_\ell}{\mathrm{d}r_\ell} = 0$$

where, as mentioned above, $\mathrm{d}q_\ell/\mathrm{d}r_\ell < 0$. Therefore we have $r_\ell^* = c$. Doing a similar substitution for (14) we obtain that

$$[(1-\lambda)(r_h-c)-\lambda(s_h-s_\ell)]\frac{\mathrm{d}q_h}{\mathrm{d}r_h}=0$$

with $\mathrm{d}q_h/\mathrm{d}r_h<0$ Hence we have that

$$r_h^*=c+\frac{\lambda}{1-\lambda}(s_h-s_\ell)>c.$$

It now is straightforward to see that $q_\ell>q_h$. Also, trivially, the full information contract that the port would impose is such that the A_i^ι's extract all rents and the r_i^ι's equal marginal cost c. This concludes the proof of part (a). Part (b) follows from part (a) and the fact that the q_i's are decreasing in the r_i's and $D'<0$. Last, part (c) follows from the fact that the high-cost shipping company pays a distorted fee per unit of cargo handled and the low-cost shipping company appropriates the information rent.

B Repetition

Consider the case in which the game is repeated each period, with a large number of periods. In this case the port franchise can offer a contract to the shipping company with the explicit threat of terminating the contract if it turns out to be a high cost firm. Note that if the firm is a high cost firm, it behaves exactly as before, lasts one period and the port franchise chooses another firm from the large number of potential firms. If it is a low cost firm, the port can pay the shipping company enough to make it profitable to reveal its type and then extract all the rent, thus getting the integrated port profits with a low cost shipping company, $\Pi(q_\ell^\iota)$, each period (Besanko, 1985). Letting V be the expected value of discounted profits, with discount factor δ, we obtain the following Bellman equation:

$$V=\max_{\{A_\ell,A_h,r_\ell,r_h\}}\lambda\left\{[A_\ell+(r_\ell-c)q_\ell]+\delta\sum_{t=0}^{\infty}\delta^t\Pi(q_\ell^\iota)\right\}+(1-\lambda)\left\{[A_h+(r_h-c)q_h]+\delta V\right\}$$

subject to

$$\begin{aligned}
(p_\ell-s_\ell-r_\ell)q_\ell-A_\ell &\geq 0,\\
(p_h-s_h-r_h)q_h-A_h &\geq 0,\\
(p_\ell-s_\ell-r_\ell)q_\ell-A_\ell &\geq (p_h-s_\ell-r_h)q_h-A_h,\\
(p_h-s_h-r_h)q_h-A_h &\geq (p_\ell-s_h-r_\ell)q_\ell-A_\ell,
\end{aligned}$$

$$
\begin{aligned}
(p_\ell - s_\ell - r_\ell) + q_\ell D'_\ell &= 0, \\
(p_h - s_h - r_h) + p_h D'_h &= 0.
\end{aligned}
$$

Note that the problem facing a shipping company is the same as before, since a low-cost shipping company receives no rent after the first period and a high-cost shipping company is discarded. There is no ratchet effect here because the high-cost shipping company is discarded in the second period, which implies that the low-cost shipping company's payoff after the second period is zero regardless of what it declares in the first period. Hence, the shipping company faces the same incentives and behaves exactly like in the one-period game. It follows that we can replace the values obtained in the one-period game to obtain the modified Bellman equation. Recall that $A^*_\ell = [D(q^*_\ell) - s_\ell - c]q^*_\ell - (s_h - s_\ell)q^*_\ell \equiv \Pi(q^*_\ell) - (s_h - s_\ell)q^*_\ell$ are the profits made by the port when contracting a low cost firm in the static game and $\Pi(q^*_h) = [D(q^*_h) - s_\ell - c]q^*_h$ are the profits when contracting with a high cost firm. Replacing in the value function we obtain that

$$
V = \lambda\left(\frac{\Pi(q^*_\ell)}{1-\delta} - (s_h - s_\ell)q^*_h\right) + (1-\lambda)[\Pi(q^*_h) + \delta V]
$$

which leads to the expression for the value function:

$$
V = \frac{1}{1-(1-\lambda)\delta}\left\{\lambda\left[\frac{\Pi(q^*_\ell)}{1-\delta} - (s_h - s_\ell)q_h\right] + (1-\lambda)\Pi(q^*_h)\right\}.
$$

Note that as $\delta \to 1$, there is no discount of the future, and the value function is dominated by the profits of a low-cost shipping company. After a number of periods, the probability that the shipping company is not an efficient firm is vanishingly small, and as waiting is not costly, the results are dominated by the profits obtained from low cost firms. It is also interesting to note that even as $\lambda \to 1$, the port franchise cannot extract all profits from the low cost firm, which can always claim being a high-cost firm.

C Specific investments and shipping company's opportunism

In this appendix we examine a different source of rent sharing and inefficiency, which arises from specific investments and opportunism. Assume that, as before, the marginal cost of handling a unit of cargo is constant, but it is a function of the amount invested by the port in site-specific assets. Thus, marginal cost is a function $c(I)$, with $c' > 0$, $c'' > 0$, where I is the amount invested. To simplify the analysis, we assume that there is symmetric information.

Assume that the port invests I. Then ex-post total profits are

$$\Pi = [p - s - c(I)]q.$$

Clearly, regardless of how Π is shared, it is optimal to set q equal to the monopoly quantity. Moreover, since the contract is incomplete any *ex ante* sharing agreement is irrelevant. Thus we assume that after bargaining ex post the port captures a fraction $\alpha \in (0,1)$ of Π. Then it will invest ex ante to

$$\max_I \alpha[D(q) - s - c(I)]q - I, \tag{15}$$

Solving this problem leads to the following result:

Proposition 3 *Let I^* be the level of investment that maximizes (15) and $\pi(I^*)$ the corresponding combined profits. Moreover, let I^{ι} be the level of investment that would had been chosen by a vertically integrated port and $\pi(I^{\iota})$ the corresponding combined profits. Then*

(a) $I^* < I^{\iota}$*;*

(b) $\Pi(I^*) < \Pi(I^{\iota})$.

Proof: Since q is chosen optimally for each I, the envelope theorem implies that the first order condition of problem (15) is

$$-c'(I^*)q(I^*) = \frac{1}{\alpha}.$$

Now q and $-c'$ are decreasing in I (the optimal monopoly quantity increases when costs fall and $c'' > 0$). Moreover

$$-c'(I^{\iota})q(I^{\iota}) = 1.$$

Hence, $I^* < I^{\iota}$. Part (b) follows trivially by noting that $I = I^{\iota}$ maximizes $[D(q) - s - c(I)]q - I$. ∎

Note that since the port has bargaining power ex ante, it will demand a payment from the shipping company. This payment can be at most $A^* = (1-\alpha)[D(q^*) - s - c(I^*)]q^*$ with $q^* = q(I^*)$. Thus, its expected utility is at most

$$\lambda\{[D(q_\ell^*) - s_\ell - c(I_\ell^*)]q_\ell^* - I_\ell^*\} + (1-\lambda)\{[D(q_h^*) - s_h - c(I_h^*)]q_h^* - I_h^*\}$$

This expected payoff is less than what the port would obtain if vertically integrated, viz.

$$\lambda\{[D(q_\ell^{\iota}) - s_\ell - c(I_\ell^{\iota})]q_\ell^{\iota} - I_\ell^{\iota}\} + (1-\lambda)\{[D(q_h^{\iota}) - s_h - c(I_h^{\iota})]q_h^{\iota} - I_h^{\iota}\}.$$

Thus underhand vertical integration is less attractive, which implies that competition becomes relatively more attractive.

D Oligopoly and collusion

In this appendix we show that collusion between two ports is made more difficult when shipping companies are vertically separated. For simplicity we assume that there is no asymmetric information between ports, that is, whatever is known by port 1 is also known by port 2 and viceversa. Nevertheless, as in the text, ports do not know shipping company's costs.[14]

We first analyze the case when two vertically integrated ports collude and then study collusion when ports are vertically separated, each closes an underhand agreement with a different shipping company and shipping companies collude. In both cases we assume that colluded firms play a trigger strategy where any deviation destroys collusion forever. Our strategy is to show that for whatever combination of collusive prices that is sustainable, ports make higher profits when vertically integrated. Thus, mandatory vertical separation makes operation for volume relatively more attractive.

D.1 Vertically integrated ports

We assume that (symmetric) collusive prices are such that $p_\ell^\iota \leq p_\ell \leq p_{\ell h} \leq p_h \leq p_h^\iota$, where p_ℓ is the collusive price when both shipping companies are low cost, $p_{\ell h}$ is the collusive price when only one is low cost, and p_h is the collusive price when both are high cost. Clearly, there is no point in colluding at prices lower than p_ℓ^ι or higher than p_ℓ^ι, since both ports can increase profits by increasing p when lower than p_ℓ^ι or higher than p_h^ι. Moreover, suppose that $p_h > p_\ell$. Then both ports increase their profits by switching prices. Last, assume that $p_{\ell h}$ is less than p_ℓ or greater than p_h. Then both can increase their profits by increasing p when lower than p_ℓ^ι or higher than p_ℓ^ι.

Under a trigger strategy ports will collude in each of the three cases if

$$\frac{1}{1-\delta}\eta(p_k - s_i - c)D(p_k) \geq (p_k - s_i - c)D(p_k)$$

with $k = \ell, \ell h, h$ and $i = \ell, h$; where $\delta \in (0,1)$ is the common discount factor and η is the smallest market share. Hence, collusion is sustainable if $\eta \geq 1-\delta$. A port's expected profits under collusion

[14] Though we have not showed it, we believe the results would be reinforced if there were asymmetric information between ports, as collusive agreements should become more difficult to supervise.

strategy are given by

$$\frac{1}{1-\delta}\eta\left[\lambda^2(p_\ell - s_\ell - c)D(p_\ell) + (1-\lambda)\lambda D(p_{\ell h})(2p_{\ell h} - s_\ell - s_h - 2c) + (1-\lambda)^2(p_h - s_h - c)D(p_h)\right].$$

We are ready to compare these profits with those that can be made when ports are vertically separated but establish underhand agreements with shipping companies.

D.2 Vertically separated ports

Suppose, again, that contingent on shipping companies' cost declaration collusive prices are given by p_ℓ, p_h and $p_{\ell h}$, with $p_\ell^\iota \leq p_\ell \leq p_{\ell h} \leq p_h \leq p_\ell^\iota$. Since we are comparing port profits with and without vertical integration for each possible set of prices p_ℓ, p_h and $p_{\ell h}$, it suffices to show that vertical separation forces ports to share part of the profits with shipping companies.

Ports jointly choose $(A_i, r_i)_{i=\ell,h}$ to maximize

$$\begin{aligned}&\lambda^2\left[A_\ell + (r_\ell - c)D(p_\ell)\right] + (1-\lambda)\lambda\left[A_\ell + (r_\ell - c)D(p_{\ell h})\right] + \\ &\lambda(1-\lambda)\left[A_h + (r_h - c)D(p_{\ell h})\right] + (1-\lambda)^2\left[A_h + (r_h - c)D(p_h)\right]\end{aligned}$$

subject to

$$\eta(p_{\ell h} - s_\ell - r_\ell)D(p_{\ell h}) - A_\ell \geq 0, \tag{16}$$

$$\eta(p_{\ell h} - s_h - r_h)D(p_{\ell h}) - A_h \geq 0, \tag{17}$$

$$\eta(p_\ell - s_\ell - r_\ell)D(p_\ell) - A_\ell \geq 0 \tag{18}$$

$$\eta(p_h - s_h - r_h)D(p_h) - A_h \geq 0 \tag{19}$$

$$\begin{aligned}&\lambda\eta(p_\ell - s_\ell - r_\ell)D(p_\ell) + (1-\lambda)\eta(p_{\ell h} - s_\ell - r_\ell)D(p_{\ell h}) - A_\ell \\ \geq\ &\lambda\eta(p_{\ell h} - s_\ell - r_h)D(p_{\ell h}) + (1-\lambda)\eta(p_h - s_\ell - r_h)D(p_h) - A_h,\end{aligned} \tag{20}$$

$$\lambda\eta(p_{\ell h}-s_h-r_h)D(p_{\ell h})+(1-\lambda)\eta(p_h-s_h-r_h)D(p_h)-A_h \quad (21)$$
$$\geq \lambda\eta(p_\ell-s_h-r_\ell)D(p_\ell)+(1-\lambda)\eta(p_{\ell h}-s_h-r_\ell)D(p_{\ell h})-A_\ell,$$

$$\frac{1}{1-\delta}\left[\eta(p_\ell-s_\ell-r_\ell)D(p_\ell)-A_\ell\right]\geq(p_\ell-s_\ell-r_\ell)D(p_\ell)-A_\ell, \quad (22)$$

$$\frac{1}{1-\delta}\left[\eta(p_{\ell h}-s_\ell-r_\ell)D(p_{\ell h})-A_\ell\right]\geq(p_{\ell h}-s_\ell-r_\ell)D(p_{\ell h})-A_\ell, \quad (23)$$

$$\frac{1}{1-\delta}\left[\eta(p_h-s_h-r_h)D(p_h)-A_h\right]\geq(p_h-s_h-r_h)D(p_h)-A_h, \quad (24)$$

$$\frac{1}{1-\delta}\left[\eta(p_{\ell h}-s_h-r_h)D(p_{\ell h})-A_h\right]\geq(p_{\ell h}-s_h-r_h)D(p_{\ell h})-A_h, \quad (25)$$

where η is the shipping company's market share. The first six are standard participation and incentive-compatibility constraints. The next four are the standard collusion conditions which assume that cheating once destroys cooperation forever. Note that the contract must be chosen to give enough incentives to each *shipping company* not to cheat; these are constraints (22) to (25).

Now note that the argument in Proposition 1 carries through to show that the low cost-shipping company can always make positive profits by claiming to be a high-cost shipping company. Hence, just as in the monopoly port case, separation forces ports to share part of the rents with shipping companies. Thus, vertical separation makes underhand agreements less attractive. ∎