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Vertical Contracting and Downstream Competition

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Vertical Contracting and Downstream Competition

A dissertation submitted in partial satisfaction of the
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by

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2017

The dissertation of Zheng Huang is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

Chair

University of California, San Diego

2017

EPIGRAPH

I heard Ahab mutter, "Here some one thrusts these cards into these old hands of mine; swears that I must play them, and no others." And damn me, Ahab, but thou actest right; live in the game, and die in it!

—Herman Melville, *Moby-Dick*

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Chapter 3 is material co-authored with Xuan Ding. I would like to thank Xuan for giving me permission to include this material in my dissertation.

VITA

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ABSTRACT OF THE DISSERTATION

Vertical Contracting and Downstream Competition

by

Zheng Huang
Doctor of Philosophy in Economics

University of California San Diego, 2017

Professor Joel Watson, Chair

When downstream firms collude, upstream firms' profits are often reduced. Yet upstream firms currently lack legal avenues to directly counter downstream collusion. This dissertation explores the strategic use of vertical contracting to restrict downstream collusion.

I model a two-tier supply chain where a monopolist upstream firm faces a group of collusive downstream firms. I take a game-theoretic approach to analyzing the behavior of the firms. Equilibrium results are derived, comparative statics are studied, and comparison is made with outcomes under downstream competition. The welfare implications of the upstream firm's contracting strategy are also discussed. The model demonstrates that a monopolist upstream supplier is able to use nonlinear pricing contracts to restrict downstream collusion, which results in a total quantity even larger than that under linear pricing in downstream competition. Consumers

and society benefit from this restriction.

A theoretical result derivative of a slight variation of the model predicts a possible linkage between upstream and downstream competition. A change in upstream competition is predicted to cause a change in downstream competition in the opposite direction. This prediction is tested in an initial empirical study of the maritime shipping and the shipbuilding industries. Yearly financial data were collected of 9 large shipbuilding companies and 14 large shipping companies over the period 2003 to 2015, which were used to derive a measure of competition for each of the two industries. Preliminary evidence suggests that upstream competition has a negative impact on downstream competition. The finding of this study lends empirical support to the main model.

Chapter 1

The Power of Upstream Contracting over Downstream Collusion

Collusion by downstream firms can be detrimental to the upstream suppliers. I show that a monopolist supplier can use nonlinear pricing contracts to weaken downstream firms' ability to engage in collusive behavior, while also generating a positive welfare effect. Regulatory policy targeting upstream nonlinear pricing may weaken downstream competition. Because upstream pricing behavior differs with and without downstream collusion, the model also provides authorities with a new tool for detecting collusion.

1.1 Introduction

Many collusion cases involve downstream firms. While downstream firms' collusive behavior hurts consumers, it also injures upstream suppliers. Yet existing theories of collusion do not address upstream suppliers' incentives to influence collusion between downstream firms. In this paper, I examine strategic contracting as one way for upstream suppliers to restrict downstream collusion, and I ask the following questions: Do some types of supply contracts make it more difficult for downstream firms to collude than other types of contracts? If so, how does policy regulating pricing of upstream suppliers impact competition in a downstream market? And can we infer collusion in a downstream market from upstream suppliers' pricing behavior?

Antitrust enforcers are interested in how collusion is affected by vertical relations. Researchers have shown that vertical restraints and vertical mergers can facilitate upstream collusion.[1] But less is known about the effects of vertical relations on downstream collusion; work in this area typically assumes downstream firms have the power to make contract offers to their suppliers.[2] This paper reverses this assumption, investigating how an upstream supplier can strategically design supply contracts to influence collusion between downstream firms. The main finding of this paper is that an upstream supplier can use nonlinear pricing to restrict downstream collusion. I use two-part tariff contracts to demonstrate this result.

I consider an industry with an upstream monopolist supplier and two identical downstream retailers. First, the supplier offers the same two-part tariff contract to the two retailers. The contract is stationary, which means it applies to trade in all future periods.[3] Then the two retailers engage in infinitely-repeated market interaction, by each choosing quantities to purchase from the supplier for resale to consumers in each period. I focus my analysis on collusion between the retailers, who strive to collectively obtain the retail monopoly profit. I will show that by utilizing a two-part tariff with the retailers, the supplier can induce colluding retailers to choose a total

[1] On vertical restraints, see, for example, [JR07] and [PR11]. On vertical mergers, see, for example, [NW07].

[2] To the best of my knowledge, only two existing papers develop theories on upstream contracting and downstream collusion: [PMT12] and [DH14]. In both papers, supply contract offers are made by downstream firms.

[3] A fixed fee is to be paid in a period if and only if a retailer purchases a positive amount from the supplier in that period.

quantity larger than what they would have chosen under optimal linear pricing. It is worth noting that in this model, two-part tariff "restricts" retail collusion not in the sense that it makes retailers less likely to collude, but in the sense that it forces retailers to collude at a larger quantity than they would otherwise be able to achieve. The key idea is that collusion relies on repeated-game punishments (Nash reversion, [Fri71]).

With a two-part tariff contract, both the per-unit price and the fixed fee have an effect on how retail collusion can be maintained. The model explores the interaction between these two effects. As a starting point, suppose the supplier offers the optimal linear price. If the supplier chooses to decrease the price, then the colluding retailers' incentive constraints will be tightened, leading to a higher quantity, and a greater surplus. The supplier would want to extract the greater surplus using a fixed fee. The addition of a fixed fee leads to an interesting trade-off: on the one hand, although the supplier would like to charge a large fixed fee, the fixed fee cannot be so large that no retailer will participate in trading; on the other hand, a large enough fixed fee can affect the retailers' punishment profile, further tightening the retailers' collusion constraints.

To understand how the fixed fee can affect the retailers' punishment profile, consider first that without a fixed fee, the retailers engage in quantity competition in a punishment period. Adding a large enough fixed fee can make quantity competition unprofitable, in which case in a punishment period, the retailers would rather purchase nothing and stay out of the market than compete and obtain negative profits. Consequently, non-participation replaces competition as the retailers' "Nash reversion". Therefore, for any quantity agreement, a retailer choosing to collude expects to pay a fixed fee in every period, while a retailer choosing to deviate expects to pay a fixed fee only once. This effect on retail punishment reduces a retailer's net gain from colluding relative to deviating for any quantity agreement. As such, some quantities become unsustainable in collusion. Particularly, the supplier can strategically choose a fixed fee such that only a large quantity is sustainable. In equilibrium, this large collusive quantity not only exceeds the retail collusive quantity under linear pricing, but, in fact, it also exceeds the retail competition quantity under linear pricing. This result means that as far as welfare is concerned, the positive effect of nonlinear pricing more than offsets the negative effect of downstream collusion.

Thus, the model predicts that downstream firms have incentives to collude, and that a two-part tariff contract is more limiting to downstream firms' ability to collude than a linear pricing contract. Although a two-part tariff is a particularly attractive limiting case of nonlinear pricing, the key property is discount pricing (decreasing per-unit price for a larger quantity).[4] For example, car-rental companies typically receive quantity discounts when purchasing fleet vehicles from auto makers. Moreover, cartel cases are relatively rare in the car-rental industry. This example is consistent with the model's predictions: While the existence of car-rental cartels manifests an incentive to collude in a downstream market, the relatively restrained collusion may be explained by nonlinear pricing upstream. For some examples of existing cases and probes in the car-rental industry, see *Alice Springs Car Rental Cartel*[5], *Shames et al. v. Hertz Corp. et al.*[6], *AENA and Car Rental*[7], and France's cartel claims over car hire firms[8].

[4]Two-part tariff is discount pricing in the extreme – it is equivalent to charging a very high price for the first unit, and a low price for additional units.

[5]See Australian Competition & Consumer Commission ("ACCC"), *Cartels case studies & legal cases*, available online at http://www.accc.gov.au/business/anti-competitive-behaviour/cartels/cartels-case-studies-legal-cases#price-fixing (accessed May 19, 2016).

[6]*Shames et al. v. Hertz Corp. et al.*, filed in the U.S. District Court for the Southern District of California, Case No. 3:07-cv-2174 (first filed in November 2007, proposed class action settled in May 2012). See Court Doc. Nos. 327 & 328, available at http://cases.justia.com/federal/district-courts/california/casdce/3:2007cv02174/258578/357/0.pdf?ts=1428879574 (accessed May 19, 2016).

[7]*AENA and Car Rental* (fines imposed on Jan 9, 2014 by the Comisión Nacional de los Mercados y la Competencia ("CNMC")), available at http://ec.europa.eu/competition/ecn/brief/01_2014/es_aena.pdf (accessed May 19, 2016). See also [Eur14] and [Sla14].

[8]See http://www.franceinfo.fr/actu/economie/article/six-loueurs-de-voitures-soupconnes-de-pratiques-anticoncurrentielles-683007 (accessed May 19, 2016).

The model has several policy implications. First, regulation affecting upstream firms' pricing behavior may affect downstream competition. Second, I show that nonlinear pricing differs in a systematic way with and without downstream collusion. In particular, the supplier charges a lower per-unit price and a higher fixed fee (or offers a steeper discount for large quantities and demands a higher payment for small quantities) when threatened by downstream collusion than otherwise. This suggests that in establishing downstream collusion, courts could permit evidence of changes in upstream pricing as a new "plus factor" (to use a term in the antitrust literature). This means that circumstantial evidence to establish collusion does not need to be confined to horizontal actions: Looking upstream may yield evidence as well. Third, upstream collusion in pricing may have a benign motivation, which is to restrict downstream collusion. Fourth, damages caused to upstream firms by downstream collusion may be less severe if nonlinear pricing is used in supply contracts than if linear pricing is used. Fifth, an upstream monopolist facing downstream collusion may price low for large quantities to restrict downstream collusion, but such pricing behavior may be misinterpreted as predatory.

This paper fits in the literature of collusion studies in vertical settings. This literature has largely focused on vertical restraints and vertical integration. Discussion mostly centers around the trade-off between the procompetitive and anticompetitive effects of vertical practices, with some focused on upstream collusion (e.g. [JR07], [PR11], [NW07], [Nor09]). A less rich line of research studies downstream collusion induced by buyer power.[9] These studies investigate the collusive effects of buyer power, but leave out of consideration upstream firms' incentives to influence downstream collusion. It remains unexplored how upstream firms can affect downstream collusion without vertical coordination. To the best of my knowledge, this paper is

[9] Abstracting away from the "countervailing power" of large buyers shown by [Sny96], a few authors worked on showing buyer power has collusive effects. These efforts include: theoretical work by [DH14], [PMT12], and experimental work by [NRS15].

the first to venture into this terrain.

This paper also adds to the literature of nonlinear pricing. A number of existing studies in the marketing and management literature analyze the channel-coordinating effects of nonlinear pricing in a competitive environment. [IP95a] establish that in a retail competitive environment, a manufacturer can use the right nonlinear pricing contract to fully coordinate the channel[10]. Further, with downstream competition, a monopolist upstream supplier is able to use nonlinear pricing (e.g. two-part tariff) to capture a large share of, if not all, surplus of a coordinated channel. Because nonlinear pricing was created for the upstream tier to increase channel profits and capture surplus better, rarely has attention been paid to other potential effects of using such contracts. But retailers are often in repeated interaction with each other. By taking into consideration retailers' repeated interaction, this paper finds another useful aspect of nonlinear pricing: the use of nonlinear pricing to influence downstream competition.

The rest of the paper is organized as follows. In Section 2, I set up the model. In Section 3, I provide equilibrium analysis, characterizing the supplier's optimal per-unit price and fixed fee when retailers collude in a symmetric fashion, as well as the market outcome. I then explore how retailers' patience affects the total quantity, and how the supplier's optimal per-unit price and fixed fee differ with and without retail collusion. Finally, I provide welfare comparison between different contracts in different competition environments. In Section 4, I discuss some policy implications of the results. In Section 5, I extend the model to allow for asymmetric collusion between the retailers, where only one retailer trades in each period. Some robustness results are provided. Section 6 concludes.

[10]Here fully coordinating the channel means that the system obtains the maximum possible surplus achievable by a single integrated entity. Related to this theme, [IP95b] show that nonlinear pricing can achieve channel coordination with non-competing retailers. Going back further, [JS83], [JS88], [Shu85] and [Moo87] studied coordinating mechanisms in a single dyadic channel where there is one manufacturer and one independent retailer.

1.2 The Model

I consider a two-tier vertical model with an upstream monopolist supplier S and two independent, identical downstream retailers R_1 and R_2. The retailers purchase a homogeneous good from the supplier, for resale to the consumers[11]. For the supplier, the marginal cost of production is c.

The timing of the game is as follows. First, the supplier offers the same wholesale contract to both retailers, which is stationary across all periods. Then, an infinitely repeated game is played by the retailers, with the following happening in every period:

1. The two retailers independently and simultaneously decide whether to accept the contract, and if they do, purchase some quantities of the product from the supplier for sale in the current period. Denote these quantities $q_1, q_2 \geq 0$. Rejection of the contract offer leads to zero profit for a retailer.

2. The market clears, with the price determined by inverse linear demand $P = a - bQ$, and all players' profits are realized.

The game is of common knowledge and perfect monitoring. Each player maximizes his or her stream of discounted payoffs over an infinite horizon. The retailers share a common discount factor $\delta \in (0, 1)$. For illustration purposes, I will use the female pronoun when referring to the supplier, and the male pronoun to refer to a retailer.

Since the focus of this paper is on downstream collusion, I assume that the retailers engage in horizontal collusion whenever collusion is profit-enhancing and sustainable with infinite "Nash reversion". It is also assumed that the downstream firms cannot resell the upstream good to one another[12].

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[11] We can also think of the transactions as downstream firms purchasing an input good from the supplier, then transforming it into an output good to sell to the consumers.

[12] We can think of resale downstream being prohibited by issues like warranty, trademark, and

The model uses two-part tariff contracts. Contract terms are as follows: In any period, a retailer purchasing a positive quantity pays a fixed fee f, plus a per-unit price of w; a retailer making zero purchase pays nothing. As a result, in any period t, retailer i gets payoff

$$\pi_{it} = \begin{cases} 0, & \text{if } q_{it} = 0\,; \\ q_{it}(a - bq_{it} - bq_{jt} - w) - f, & \text{if } q_{it} > 0\,. \end{cases}$$

1.3 Equilibrium Analysis

1.3.1 Symmetric Collusive Equilibrium

The retailers consider collusion when collusion is more profitable than competing. In this subsection, I derive all players' equilibrium behavior when retailers collude symmetrically. By symmetric collusion, I refer to a collusive scheme where both retailers are expected to adopt the same behavior in every period. Such a collusive scheme prescribes that each retailer purchase quantity q from the supplier in each period. The solution concept is formally defined as follows:

Definition 1. *A Symmetric Collusive Equilibrium is a subgame perfect Nash equilibrium given by the supplier's strategy (w, f), and each retailer's strategy q_{it} such that:*

1. *given (w, f), $Q_t = q_{1t} + q_{2t}$ maximizes the retailers' collective profits in each period t;*

2. *$q_{it} = q$.*

Using standard infinite Nash reversion as punishment for deviation, I denote firm i's profit in a collusive period by π_i^{Coll}, his deviation profit by π_i^{Dev}, and his

sales tax.

profit in a punishment period by π_i^{Pun}, respectively. Given the symmetric nature of the collusive scheme, I will omit the subscript i. The condition to sustain retail collusion is:

$$\pi^{Coll} \geq (1-\delta)\pi^{Dev} + \delta\pi^{Pun}\,,$$

or

$$\begin{aligned}(a-2bq-w)q-f \ &\geq (1-\delta)\frac{1}{4b}(a-bq-w)^2 - f(1-\delta) \\ &\quad + \delta \max\left\{\frac{(a-w)^2}{9b} - f,\ 0\right\}.\end{aligned} \tag{1.1}$$

Note the punishment profit above. $f_0(w) = \frac{(a-w)^2}{9b}$ is a retailer's profit in Cournot competition when he faces a unit price w and no fixed fee. If the fixed fee f exceeds this profit, then "Nash reversion" becomes no purchase, and the punishment profit becomes zero.[13]

Let collusion condition (1.1) be rewritten as $h(q,w,f) \geq 0$. That is, let $h(q,w,f) \equiv (a-2bq-w)q - (1-\delta)\frac{1}{4b}(a-bq-w)^2 - \delta f - \delta\max\left\{\frac{(a-w)^2}{9b} - f,\ 0\right\}$. And let $\Theta(w,f)$ denote the set of collusive quantities that can be sustained by the retailers under contract terms (w,f), so $\Theta(w,f) \equiv \{q : h(q,w,f) \geq 0\}$.

After observing w and f, the retailers' problem is

$$\begin{aligned}&\underset{q}{\text{maximize}} \quad \pi^{Coll} = (a-2bq-w)q - f \\ &\text{subject to} \quad h(q,w,f) \geq 0.\end{aligned} \tag{R}$$

Notice that when $\frac{(a-w)^2}{9b} - f > 0$, or $f < \frac{(a-w)^2}{9b}$, slightly increasing f without changing w does not have any impact on collusion condition (1.1), or the constraint

[13]Technically, no pure-strategy Nash equilibrium exists in a punishment period. In fact, the"Nash reversion" behavior of retailers in punishment periods is characterized by mixing between staying out of the market and staying in at a positive quantity. But the key point to recognize is that the retailers' expected payoff is exactly zero, which is as if the retailers were staying out of the market. Therefore, the critical continuation value that enters the incentive constraint is zero.

$h(q, w, f) \geq 0$. In other words, the supplier can always increase her profit by increasing f without changing the total quantity purchased by colluding retailers. This implies that strategies satisfying $\frac{(a-w)^2}{9b} - f > 0$ will never be played in equilibrium.

Lemma 1. *In symmetric collusive equilibrium, $f \geq f_0(w)$.*

The supplier's problem is:

$$\begin{aligned} &\underset{w,f}{\text{maximize}} \quad \pi_S = 2[q(w-c)+f] \\ &\text{subject to:} \quad q \text{ solves } (R)\,. \end{aligned} \tag{S}$$

Lemma 1 implies that the retailers' problem may not have an interior solution. Intuitively, a fixed fee exceeding a retailer's profit in competition leads the retailers to stay out of the market in a punishment period. So retailers expect a larger burden of fixed fees from colluding than from deviating. As a result, there may only be a small set of quantities sustainable in collusion ($\Theta(w, f)$ being a small set), thus an interior solution may not be attainable. This also has consequences for the supplier's problem. To deal with these complications, I will parse the problem into two steps: (1) I show that in equilibrium, every w maps to a unique optimal f for the supplier, as well as a unique optimal q for the retailers. (2) The supplier's problem then reduces to choosing an optimal w, which can be solved mathematically.

To analyze the equilibrium, it will be useful to have the following glossary of notation:

$q^N(w) = \frac{a-w}{3b}$, a retailer's quantity in Cournot competition when facing per-unit price w and no fixed fee;

$\hat{q}(w) = \frac{a-w}{4b}$, the unconstrained maximizer for $\pi^{Coll}(q, w, f)$;

$\hat{\hat{q}}(w) = \frac{a-w}{b} \cdot \frac{3-\delta}{9-\delta}$, the unconstrained maximizer for $h(q, w, f)$;

$\tilde{q}(w, f) =$ the solution to the retailers' problem (R) when contract terms are (w, f);

$f^*(w)$ = the supplier's optimal fixed fee for a given w;

$q^*(w)$ = the solution to the retailers' problem (R) when the contract terms are $(w, f^*(w))$.

Step (1): Given a per-unit price w, consider the supplier's choice of a corresponding fixed fee f. That is, find $f^*(w)$.

In equilibrium, $h(q, w, f) = 0$. To see this, notice that when $h(q, w, f) > 0$, the supplier can always do better by slightly increasing the fixed fee f without affecting the retailers' collusive quantity. Therefore, the supplier would keep increasing f, at least until $h(q, w, f) = 0$. Hence, all strategies by the supplier that would lead to $h(q, w, f) > 0$ will never by played in equilibrium. This implies that the equilibrium collusive quantity q is a corner solution to the retailers' problem. The retailers want to choose a collusive quantity as close to $\hat{q}(w)$ as possible, but are constrained by the condition $h(q, w, f) = 0$. As long as $\Theta(w, f)$ is not empty, the larger the fixed fee f is, the larger the collusive quantity q is. Knowing this, the supplier would keep raising f until there is only one point left in $\Theta(w, f)$. The result is the following proposition.

Proposition 1. *For any w, the supplier's optimal fixed fee is $f^*(w) = \frac{1}{\delta}[(a-2b\hat{\hat{q}}(w)-w)\hat{\hat{q}}(w) - (1-\delta)\frac{1}{4b}(a - b\hat{\hat{q}}(w) - w)^2] > 0$, and the retailers' corresponding optimal individual collusive quantity is $q^*(w) = \hat{\hat{q}}(w) = \frac{a-w}{b} \cdot \frac{3-\delta}{9-\delta} > \hat{q}(w)$.*

Proof. See Appendix A. □

Proposition 1 shows that using a fixed fee, a monopolist supplier does not technically prevent the retailers from colluding, but in fact makes retailers collude at a quantity larger than what they would have colluded on under linear pricing.

Figures 1.1 - 1.3 graph the retailers' individual collusive profit $\pi^{Coll}(q, w, f)$ and their collusion condition $h(q, w, f)$ against the collusive quantity q. They illustrate how the retailers' optimizing q changes as only f (not w) changes. Progressing from

Figure 1.1 to Figure 1.3, f increases: $f_1 < f_2 < f^*$.[14] Figure 1.1 depicts a case where δ is large enough to sustain retail collusion at the downstream monopoly quantity when there is no fixed fee. However, the assumption of a large δ is not needed for the equilibrium analysis. If δ is otherwise small, it simply means $\inf \Theta(w, f) > \hat{q}(w)$ for all $f \geq 0$. It does not change the optimality of $f^*(w)$ for the supplier, and $q^*(w)$ for the retailers.

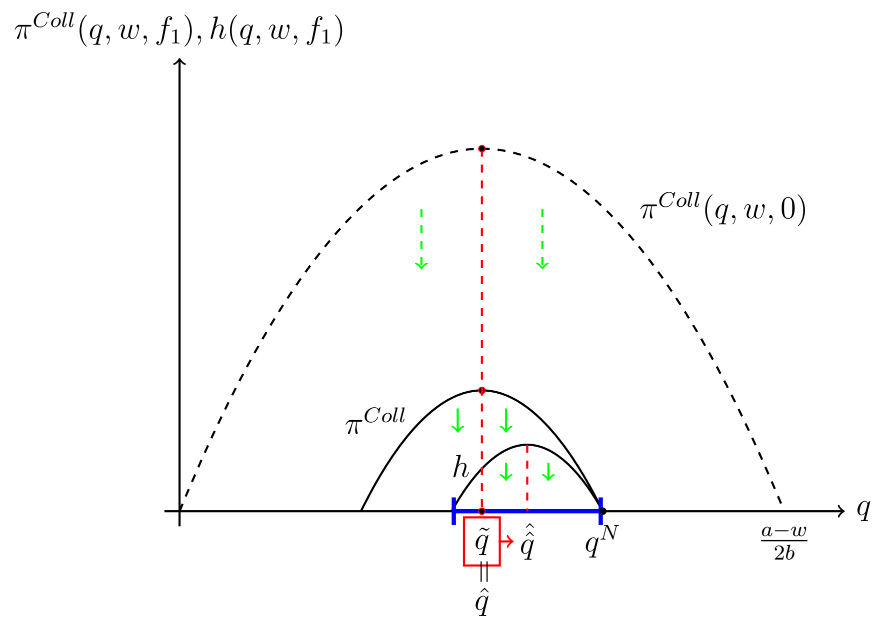

Figure 1.1: Retailers' optimal choice of collusive quantity: interior solution.

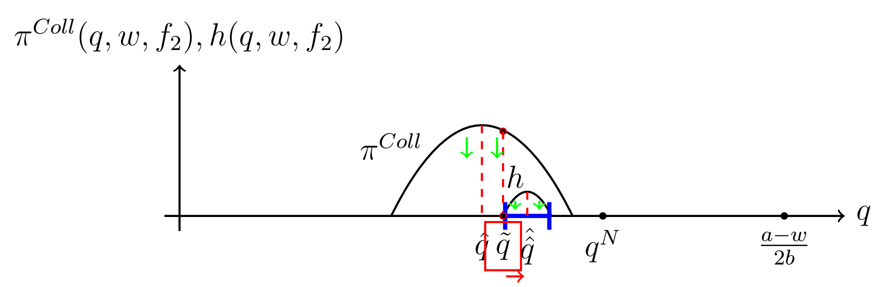

Figure 1.2: Retailers' optimal choice of collusive quantity: corner solution.

[14] All notations in the graphs represent functions of w. I omit the arguments in the graphs for clarity of presentation.

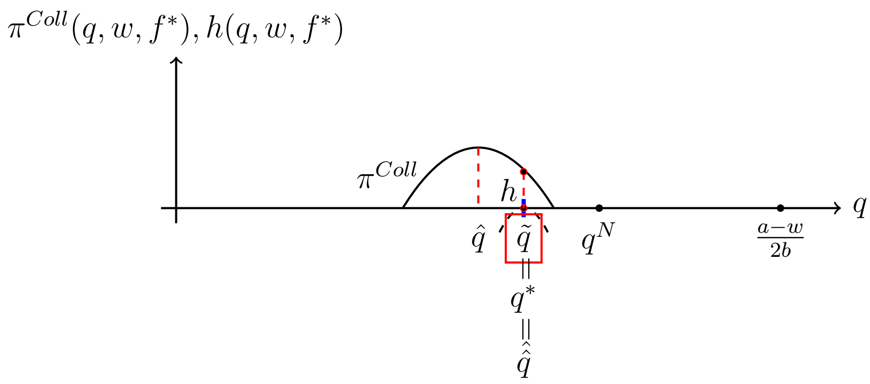

Figure 1.3: The supplier chooses the optimal fixed fee f^*.

Next, I examine how δ affects the retailers' choice of collusive quantity.

Lemma 2. *(i)* $\hat{\hat{q}}(w) \to \hat{q}(w)$ *as* $\delta \to 1$*. (ii)* $\hat{\hat{q}}(w) \to q^N(w)$ *as* $\delta \to 0$*.*

Despite the fixed fee, the most patient retailers can sustain collusion at the downstream monopoly quantity under linear pricing, and the most impatient retailers choose the competitive quantity. The fixed fee has a restrictive effect on collusion when $\delta \in (0, 1)$.

Step (2): With the result in Proposition 1, it is now clear that the supplier's problem is:

$$\begin{aligned} &\underset{w}{\text{maximize}} \quad \pi_S = \frac{2[q(w-c)+f]}{1-\delta} \\ &\text{where} \quad q = q^*(w) = \hat{\hat{q}}(w) = \frac{a-w}{b} \cdot \frac{3-\delta}{9-\delta}, \\ &\text{and } f = f^*(w) = \frac{1}{\delta}[(a-2bq-w)q - (1-\delta)\frac{1}{4b}(a-bq-w)^2]. \end{aligned} \tag{S'}$$

The following is a closed-form solution to the supplier's problem:

Proposition 2. *In equilibrium, the supplier sets a unit price* $w^{**} = c + (a-c)\frac{1-\delta}{4-2\delta} \in (c, \frac{a+c}{2})$*, and a positive fixed fee:* $f^{**} = \frac{(a-c)^2}{4b} \cdot \frac{(3-\delta)^2}{(2-\delta)^2(9-\delta)} > 0$*.*

Proof. See Appendix A. $\square$

Denote the equilibrium total quantity of the model Q^{**}, i.e., $Q^{**} = 2\hat{\hat{q}}(w^{**})$. And denote with Q_c^L the equilibrium total quantity under linear pricing with retail competition. I compare these two quantities, and have the following result:

Proposition 3. *The total quantity under two-part tariff when retailers collude is larger than the total quantity under optimal linear pricing when retailers compete. That is,* $Q^{**} > Q^{RC}$.

Proof. See Appendix A. □

Figures C.1 - C.6 in Appendix C provide a summary of the results in Propositions 1, 2 and 3. They show that when retailers collude, contracting with two-part tariff leads to a larger total quantity than contracting with linear pricing. Further, it is also larger than the total quantity with linear pricing when retailers compete. Figure C.1 exhibits the standard double marginalization problem under linear pricing: Point A represents the market price and quantity when retailers collude[15], while point B represents the market price and quantity when retailers engage in Cournot competition. Q^M denotes the industry monopoly quantity. Figure C.2 shows the retailers' set of sustainable collusive quantities. If this set brackets the retail monopoly quantity under linear pricing Q^{RM}, the retailers would optimize by colluding at Q^{RM}. However, according to the results obtained above, if the supplier simply adds a fixed fee to the contract (while keeping the wholesale unit price at the industry monopoly level P^M), she can in fact already restrict the retailers' set of sustainable collusive quantities down to a single point: point C in Figure C.4. Point C represents a quantity larger than the retail monopoly level under linear pricing. In addition, as shown in Figure C.5, the supplier will also adjust the wholesale unit price down, which results in a quantity even larger than that at point C. Finally, equilibrium is shown as point C in Figure C.6.

[15]Here, I am again making the harmless assumption that retailers are patient enough to cooperate at the retail monopoly quantity when facing linear pricing.

Essentially, the model shows that an upstream monopolist supplier can use a two-part tariff to effectively force the downstream retailers to collude at a large quantity. The resulting quantity is larger than the retail monopoly quantity under optimal linear pricing, and close to the industry monopoly quantity.

1.3.2 Comparative Statics

Lemma 3. *As δ changes, total quantity $Q^{**} = 2\hat{\hat{q}}(w^{**})$ changes in the following way, all else held constant: $\frac{\partial Q^{**}}{\partial \delta} < 0$ for $\delta < \frac{3}{5}$, $\frac{\partial Q^{**}}{\partial \delta} = 0$ for $\delta = \frac{3}{5}$, and $\frac{\partial Q^{**}}{\partial \delta} > 0$ for $\delta > \frac{3}{5}$.*

Proof. See Appendix A. □

In a nutshell, Lemma 3 shows that under wholesale two-part tariff, the change in retailers' total collusive quantity is not monotonic in δ. This is in contrast to wholesale linear pricing, under which an increase in δ from 0 to 1 monotonically decreases the retailers' total collusive quantity, until the total quantity is pushed down to the retail monopoly level.

To understand this result, note that when $\delta = 0$, retailers compete, and the supplier is able to achieve the industry monopoly quantity with the right pair of (w, f). As δ exceeds zero, retail cartelization takes effect, resulting in a total quantity smaller than the monopoly quantity. When a small δ increases, the retail cartel gets stronger and is able to sustain collusion to a larger extent, pushing down the total quantity.[16] However, as retailers become even more patient, the trend reverses: The total quantity increases, approaching the monopoly quantity again. The reason is that δ being close enough to 1 indicates the retailers' willingness to sustain collusion for even just a small amount of benefits, which enables the supplier to treat them as close to a single entity. When there is a single entity downstream, the supplier can

[16] Note, however, that the use of two-part tariff makes sure this small total quantity is not as small as it would have been, had linear pricing been in place. This is the result of Proposition 1.

again achieve the industry monopoly quantity and obtain all channel profits using two-part tariff.

Next, I explore the effects of changing δ on the supplier's optimal choice of two-part tariff terms. An examination of Proposition 2 reveals the following results:

Proposition 4. $\frac{\partial w^{**}}{\partial \delta} < 0$, $\frac{\partial f^{**}}{\partial \delta} > 0$.

Proof. See Appendix A. □

More patient retailers can sustain collusion more easily, so the supplier would need to use a lower per-unit price and a larger fixed fee to tighten the retailers' collusion conditions.

1.3.3 Comparison with No Collusion

Now that we know the players' equilibrium behavior, I juxtapose the supplier's optimal strategy (w^{**}, f^{**}) under retail collusion and her optimal strategy (w_c^*, f_c^*) when retailers play the static Nash equilibrium. I find that the supplier offers a lower per-unit price and a higher fixed fee under retail collusion than under retail competition:

Proposition 5. *$w^{**} < w_c^*$, and $f^{**} > f_c^*$.*

Proof. When the two retailers compete, the supplier using a two-part tariff obtains surplus amount $\frac{(a-c)^2}{4b}$, by imposing $w_c^* = \frac{a+3c}{4}$, and $f_c^* = \frac{(a-c)^2}{16b}$[17].

To show that $w^{**} < w_c^*$, we use the result $\frac{\partial w^{**}}{\partial \delta} < 0$ from Proposition 4. Combine $\frac{\partial w^{**}}{\partial \delta} < 0$ with the fact that when $\delta = 0$, $w^{**} = w_c^* = \frac{a+3c}{4} > c$, and when $\delta = 1$, $w^{**} = c$, and it follows that $w^{**} \in (c, w_c^*)$.

[17] These are the one-shot equilibrium price and fixed fee. They confirm our earlier calculations in the repeated game with retail collusion: Letting $\delta = 0$ (no collusion) in both $w^{**} = c + (a-c)\frac{1-\delta}{4-2\delta}$ and $f^{**} = \frac{(a-c)^2}{4b} \cdot \frac{(3-\delta)^2}{(2-\delta)^2(9-\delta)}$ gives precisely $w_c^* = \frac{a+3c}{4}$ and $f_c^* = \frac{(a-c)^2}{16b}$.

To show that $f^{**} > f_c^*$, we use the result $\frac{\partial f^{**}}{\partial \delta} > 0$ from Proposition 4. Combine $\frac{\partial f^{**}}{\partial \delta} > 0$ with the fact that when $\delta = 0$, $f^{**} = f_c^* = \frac{(a-c)^2}{16b}$, and when $\delta = 1$, $f^{**} = \frac{(a-c)^2}{8b}$, and it follows that $f^{**} > f_c^*$.

□

Compared to retail competition, retail collusion causes the supplier to charge a higher fixed fee in order to restrict the collusive quantity. This enables the supplier to induce a larger total quantity using a lower per-unit price.

For direct comparison, Table B.1 in Appendix B lists equilibrium prices/tariffs, along with total quantities under linear pricing and two-part tariff, in settings with and without retail collusion. Note that in equilibrium, the total quantity exceeds the retail competition quantity under linear pricing, and is very close to the industry monopoly quantity.

1.3.4 Supplier's Incentive for Choosing Two-Part Tariff

Under retail collusion, two-part tariff works better than linear pricing for the supplier, not only because two-part tariff affords the supplier the ability to capture retailers' surplus[18], but also because a supplier using two-part tariff can adjust the wholesale marginal price to mitigate her profit loss due to retail collusion. With linear pricing, the supplier does not have the ability to limit retail collusion, and thus has to absorb all the resulting profit loss.

The result in Proposition 1 applies to any w, and has the following implication. Suppose a supplier is currently adopting a linear pricing rule with her downstream retailers, and is experiencing a less-than-expected profit due to retail collusion. Proposition 1 suggests that the supplier can in fact lift her profit simply by adding a fixed fee to the wholesale contract, without even changing the wholesale per-unit price.

In summary, Proposition 1 implies the following:

[18] This is the standard one-shot result.

Corollary 1. *When facing retail collusion, the supplier prefers contracting with two-part tariff to contracting with linear pricing.*

Proof. This is an immediate result from $f^*(w) > 0$ for any w. □

Importantly, as will be shown in the next part, when there is retail collusion, the supplier's self-incentivized choice of two-part tariff over linear pricing is also beneficial to consumers and society.

1.3.5 Welfare Analysis

In a one-shot scenario, two-part tariff is superior to linear pricing in terms of supplier surplus, consumer surplus, and total surplus for society. In a setting with retail collusion, we have established that two-part tariff rewards the supplier with higher surplus than linear pricing (from Corollary 1). In fact, with retail collusion, consumers also obtain a higher surplus under two-part tariff, so does society.

Proposition 6. *With retail collusion, consumer surplus is higher under two-part tariff than under linear pricing.*

Proposition 7. *With retail collusion, total surplus for society is higher under two-part tariff than under linear pricing.*

Table B.2 in Appendix B lists all surpluses under linear pricing and two-part tariff for comparison. It shows that when faced with retail collusion, the supplier has an incentive to adopt two-part tariff. In addition to helping the supplier capture downstream surplus, two-part tariff restricts downstream collusion, leading to large consumer surplus and total surplus.

1.4 Policy Discussion

The relation between upstream contracting and downstream collusion has implications for a variety of policy issues on antitrust and regulation. In this section, I discuss some of these policy implications.

1.4.1 Relation Between Upstream and Downstream Collusion Cases

In the United States, public antitrust enforcers are the Antitrust Division of the Department of Justice (DoJ), the Federal Trade Commission (FTC), and the State Attorneys General. According to *Antitrust Guidelines for Collaborations Among Competitors*, which were jointly issued by FTC and DoJ in 2000, the Supreme Court uses two types of analysis to determine the lawfulness of an agreement among competitors: per se and rule of reason. Some types of agreements have been determined to be highly likely to harm competition while providing no significant procompetitive benefit. These agreements, once identified, can be challenged as per se illegal, and other types of agreements are evaluated under the rule of reason:

> Types of agreements that have been held per se illegal include agreements among competitors to fix prices or output, rig bids, or share or divide markets by allocating customers, suppliers, territories, or lines of commerce. The courts conclusively presume such agreements, once identified, to be illegal, without inquiring into their claimed business purposes, anticompetitive harms, procompetitive benefits, or overall competitive effects. Agreements not challenged as per se illegal are analyzed under the rule of reason to determine their overall competitive effect. These include agreements of a type that otherwise might be considered per se illegal, provided they are reasonably related to, and reasonably necessary to achieve procompetitive benefits from, an efficiency-enhancing integration of economic activity.[19]

[19] [Fed00].

In designing these guidelines, the Agencies' goal is to protect consumers and society from harmful agreements. But from a practical standpoint, perhaps it is fair to say that the guidelines (or at least the implementation of them) mainly focus on the impact of agreements on direct purchasers. In long supply chains, where there are many tiers of intermediaries, agreement among firms within one tier affects not only their direct customers, but also their indirect customers (and their direct and indirect suppliers). In this case, the true overall impact on society is almost impossible to quantify in practice, and remains a distant unknown.

Furthermore, it is possible that customers of colluding firms are intermediaries who can also form agreements among themselves. When two adjacent tiers of a supply chain separately but simultaneously collude, it would be wrong to dismiss the effects of the two instances of collusion on each other. Since collusion in one layer is likely to injure firms in an adjacent tier, one can reasonably assume that the two simultaneous cases of collusion are at odds with each other. If the two tiers of collusion undermine each other, then eliminating only one of them can in some cases leave the society worse off than eliminating neither. Yet current implementation of the Guidelines does not seem to address or recognize this issue. It seems that the courts have only been interested in tackling cartel cases one by one, without considering the possible relation between some of them which may happen in the same supply chain. This paper finds that an upper tier has both the incentive and the means (contracting) to restrict collusion of its direct purchasers, pushing up the quantity and lowering the price for consumers. It then follows that upstream collusion (upstream firms collaborating with each other on writing contracts with downstream firms) should not be dismissed as downright harmful in all cases. If downstream collusion exists but is not caught, then catching and eliminating upstream collusion can actually do a disservice to consumers and society. To make things worse, downstream colluding firms have an absolute incentive to sue upstream firms for collusion, while hiding their own colluding behavior. Given the current antitrust legal standing, unless the upstream firms can produce sufficient evidence to counter sue the downstream firms, the court is likely to award the downstream colluding firms treble damages when they are in fact the ones doing the most damaging to society, and the treble damages come from fining the relatively benign upstream agreement. This type of surplus reallocation would undermine our sense of fairness. There may not be an easy solution to this problem, since private plaintiffs carry the burden of proof, but perhaps an initial improvement can be achieved if the courts start considering upstream and downstream collusion cases together whenever relevant and possible.

The Guidelines hold that price fixing is per se unlawful. In light of the finding of this paper, perhaps regulators should adopt a more granular approach if an upstream group of firms are accused of price fixing when the court is uncertain about the competitive environment downstream.

The Guidelines also stipulate that agreements that are not challenged per se unlawful be judged based on the court's inquiry into their overall competitive effects - the combination of anticompetitive harm and procompetitive benefit. This paper suggests broadening the interpretation of "overall competitive effects" to include possible effects on competition in other tiers of the same supply chain.

The finding of this paper could potentially also be applied to mergers. Although mergers are different from collusion, they sometimes impose effects on competition similar to those imposed by collusion. According to [Fed00],

> The Agencies treat a competitor collaboration as a horizontal merger in a relevant market and analyze the collaboration pursuant to the *Horizontal Merger Guidelines* if appropriate, which ordinarily is when: (a) the participants are competitors in that relevant market; (b) the formation of the collaboration involves an efficiency-enhancing integration of economic activity in the relevant market; (c) the integration eliminates all competition among the participants in the relevant market; and (d) the collaboration does not terminate within a sufficiently limited period by its own specific and express terms.

Moreover, as acknowledged by [U.S10], a merger may diminish competition by enabling or encouraging post-merger coordinated interaction among firms that harms customers. At least in some cases, the merging of upstream firms facilitates upstream efforts to coordinate contracting terms, and the model predicts a procompetitive effect on the downstream market analogous to that in the case of upstream collusion. This implication may be of interest to antitrust enforcers who have been busy policing the recent boom in mergers-and-acquisition activity involving U.S. companies.

1.4.2 Collusion Detection

A cartel raises profits of its members by artificially restricting output and increasing prices at the expense of customers and suppliers, reducing the total surplus for society. Thus to public enforcers, the value of correctly detecting and deterring collusion is self-evident. To private plaintiffs, it is also vital to be able to prove collusive behavior when such behavior exists.

Needless to say, even with explicit collusion, evidence of communication between cartel members is hard to come by, because communication of this nature is illegal and thus is always surreptitious if carried out. Hence besides finding evidence of explicit communication, other methods are needed to detect collusion. There are corporate leniency programs in place in both the U.S.[20] and Europe[21], encouraging whistle blowing. The U.S. Department of Justice also uses an individual leniency policy[22]. By offering leniency on legal sanctions, these programs incentivize a "race to the courthouse" among cartel participants. These programs are helpful in catching collusion, but they are far from being sufficient.

In order for antitrust laws concerning collusion to operate effectively, it is crucial to develop rigorous methods to identify cartel behavior using economic evidence.

[20] See [U.S93].
[21] See http://ec.europa.eu/competition/cartels/leniency/leniency.html.
[22] See [U.S94].

In practice, this is not an easy task because many actions taken by firms to ensure successful operation of a cartel can also have legitimate noncollusive grounds. For example, simultaneous increases in prices can simply be oligopolistic behavior after an industry-wide cost increase. Therefore, it is important for antitrust practitioners to infer collusion from economic evidence using reliable empirical methods.

Currently, courts accept inference of collusion based on strong enough circumstantial evidence. Firms that make collusive arrangements violate Section 1 of the Sherman Act[23]. To reach the conclusion of violation without direct evidence of collusion, courts require presentation of sufficient economic circumstantial evidence that goes beyond the parallel movement of prices by firms. The collection of such economic circumstantial evidence is referred to as "plus factors".[24] [KMMW11] and [MM12] provide detailed discussion on collusion detection using plus factors. Examples of cartel actions that can act as plus factors include: price elevation, quantity restriction, allocation of collusive gain, redistributions, enforcement and punishment, dominant-firm conduct, to name a few. Evidence of individual or joint appearances of plus factors can help with collusion diagnosis.

One result of the model in this paper identifies systematically different pricing behavior by the upstream tier with and without downstream cartelization. Particularly, the model suggests that downstream collusion causes the optimizing upstream supplier to offer a steeper discount for large quantities but demand a higher payment for small quantities (in two-part tariff, a lower per-unit price and a higher fixed fee), compared to a market with no downstream collusion. This result suggests an interesting new plus factor that is associated with upstream pricing behavior. Strategically, it makes economic sense for suppliers to adjust prices when their profits are threatened by the collusive conduct of their customers, who are resellers (or intermediaries) of their products. How these price adjustments are made depends on the types of sup-

[23] 15 U.S.C. §§ 1-7.

[24] ABA Section of Antitrust Law, Antitrust Law Developments (2007):11-16.

ply contracts. In general, linear pricing contracts do not give suppliers much scope to work with to contain profit loss due to downstream collusion, because optimizing suppliers charge the same linear price with and without downstream collusion. But nonlinear pricing contracts do, and many industries traditionally adopt nonlinear pricing to enhance total profits of the supply chain. Many nonlinear pricing contracts are simply various forms of quantity discount (two-part tariff is quantity discount in the extreme). With these contracts, price adjustments in response to downstream collusion could follow a similar pattern. If this pattern is identified, then courts may add it to the basket of plus factors permitted as circumstantial evidence of collusion. The novelty lies in the fact that this potential new plus factor would be upstream behavior used as circumstantial evidence of downstream collusion.

1.4.3 Antitrust Damages

The supplier's ability to use supply contracts to restrict downstream collusion renews our understanding of collusion damages.

In the United States, The Clayton Act of 1914 awards treble damages and the cost of suit to "any person who shall be injured in his business or property by reason of anything forbidden in the antitrust laws"[25], providing incentives for private enforcement efforts. In cartel cases, courts are willing to award overcharge to direct purchasers, but are reluctant to restore suppliers' lost profits due to anticompetitively reduced demand [see *Associated General Contractors*[26]]. While the flaw of direct purchaser overcharge as a measure of antitrust harm is recognized [see, for example, [Fis06] and [HST09]], it remains difficult, if not impossible, to accurately calculate damages to direct and indirect suppliers of cartel members. One difficulty in measuring harm to direct suppliers is that suppliers can adjust pricing in response

[25] 15 U.S.C. §§ 12-27, 29 U.S.C. §§ 52-53.

[26] *Associated General Contractors of California, Inc. v. California State Council of Carpenters and Carpenters Northern Counties Conference Board et al.*, 459 U.S. 519 (1983).

to decreased demand. Thus, for antitrust practitioners who want to correctly measure upstream damages, it is crucial to soundly understand suppliers' responses to downstream cartel behavior.

It would be an oversimplification of the problem to assume that suppliers respond to decreased demand the same way regardless of the cause of the demand decrease. Particularly, if the cutback in demand has a collusive motive, then suppliers can adjust pricing to rein in downstream collusion (as this paper shows); but if the demand reduction is not caused by anticompetitive activity, then suppliers would adjust pricing in a different way.

Admittedly, in practice, suppliers may not know whether downstream firms are colluding when deciding on pricing, and even if they do know, they may not be aware that using nonlinear pricing can constrict downstream collusion and mitigate their profit loss compared to using linear pricing. So how can the finding of this paper be used to improve upstream damage calculation in practice? My answer to this question is twofold:

(1) If suppliers have only offered the same linear pricing contracts in both collusion and non-collusion periods, then it is a sign that their pricing strategies have been taken advantage of by the downstream firms in forming a cartel. In this case, it is reasonable to compare the actual demand with the demand that would have realized without cartelization (the "but-for" consideration), and multiply the difference in demand by the upstream per-unit profit to obtain an estimation of upstream damages.[27]

(2) If suppliers have offered nonlinear pricing contracts during periods of collusion, then there is reason to believe that the negative impact of downstream collusion is minimal due to the limited scope of collusion allowed for by upstream nonlinear pricing. This information could also have ramifications for overcharge measurement

[27]Strategically, suppliers who only offer linear pricing optimally maintain the same unit price with and without downstream collusion.

when the plaintiffs are direct purchasers, but arguments would be more delicate on that front: Given upstream nonlinear pricing contracts, colluding may be the only way for the downstream firms to survive. In this situation, one could argue that it may actually be unfair to impose all antitrust fines on the downstream cartel, because suppliers' nonlinear pricing behavior alone could have left these firms with no other choice but to collude. But one could also argue that suppliers would not have needed to price this way if there had not been any threat of downstream cartelization to begin with. In this sense, there seems to be no simple way to cleanly isolate the amount of responsibility borne by the downstream firms alone in creation of the cartel. Thus, decisions to transfer the amount of "overcharge" from cartel members to their direct customers simply based on the so-called "but-for" transactions between the two groups may be misguided.

The above is far from suggestion of a perfect solution to the problem of measuring upstream damages. Rather, it proposes one possible way to partially reconcile the theoretical ideal of awarding all injured parties their respective antitrust damages, and the Court's concern that an overly complex apportionment of damages would undermine the effectiveness of treble-damages suits. The Court is willing to forgo the benefit of appropriately compensating injured parties who are not direct purchasers, in exchange for a simple, low-cost judicial process, in order to preserve private litigation efforts. The above discussion does not speak for all injured parties, but it suggests that allowing suppliers legal standing to sue for collusion damages could actually be viable (and not too complex to implement) if upstream pricing is linear. Denying standing to suppliers who price nonlinearly could be less costly to society than denying standing to those who price linearly.

1.4.4 Predatory Pricing Diagnosis

In this part, I dabble in the territory of Section 2 of the Sherman Act[28], which penalizes monopolization behavior and attempts to monopolize. Predatory pricing cases fall into this category.

In their seminal article, [AT75] proposed a test for proving predatory pricing (strategically pricing low temporarily to force out competition), which has since had a significant amount of legal impact. As stated by [Hov15], every federal circuit court except the Eleventh has embraced some variation of the test, and the Supreme Court has also come very close to adopting it.

The Areeda-Turner Test in its original form has two components: (1) test for "recoupment", and (2) the AVC (average variable cost) test. In essence, to prove that a firm's pricing behavior is predatory, the plaintiff must show two things: (1) the predator can reasonably expect future monopoly profits to more than cover the initial cost of pricing low temporarily, (2) the predator prices below average variable cost.

But for many years since Areeda and Turner's article was popularized in 1975, the courts mostly used only the second part of the test to rule on predatory pricing cases. This practice has drawn criticisms from many economists. One criticism is that in markets with high fixed costs, pricing low but above average variable cost can still have exclusionary effects. Thus the AVC test alone could produce too many false negatives, and under-deter predation. This problem is only exacerbated by the fact that markets with high fixed costs are precisely the ones most susceptible to predatory pricing. It is then perhaps not surprising that predatory pricing claims have often been difficult to win. The Areeda-Turner AVC test, though still in use, has much room for improvement.[29] In particular, finding a good way to determine

[28] 15 U.S.C. §§ 1-7.

[29] One attempt to improve the test is by [AH15], who refine the definition of "variable" cost. However, this refinement hugely complicates fact finding, and has so far not seen much success in

above-cost predatory pricing is difficult, but it would be of great value.

There are two other popular criticisms of the Areeda-Turner AVC test. One of them is the inadequacy of average variable cost as a proxy for short-run marginal cost. The other one is the more fundamental flaw of using short-run measures to infer predation.

The recoupment requirement has been brought back into discussion in the courtroom since *Matsushita*[30], but the AVC assessment still remains an important part of the Areeda-Turner test.

In order to improve the test on predatory pricing, we need to have a solid understanding of all underlying economic factors that could possibly cause a defendant to price low. Traditional places to look for these factors are the defendant's cost structure and competitive landscape. But the results of this paper suggest that antitrust practitioners should also examine competition in the downstream market, provided that the downstream market is not the end user market, and the defendant prices nonlinearly. This is because an upstream supplier with market power who prices nonlinearly can and will optimally adjust pricing in response to changes in downstream competition, which means competition in the downstream market should also influence a defendant's pricing decision. A supplier raising the fixed fee and lowering the unit price (or offering a steeper discount for large quantities while demanding a higher payment for small quantities) may simply be responding to downstream cartelization, though this pricing behavior could have the appearance of predation.

1.4.5 Regulation

Different regulations aim to achieve different goals, not all of which are economic. Regulations with economic goals may also try to achieve different outcomes. One regulation may be in place to increase economic efficiency, while another may be

case law.

[30] *Matsushita Electric Industrial Co., Ltd. v. Zenith Radio Corp.*, 475 U.S. 574 (1986).

enforced for redistribution.

A large part of economic regulation, with various goals, has to do with pricing. The government may want to regulate a natural monopoly not because it is inefficient in production, but because it is inefficient in allocation. By regulating how a monopolist prices, we can potentially achieve increases in both quantity and total surplus.

Ideally, all regulations should result from full analyses of benefits and costs. A regulation based on only partial benefit-cost analysis could have unintended consequences. This paper aims to shed some new light on the relationship between pricing by an upstream supplier and competition in the direct downstream market. The main conclusion of the model is that downstream competition can be influenced by upstream pricing. Thus it becomes an issue that price regulation on an upstream industry may unintentionally affect downstream competition. It seems that price regulations are rarely made with a holistic consideration of their competitive effects on all related markets. This could be a potential area for improvement for regulators.

1.4.6 Implication for Antitrust Enforcement

In view of the above policy implications, the following scenario reflects some potential weaknesses of antitrust enforcement in its current state.

Consider Supplier A, a natural monopolist who manufactures and sells a product to retailers, who then compete in reselling to consumers. Supplier A has acquired monopoly power through production efficiency, and offers quantity discounts to all retailers. Using quantity discounts, Supplier A is able to coordinate the supply chain and capture a large portion of the total profit. But at some point, the retailers form a cartel, and enter into a secret agreement to all cut back on their orders from Supplier A. By colluding to reduce quantities available in the consumer market, the retailers are able to increase the price of the product, and obtain higher profits than before.

As a result, consumer surplus is reduced, and Supplier A's profit falls. Unsuspecting consumers have not taken any legal action against the colluding retailers, and Supplier A cannot take the retailers to court because as a supplier, not customer of the retailers, it will not be given antitrust standing to sue for damages. However, Supplier A can change the terms of the supply contracts to influence the colluding retailers' behavior. It starts offering retailers steeper discounts for large quantities and charging higher prices for small quantities.[31] In response, the retailers increase their collusive quantities.[32] Consequently, Supplier A's profit loss is reduced, and consumer surplus is restored to almost the same level as before retail collusion took place.

Supplier A's execution of price change is noticed by Supplier B, a company that has been eying the industry but has not been successful in entering the market, because it owns outdated technology, and simply cannot produce a product as good as Supplier A's, or offer a price as low as Supplier A's. Supplier B now sees an opportunity, and sues Supplier A for predatory pricing, based on the steeper discounts Supplier A recently started to offer to retailers. Supplier B's claim is that it is not able to enter the market because Supplier A has decided to price low anticompetitively in order to keep out potential competitors. The judge examines Supplier A's costs, and applies the Areeda-Turner AVC test. Evidence shows that Supplier A's average variable cost (AVC), used as a proxy for its short-run marginal cost (SRMC), is higher than the discounted price it currently offers. And the judge concludes that Supplier A can reasonably anticipate future monopoly profits to more than cover its "investment" of temporarily pricing at a loss. Supplier A defends its pricing strategy by explaining the need to restrict retail collusion. But the court dismisses Supplier A's defense as baseless and irrelevant, and rules in Supplier B's favor. (In this case,

[31] Refer to Proposition 5.

[32] Now the retailers have technically lost their ability to compete, but are forced to collude at a large quantity.

AVC is a poor proxy for SRMC. Areeda and Turner themselves noted that only in a competitive market in equilibrium, and with modest fixed costs, AVC and SRMC are close together. Supplier A owns a superior technology. Its fixed cost is not modest. It is also likely not operating in equilibrium at this point, as quantity has just been artificially reduced anticompetitively, and it is responding to this change. In such a response, Supplier A may be pricing below AVC, but it is not pricing below SRMC, thus it is not incurring a loss in the short run.)

With its pricing behavior being "disciplined" by the court, Supplier A now has no way to reverse the profit loss caused by retail collusion. So it turns to cost cutting, and in doing so, sacrifices the quality of its once superior product. This creates an opening for Supplier B to enter the market with a subpar product, and share some of the industry profit. Meanwhile, retailers continue to collude, because collusion still gives them higher profits than competing. After a while, Supplier A and Supplier B decide that it would help both of them if they collude in pricing in order to restrict retail collusion. Retailers soon find out about the two suppliers' collusive arrangement, and sue them for damages as direct customers. Retailers win the case and receive compensation, yet their own colluding behavior stays unpunished.

1.5 Extension: Asymmetric Collusion

In this section, I show that Propositions 1 is robust to retailers adopting a common asymmetric collusive scheme, in the sense that when confronted with asymmetric downstream collusion, two-part tariff still induces a larger total quantity than linear pricing, and it is still preferred by the supplier (as well as consumers and society) to linear pricing.[33]

I analyze an asymmetric equilibrium where the two retailers collude in the

[33] I am writing another paper to examine how upstream contracting influences downstream collusion when there are $N \geq 2$ retailers in the downstream market. In that paper, I provide more robustness results for asymmetric collusion.

following way under two-part tariff: in each period, only one retailer purchases a positive amount for resale, while the other stays off the market. The idea of the collusive agreement is to maximize the retailers' collective profit in each period by having only one of them pay the fixed fee. The two retailers take turns staying off the market.[34]

In the asymmetric formulation, after observing w and f, the retailers' problem is

$$\begin{aligned} \underset{q}{\text{maximize}} \quad & \Pi^{Coll} = \pi^{Coll} = (a - bq - w)q - f \\ \text{subject to} \quad & h_{In}(q, w, f) \geq 0 \\ \text{and} \quad & h_{Out}(q, w, f) \geq 0\,, \end{aligned} \tag{R_A}$$

where $h_{In}(q, w, f)$ is the collusion condition for an active retailer, and $h_{Out}(q, w, f)$ is the collusion condition for an inactive retailer. $h_{In}(q, w, f)$ and $h_{Out}(q, w, f)$ together constitute the retailers' individual rationality constraint.

The supplier wants to maximize $\pi_S = q(w - c) + f$ by choosing w and f. We will be able to backward induct how these choices are made by the supplier after analyzing the retailers' best responses.

Suppose such an asymmetric collusive equilibrium exists. Then in equilibrium, two collusion conditions must hold simultaneously for any one period: a retailer who is in the market finds it at least as profitable to adhere to the collusive agreement as to deviate, and the same goes for a retailer who is outside of the market. As such, we have the following two conditions:

$$\begin{aligned} &(1-\delta)[(a - bq - w)q - f] + \frac{1}{2}\delta[(a - bq - w)q - f] \\ &\geq (1-\delta)\frac{(a-w)^2}{4b} - (1-\delta)f + \delta \max\left\{\frac{(a-w)^2}{9b} - f,\ 0\right\} \end{aligned} \tag{In}$$

[34]In practice, this phenomenon may take the form of retailers reselling the good to one another.

for the active retailer, and

$$\begin{aligned}&\frac{1}{2}\delta[(a-bq-w)q-f]\\&\geq(1-\delta)\frac{1}{4b}(a-bq-w)^2-(1-\delta)f+\delta\max\left\{\frac{(a-w)^2}{9b}-f,\ 0\right\}\end{aligned} \tag{Out}$$

for the inactive retailer.[35]

Let collusion condition (In) be rewritten as $h_{In}(q,w,f)\geq 0$. In other words, let $h_{In}(q,w,f)\equiv(1-\delta)[(a-bq-w)q-f]+\frac{1}{2}\delta[(a-bq-w)q-f]-(1-\delta)\frac{(a-w)^2}{4b}+(1-\delta)f-\delta\max\left\{\frac{(a-w)^2}{9b}-f,\ 0\right\}$.

Let collusion condition (Out) be rewritten as $h_{Out}(q,w,f)\geq 0$. In other words, let $h_{Out}(q,w,f)\equiv\frac{1}{2}\delta[(a-bq-w)q-f]-(1-\delta)\frac{1}{4b}(a-bq-w)^2+(1-\delta)f-\delta\max\left\{\frac{(a-w)^2}{9b}-f,\ 0\right\}$.

First the supplier chooses a pair (w,f) as the contract offer, then the two retailers agree on q, the quantity purchased by an active retailer in a period. Each player maximizes the value of a discounted stream of profits going into the future. The supplier makes her decision at only one point in time, whereas the retailers first make a collective decision on the choice of q, then each retailer individually purchases his own quantity in each period.

Similarly to the previous case of retail symmetric collusion, complications arise in solving the supplier's optimization problem, due to the non-interior nature of the solution. However, we can still reach some meaningful conclusions by analyzing how the supplier would choose the fixed fee f for any per-unit price w. In what follows, I show that the main result is robust to asymmetric collusion.

For a given w, Lemmas 12 - 15 show the dynamics of the collusion conditions caused by a changing fixed fee. Understanding these dynamics will be helpful to

[35] Profits are a discounted stream of values, counting from the current period. For example, an active retailer could choose to collude or deviate in a period. If he chooses to collude, then he gets a collusive profit in the current period, and expects to get half of the total collusive profit for all future periods, conditional on the other retailer colluding.

analyzing both the supplier and the retailers' incentives in the asymmetric collusion setting. With this understanding, I will then go as far as I can to characterize the players' equilibrium behavior, as relevant to the robustness result. Lemmas 12 - 15 are presentations of the dynamics of the individual collusion conditions in response to a changing fixed fee, while holding w constant.

Lemma 4. *For any given w, when $f < f_0 = \frac{(a-w)^2}{9b}$, increasing f loosens individual collusion condition* (In)*, by enlarging the set of sustainable collusive quantities* $\Theta_{In}(w,f) \equiv \{q : h_{In}(q,w,f) \geq 0\}$.

Proof. When $f < f_0 = \frac{(a-w)^2}{9b}$, $\max\left\{\frac{(a-w)^2}{9b} - f,\ 0\right\} = \frac{(a-w)^2}{9b} - f$. Thus, condition (In) can be written as

$$h_{In}(q) = \kappa_1 + \frac{1}{2}\delta f \geq 0\,, \tag{In:1}$$

where $\kappa_1 = (1 - \frac{1}{2}\delta)(a - bq - w)q - (1-\delta)\frac{1}{4b}(a-w)^2 - \delta\frac{(a-w)^2}{9b}$ is independent of f. $h_{In}(q)$ is a quadratic in q, whose graph opens downward. Since $\frac{1}{2}\delta > 0$, increasing f loosens the individual collusion condition. □

Lemma 5. *For any given w, when $f \geq f_0 = \frac{(a-w)^2}{9b}$, increasing f tightens individual collusion condition* (In)*, by shrinking the set of sustainable collusive quantities* $\Theta_{In}(w,f) \equiv \{q : h_{In}(q,w,f) \geq 0\}$.

Proof. When $f \geq f_0 = \frac{(a-w)^2}{9b}$, $\max\left\{\frac{(a-w)^2}{9b} - f,\ 0\right\} = 0$. Thus, condition (In) can be written as

$$h_{In}(q) = \kappa_2 - \frac{1}{2}\delta f \geq 0\,, \tag{In:2}$$

where $\kappa_2 = (1 - \frac{1}{2}\delta)(a - bq - w)q - (1-\delta)\frac{1}{4b}(a-w)^2$ is independent of f. $h_{In}(q)$ is a quadratic in q, whose graph opens downward. Since $-\frac{1}{2}\delta < 0$, increasing f tightens the individual collusion condition. □

Lemma 6. *For any given w, when $f < f_0 = \frac{(a-w)^2}{9b}$, increasing f loosens individual collusion condition* (Out)*, by enlarging the set of supportable collusive quantities*

$\Theta_{Out}(w,f) \equiv \{q : h_{In}(q,w,f) \geq 0\}$.

Proof. When $f < f_0 = \frac{(a-w)^2}{9b}$, $\max\left\{\frac{(a-w)^2}{9b} - f,\ 0\right\} = \frac{(a-w)^2}{9b} - f$. Thus, condition (Out) can be written as

$$h_{Out}(q) = \kappa_3 + \left(1 - \frac{1}{2}\delta\right) f \geq 0\,, \tag{Out:1}$$

where $\kappa_3 = \frac{1}{2}\delta(a - bq - w)q - (1-\delta)\frac{1}{4b}(a - bq - w)^2 - \delta\frac{(a-w)^2}{9b}$ is independent of f. $h_{Out}(q)$ is a quadratic in q, whose graph opens downward. Since $1-\frac{1}{2}\delta > 0$, increasing f loosens the individual collusion condition. □

Lemma 7. *For any given w, when $f \geq f_0 = \frac{(a-w)^2}{9b}$, increasing f would:*

- *loosen individual collusion condition* (Out)*, by enlarging the set of sustainable collusive quantities $\Theta_{Out}(w,f) \equiv \{q : h_{In}(q,w,f) \geq 0\}$, if $\delta < \frac{2}{3}$;*
- *tighten individual collusion condition* (Out)*, by shrinking the set of sustainable collusive quantities $\Theta_{Out}(w,f) \equiv \{q : h_{In}(q,w,f) \geq 0\}$, if $\delta > \frac{2}{3}$; or*
- *not affect individual collusion condition* (Out)*, if $\delta = \frac{2}{3}$.*

Proof. When $f \geq f_0 = \frac{(a-w)^2}{9b}$, $\max\left\{\frac{(a-w)^2}{9b} - f,\ 0\right\} = 0$. Thus, condition (Out) can be written as

$$h_{Out}(q) = \kappa_4 + \left(1 - \frac{3}{2}\delta\right) f \geq 0\,, \tag{Out:2}$$

where $\kappa_4 = \frac{1}{2}\delta(a - bq - w)q - (1-\delta)\frac{1}{4b}(a - bq - w)^2$ is independent of f. $h_{Out}(q)$ is a quadratic in q, whose graph opens downward. The sign of the coefficient $(1 - \frac{3}{2}\delta)$ depends on the value of δ. If $\delta < \frac{2}{3}$, then increasing f loosens the individual collusion condition; if $\delta > \frac{2}{3}$, then increasing f tightens the individual collusion condition; if $\delta = \frac{2}{3}$, then changing f does not affect the individual collusion condition. □

The dynamics of changing the fixed fee f goes as follows: Increasing the fixed fee from zero to the Cournot-Nash profit f_0 makes both types of retailers (the active and the inactive) better able to collude[36], where the individual collusion condition for the inactive retailer loosens at a faster rate than that for the active retailer[37]. To understand this effect, note that in a cooperative period, an inactive retailer would only have to pay the fixed fee if he chooses to deviate. Thus, increasing a small fixed fee makes an inactive retailer more willing to collude (thereby avoiding a larger fee). As for an active retailer, increasing a small fixed fee also makes him more willing to collude, because an active retailer who chooses to collude also expects to save the fixed fee in some future periods.

Once f exceeds f_0, the collusion condition for the active retailer begins to tighten, for the same reason we previously discussed in the symmetric case: A fixed fee exceeding f_0 wipes out the entirety of the Cournot-Nash profit, in which case the punishment profit is zero because exiting the market would serve a retailer better than staying and paying a hefty fixed fee. On the other hand, when f exceeds f_0, the individual collusion condition for the inactive retailer could either loosen or tighten, depending on the value of δ. Three possible scenarios:

1. If $\delta < \frac{2}{3}$, then further increasing the fixed fee above the threshold f_0 only works to further loosen the individual collusion condition for the inactive retailer. In this case, the binding individual collusion condition would be h_{In}, and the supplier would keep increasing f until $h_{In} = 0$.

2. If $\delta = \frac{2}{3}$, then further increasing the fixed fee above the threshold f_0 does not affect the individual collusion condition for the inactive retailer. In this case, the binding individual collusion condition would still be h_{In}, and the supplier would keep increasing f until $h_{In} = 0$.

3. If $\delta > \frac{2}{3}$, then further increasing the fixed fee above the threshold f_0 tightens

[36] The expansion of the set of sustainable collusive quantity indicates a group better able to collude.
[37] This can be seen with a contrast of conditions (In:1) and (Out:1): the coefficient of f in (Out:1) is larger than the coefficient of f in (In:1).

the individual collusion condition for the inactive retailer. In this case, it is not immediately clear whether (In) or (Out) would be the binding individual collusion condition. But note that for the purpose of proving robustness of the main result, it is sufficient to know that one of (In) and (Out) would bind.

The above three scenarios can be explained by two opposing forces. On the one hand, there is a strictly positive benefit of colluding: Retailers can expect to save some fixed fees in at least some periods. This consideration makes an inactive retailer more willing to collude when the fixed fee increases, because when the fixed fee increases, the benefit of colluding becomes higher. This is the force that expands the retailers' set of sustainable collusive quantities when the fixed fee increases. On the other hand, similarly to the case of symmetric collusion, increasing the fixed fee above the Cournot-Nash profit impacts the retailers' punishment profile, and thus reduces the set of sustainable collusive quantities. Which effect is stronger depends on how big δ is. If δ is small, then the fixed-fee saving effect dominates (Scenario 1); if δ is large, then the collusion restriction effect dominates (Scenario 3).

Assumption 1. *For each per-unit price w, we only study $\delta(w)$ sufficiently large to support the retail monopoly quantity under the wholesale linear pricing rule $\Phi(q_i) = wq_i$, where $\Phi(q_i)$ is the required payment to the supplier from retailer i who purchases quantity q_i.*

Assumption 1 does not undermine the robustness result in a meaningful way, because from a welfare standpoint, it is when retailers are patient enough to sustain a retail monopoly quantity that methods to restrict collusion are of the most interest. If retailers are rather impatient, then the downstream market would be rather competitive under all types of supply contracts. In that case, the supplier would be less concerned about retail collusion, and can easily coordinate the supply channel, so any constraint that can be put on downstream collusion in theory would be less interesting and useful for practice.

If δ satisfies Assumption 1, then Proposition 1 is robust to retailers adopting the asymmetric collusive scheme. This result is summarized below in Propositions 17 and 18.

Proposition 8. *When confronted with asymmetric retail collusion, a monopolist supplier still prefers offering a two-part tariff contract to offering a linear pricing contract.*

Proof. It suffices to show that for any per-unit price w, $f^*(w) > 0$ is true. To do that, I argue that $f(w) = 0$ cannot be in equilibrium.

Suppose $f(w) = 0$. Then optimizing retailers must choose q such that $q = Q^{RM}(w) = \frac{a-w}{2b}$, where $Q^{RM}(w)$ is the retail monopoly quantity for a given w.[38] For any given w, the individual Cournot-Nash profit is $f_0(w) = \frac{(a-w)^2}{9b} > 0$. Since $f(w) = 0$, each retailer obtains $f_0(w)$ in any punishment period. Due to Lemmas 12 and 14, the supplier could deviate to charging a positive fixed fee $f(w) \in (0, f_0(w))$ without affecting the retail cartel's choice of q. Such deviation would strictly increase the supplier's profit. Therefore, $f(w) = 0$ cannot be in equilibrium.

□

We can again go further than Proposition 17 to investigate finer characteristics of $f^*(w)$ under asymmetric retail collusion, which would be essential for examination of the collusion-restricting effect of a two-part tariff contract.

Proposition 9. *Under asymmetric retail collusion, a monopolist supplier offering a two-part tariff chooses $(w, f^*(w))$ such that $f^*(w) > f_0(w) = \frac{(a-w)^2}{9b}$. As a result, when $\delta > \frac{2}{3}$, the total quantity in equilibrium exceeds the retail monopoly quantity under linear pricing $Q^{RM}(w) = \frac{a-w}{2b}$.*

Proof. Under Assumption 1, $f(w) \in [0, f_0(w))$ cannot be in equilibrium, since the supplier can always do better by adding $\epsilon > 0$ to $f(w) \in [0, f_0(w))$.

[38] Assumption 1 guarantees that the retailers are patient enough to sustain this collusive quantity.

For $f(w) \in [f_0(w), \infty)$, the punishment profile is no longer the Cournot-Nash profile, but a profile where all retailers exit the market and obtain zero profit. This is the mechanism through which an appropriately set fixed fee that is high enough can restrict retail collusion. The supplier would keep increasing f beyond the Cournot-Nash profit $f_0(w)$, until the set of sustainable collusive quantities, $\bar{\Theta}_{Asym}(w, f) \equiv \{q : h_{In}(q, w, f) \geq 0 \text{ and } h_{Out}(q, w, f) \geq 0\}$, becomes a singleton. This is because when $\bar{\Theta}_{Asym}(w, f)$ becomes a singleton, either $h_{In}(q, w, f) = 0$ with a single quantity $\hat{\hat{q}}_{A,In}$[39], or $h_{Out}(q, w, f) = 0$ with a single quantity $\hat{\hat{q}}_{A,Out}$[40]. When $h_{In}(q, w, f) = 0$ at $q = \hat{\hat{q}}_{A,In}$, each participating retailer purchases

$$\hat{\hat{q}}_{A,In} = \frac{a - w}{2b} \, ;$$

when $h_{Out}(q, w, f, M) = 0$ at $q = \hat{\hat{q}}_{A,Out}$, each participating retailer purchases

$$\hat{\hat{q}}_{A,Out} = \frac{a - w}{b} \cdot \frac{1}{\delta + 1} \, .$$

Since $Q^{RM}(w) = \frac{a-w}{2b}$, we have the following:

$$Q^{RM}(w) = \hat{\hat{q}}_{A,In} < \hat{\hat{q}}_{A,Out} \, , \tag{1.2}$$

for any $\delta \in (0, 1)$. Lemmas 12 - 15 imply that when $\delta > \frac{2}{3}$, $\hat{\hat{q}}_{A,Out}$ will be reached. This result says that patient retailers' ability to sustain the downstream monopoly quantity with an asymmetric collusive scheme can be restricted by a supplier demanding a fixed fee higher than the Nash threshold. The supplier is self-incentivized to pick such a high fixed fee, since this high fee also induces a large total quantity in equilibrium.

□

[39] $q = \hat{\hat{q}}_{A,In}$ is the unconstrained maximizer of $h_{In}(q, w, f)$.

[40] $q = \hat{\hat{q}}_{A,Out}$ is the unconstrained maximizer of $h_{Out}(q, w, f)$.

1.6 Conclusion

Collusion increases cartel members' profits at the expense of not only their customers, but also their suppliers. While not having much legal standing to sue for damages caused by downstream collusion, a supplier with market power can nonetheless adjust nonlinear pricing (e.g., two-part tariff) in supply contracts to contain profit loss. The supplier adjusts pricing in a way that pushes downstream firms to collude at a large quantity. This adjustment of price by suppliers also increases the welfare of consumers and of society overall.

Because this effect of price adjustment on downstream collusion is only possible with nonlinear pricing, but not linear pricing, there is a new incentive for suppliers to contract with nonlinear pricing.

When upstream contracts are nonlinear, the presence of downstream collusion changes upstream pricing in a systematic way. This points to a potential new place for competition authorities to look for circumstantial evidence of collusion. Examination of changes in upstream pricing behavior may assist with detection of downstream collusion.

Regulation on upstream suppliers' pricing behavior may impact competition in the downstream market.

Upstream collusion or mergers may facilitate the type of nonlinear pricing that restricts downstream collusion. Examination on upstream cartelization should not be isolated from examination on the downstream competitive environment.

Downstream collusion can cause damages to upstream suppliers. Such damages are less severe with upstream nonlinear pricing than with upstream linear pricing.

An upstream monopolist supplier can offer steep quantity discounts to restrict downstream collusion, but such an offering could have the appearance of predatory pricing.

1.7 Acknowledgement

Chapter 1, in part, is currently being prepared for submission for publication of the material. Huang, Zheng. The dissertation author was the author of this material.

Chapter 2

Vertical Contracting and Downstream Collusion with Many Firms

Upstream nonlinear pricing is more limiting to downstream collusion than upstream linear pricing, as I showed in Chapter 1. In this paper, I generalize this result with upstream two-part tariff to allow for: (1) an arbitrary number of downstream firms, and (2) an asymmetric cartel agreement, where in each period, only a subset of all downstream firms participate in trade in order to reduce the total amount of fixed fees paid by the downstream cartel. I also find that when downstream firms collude symmetrically under a two-part tariff, the total quantity in equilibrium is decreasing in the number of downstream firms.

2.1 Introduction

The standard economic models of vertical contracting are one-shot games. Some dynamic models consider cartelization, but typically only as an ex post effect—each downstream firm is assumed to act independently. In Chapter 1, I provided a model where two downstream firms act as a collusive pair, and discovered a strategic use of vertical contracting by the upstream monopolist to rein in downstream collusion. Nonlinear contracting (in particular, two-part tariff) by the upstream monopolist achieves such an outcome.

In this chapter, I generalize the analysis in Chapter 1 by allowing for an arbitrary number of downstream firms, where the number of downstream firms is exogenously assigned. The key results from Chapter 1 can be carried over to the general model. In this general setting, when downstream firms collude symmetrically under a two-part tariff contract, an increase in the number of downstream firms decreases the equilibrium quantity. This is somewhat counterintuitive, since we typically understand the optimal quantity choice by a cartel to be independent of the number of firms within the cartel. I also devote a large part of this chapter to analyzing one form of asymmetric collusion in the general model. The collusion-restricting effect of nonlinear pricing remains.

2.2 The Model

I consider a two-tier vertical model with one upstream monopolist supplier S and N independent, identical downstream retailers $R_1, R_2, \cdots, R_N$. The supplier produces a homogeneous good at marginal cost c, which it sells to the N retailers, who then resell the product to consumers.

First, the supplier offers the same wholesale contract to all N retailers, which is to be enacted in all periods.

Then, an infinitely repeated game is played by the retailers, with the following happening in every period:

1. The N retailers independently and simultaneously decide whether to accept

the contract, and if they do, purchase some quantities of the product from the supplier for sale in the current period. Denote these quantities $q_1, q_2, \cdots, q_N \geq 0$. Rejection of the contract offer leads to zero profit for a retailer.

2. The market clears, with the price determined by inverse linear demand $P = a - bQ$, and all players' profits are realized.

The game is again of common knowledge and perfect monitoring. Each player maximizes his or her stream of discounted payoffs over an infinite horizon. Retailers share a common discount factor $\delta \in (0, 1)$.

Two assumptions continued from the original model: (1) The supply contracts are take-it-or-leave-it offers written by the supplier. (2) It is assumed that retailers engage in horizontal collusion whenever collusion is sustainable and profit-enhancing.

Adding to the previous paper, I provide the following comment on the stationarity assumption on the upstream pricing rules. In the model, it is assumed that without demand variation, the supplier follows through with the same contract in every period. I argue that this assumption is in fact not too restrictive. Based on the aforementioned assumption that retailers collude whenever collusion is sustainable and profit-enhancing, it is not an equilibrium strategy for the supplier to change in any period from the optimal contract in a retail collusive environment, not even after a retail deviation. If the supplier's strategy is such that after retail deviation, she changes to a contract that is not optimal under retail collusion—for example, if she changes to the optimal contract under retail competition, then retailers' best response to this strategy is not to enter into punishment after deviation, but continue colluding after deviation. In this case, the supplier's best response would be to go back to the optimal contract under retail collusion.

I illustrate how the supplier can utilize her contracting power to influence downstream retailers' interactions. In particular, the supplier can design terms of the contract in ways that restrict retail collusion, and she is self-incentivized to do so without external enforcement. As a reminder, the model operates under the condition that resale is prohibited downstream.

The model studies two-part tariff contracts. Contract terms are as follows: A retailer purchasing a positive quantity pays a fixed fee f, plus a per-unit price of w; a retailer pays nothing if no quantity is purchased. In any period t, retailer i gets payoff

$$\pi_{it} = \begin{cases} 0, & \text{if } q_{it} = 0\,; \\ q_{it}(a - bq_{it} - bQ_{-it} - w) - f, & \text{if } q_{it} > 0\,. \end{cases}$$

2.3 Equilibrium Results and Discussion

As the number of retailers is generalized to N, the condition to sustain retail collusion: $\frac{\pi^{Coll}}{1-\delta} \geq \pi^{Dev} + \frac{\delta}{1-\delta}\pi^{Pun}$, becomes

$$\begin{aligned} (a - bqN - w)q - f \ \geq\ & (1-\delta)\frac{1}{4b}(a - b(N-1)q - w)^2 - f(1-\delta) \\ & + \delta \max\left\{ \frac{(a-w)^2}{b(N+1)^2} - f,\ 0 \right\}\,. \end{aligned} \tag{2.1}$$

$f_0(w) = \frac{(a-w)^2}{b(N+1)^2}$ is a retailer's profit in Cournot competition when he faces a unit price w and no fixed fee. If the fixed fee f exceeds this profit, then "Nash reversion" becomes no purchase, and the punishment profit becomes zero. For a given per-unit price w, as the number of retailers in the market increases, the fixed fee required to effect a punishment profile of no purchase is reduced. This is because increasing the number of retailers, all else equal, intensifies downstream competition, leading to a lower competition profit for all retailers. Consequently, the supplier would not need as large a fixed fee to influence the retailers' behavior in a punishment period.

Parallel to the symmetric equilibrium analysis in Chapter 1, with N retailers in the market, I first derive the following result:

Lemma 8. *In symmetric collusive equilibrium, $f \geq f_0(w)$.*

It is necessary to display the glossary of notation in the case of N retailers:

$q^N(w) = \frac{a-w}{b(N+1)}$, the competitive Nash equilibrium quantity for an individual retailer, when the per-unit wholesale price is w, and there is no fixed fee;

$\hat{q}(w) = \frac{a-w}{2bN}$, the maximizing q for $\pi^{Coll}(q, w, f)$;

$\hat{\hat{q}}(w) = \frac{a-w+\frac{1-\delta}{2}(a-w)(N-1)}{2bN+\frac{1-\delta}{2}b(N-1)^2}$, the maximizing q for $h(q, w, f)$;

$\tilde{q}(w, f) =$ the solution to the retailers' problem (R) when the contract terms are (w, f);

$f^*(w) =$ the supplier's optimal fixed fee for a given w;

$q^*(w) =$ the solution to the retailers' problem (R) when the contract terms are $(w, f^*(w))$.

More results follow correspondingly, along with additional comments on market outcome dynamics resulting from introducing the variable N:

Proposition 10. *For any w, the supplier's optimal fixed fee is $f^*(w) = \frac{1}{\delta}[(a - b\hat{\hat{q}}(w)N - w)\hat{\hat{q}}(w) - (1-\delta)\frac{1}{4b}(a - b(N-1)\hat{\hat{q}}(w) - w)^2] > 0$, and the retailers' corresponding optimal individual collusive quantity is $q^*(w) = \hat{\hat{q}}(w) = \frac{a-w+\frac{1-\delta}{2}(a-w)(N-1)}{2bN+\frac{1-\delta}{2}b(N-1)^2} > \hat{q}(w)$.*

Proof. See Appendix D. □

Lemma 9. *(i) $\hat{\hat{q}}(w) \to \hat{q}(w)$ as $\delta \to 1$. (ii) $\hat{\hat{q}}(w) \to q^N(w)$ as $\delta \to 0$.*

A closed-form solution to the supplier's problem:

Proposition 11. *At her optimum, the supplier sets a unit price $w^{**} = c + (a - c)\frac{(1-\delta)(N-1)}{2(1-\delta)(N-1)+2} \in (c, \frac{a+c}{2})$, and sets a positive fixed fee: $f^{**} = \frac{(a-c)^2\left[\frac{(1-\delta)(N-1)+2}{2(1-\delta)(N-1)+2}\right]^2}{4b\left[N+\frac{(1-\delta)(N-1)^2}{4}\right]} > 0$.*

Proof. See Appendix D. □

Let Q^{**} denote the equilibrium total quantity of the model, i.e., $Q^{**} = N\hat{\hat{q}}(w^{**})$. And let Q^{RC} denote the equilibrium total quantity under linear pricing with retail competition. Comparing these two quantities gives the following result:

Proposition 12. *The total quantity under two-part tariff when N retailers collude is larger than the total quantity under optimal linear pricing when these N retailers compete. That is, $Q^{**} > Q^{RC}$.*

Now let's turn our attention to some comparative statics results in the N-retailer case.

Lemma 10. *As δ changes, total quantity $Q^{**} = N\hat{\hat{q}}(w^{**})$ changes in the following way, all else held constant: $\frac{\partial N\hat{\hat{q}}(w^{**})}{\partial \delta} < 0$ for $\delta < \frac{N+1}{N+3}$, $\frac{\partial N\hat{\hat{q}}(w^{**})}{\partial \delta} = 0$ for $\delta = \frac{N+1}{N+3}$, and $\frac{\partial N\hat{\hat{q}}(w^{**})}{\partial \delta} > 0$ for $\delta > \frac{N+1}{N+3}$.*

Proof. See Appendix D. □

While the two-retailer treatment in Chapter 1 already demonstrated that a monopolist supplier can only completely leverage its monopoly power downstream when δ takes the extreme value of 0 or 1, but not in between; here we provide an additional insight that the effect of a changing δ also depends on the number of retailers in the market.

The effects of changes in δ on the equilibrium two-part tariff terms are in the same directions as in the two-retailer model. In addition, we can show analogous effects of changes in N on the equilibrium contract terms:

Proposition 13. $\frac{\partial w^{**}}{\partial N} > 0$, $\frac{\partial w^{**}}{\partial \delta} < 0$, $\frac{\partial f^{**}}{\partial N} < 0$, $\frac{\partial f^{**}}{\partial \delta} > 0$.

Proof. See Appendix D. □

Next, I verify that with a general N number of retailers, it is still the case that the supplier offers a lower per-unit price and a higher fixed fee in the repeated game than in the one-shot game:

Proposition 14. *$w^{**} < w^{*}_{\text{1-shot}}$, and $f^{**} > f^{*}_{\text{1-shot}}$.*

Proof. In a one-shot game with $N > 1$ retailers, the supplier using a two-part tariff obtains surplus amount $\frac{(a-c)^2}{4b}$, by imposing $w^*_{\textit{1-shot}} = \frac{a+c}{2} - \frac{a-c}{2N}$, and $f^*_{\textit{1-shot}} = \frac{(a-c)^2}{4b} \cdot \frac{1}{N^2}$[1].

To show that $w^{**} < w^*_{\textit{1-shot}}$, we use the result $\frac{\partial w^{**}}{\partial \delta} < 0$ from Proposition 13. Combine $\frac{\partial w^{**}}{\partial \delta} < 0$ with the fact that when $\delta = 0$, $w^{**} = w^*_{\textit{1-shot}} = \frac{a+c}{2} - \frac{a-c}{2N} > c$, and when $\delta = 1$, $w^{**} = c$, and it follows that $w^{**} \in (c, w^*_{\textit{1-shot}})$.

To show that $f^{**} > f^*_{\textit{1-shot}}$, we use the result $\frac{\partial f^{**}}{\partial \delta} > 0$ from Proposition 13. Combine $\frac{\partial f^{**}}{\partial \delta} > 0$ with the fact that when $\delta = 0$, $f^{**} = f^*_{\textit{1-shot}} = \frac{(a-c)^2}{4b} \cdot \frac{1}{N^2}$, and when $\delta = 1$, $f^{**} = \frac{(a-c)^2}{4b} \cdot \frac{1}{N}$, and it follows that $f^{**} > f^*_{\textit{1-shot}}$.

□

With the above results in place, we can carry over from the two-retailer model the optimizing supplier's self-incentivized decision to curb downstream collusion using nonlinear pricing, as well as the welfare consequences of this decision. I restate these implications below:

Corollary 2. *When facing retail collusion, the supplier prefers contracting with two-part tariff to contracting with linear pricing.*

Proposition 15. *With retail collusion, consumer surplus is higher under two-part tariff than under linear pricing.*

Proposition 16. *With retail collusion, total surplus for society is higher under two-part tariff than under linear pricing.*

Table E.2 in Appendix E lists for the N-retailer case all surpluses under linear pricing and two-part tariff for comparison. It is a demonstration of Corollary 2, and Propositions 15 and 16.

[1]The one-shot equilibrium price and fixed fee confirm our earlier calculations in the repeated game: letting $\delta = 0$ (no collusion) in both $w^{**} = c + (a-c)\frac{(1-\delta)(N-1)}{2(1-\delta)(N-1)+2}$ and $f^{**} = \frac{(a-c)^2\left[\frac{(1-\delta)(N-1)+2}{2(1-\delta)(N-1)+2}\right]^2}{4b\left[N+\frac{(1-\delta)(N-1)^2}{4}\right]}$ gives precisely $w^*_{\textit{1-shot}} = \frac{a+c}{2} - \frac{a-c}{2N}$ and $f^*_{\textit{1-shot}} = \frac{(a-c)^2}{4b} \cdot \frac{1}{N^2}$.

Finally, Figure F.6 in Appendix F graphs the retailers' total revenue $R(Q)$ and total payment to the supplier $C(Q)$ against the total quantity. It summarizes the equilibrium analysis of the basic model, and compares different market results when the supplier adopts different contract terms. The reader can refer to Appendix F for a detailed illustration of this graphical summary.

Note that the supplier's revenue is $C(Q)$, and her cost is cQ, where c is the constant marginal cost of production. For any $w > c$, the supplier wants to supply as many units as possible.

2.4 A Further Result

Lemma 11. *Total quantity $N\hat{\hat{q}}(w^{**})$ decreases as N increases, all else held constant, i.e.,* $\frac{\partial N\hat{\hat{q}}(w^{**})}{\partial N} < 0$.

Proof. See Appendix D. □

Lemma 11 reveals an interesting fact: when retailers collude under wholesale linear pricing, the number of retailers does not affect the total quantity; but when retailers collude under two-part tariff, a larger number of retailers would lead to a smaller total quantity. At first glance, this result may seem counterintuitive. But there are two levels of supply relations in this model, and what the result really shows is that when there are a large number of retailers with $\delta < 1$, the supplier's ability to use both the fixed fee and the unit price as vehicles to circumscribe retail collusion is compromised.

2.5 Asymmetric Collusion: General Results

Perhaps the most interesting question to explore with an arbitrary number of retailers is if and how the retailers may choose to collude in an asymmetric fashion. In this section, I derive a more general set of equilibrium results on asymmetric collusion by an arbitrary number of retailers.

I show that Propositions 10, 14 and Corollary 2 are robust to retailers adopting a common asymmetric collusive scheme, in that when confronted with asymmetric downstream collusion, two-part tariff still induces a larger total quantity than linear pricing, and it is still preferred to linear pricing by the supplier, consumers and society. Also, the equilibrium per-unit price would fall below the one-shot level, and the equilibrium fixed fee would be higher than the one-shot level.

The analysis is on an asymmetric equilibrium where symmetric retailers collude in the following way under two-part tariff: in each period, out of the N retailers, M number of them purchase a positive amount for resale ($M \leq N$), making quantity decisions collectively, while the remaining $(N-M)$ retailers stay off the market. The idea of the collusive agreement is that each of the N retailers takes turns opting out of the market (using a randomization process to ensure identical expected profits across retailers). For example, in each period, we could let a random draw determine which M firms should enter the market. Let draws for different periods be independent processes. Then in the long term, all retailers have the same expected rate of being selected in equilibrium. The number of periods for which a retailer gets selected in a cycle of N periods, n, is a binomial variable:

$$n \sim B(N, p)\,,$$

where $n = 0, 1, \ldots, N$, and

$$p = \frac{\binom{N-1}{M-1}}{\binom{N}{M}} = \frac{M}{N}$$

is the probability that a retailer is selected to participate in the market in any one period[2]. For n,

$$E(n) = M\,, \text{ and } Var(n) = \frac{M(N-M)}{N}\,.$$

In the asymmetric formulation, after observing w and f, the retailers' problem is

$$\begin{aligned} &\underset{M,q}{\text{maximize}} && \Pi^{Coll} = M\pi^{Coll} = M[(a-bqM-w)q-f] \\ &\text{subject to} && h_{In}(q,w,f) \geq 0 \\ &\text{and} && h_{Out}(q,w,f) \geq 0\,, \end{aligned} \tag{R_A}$$

where $h_{In}(q,w,f)$ is the collusion condition for the selected group of retailers, and $h_{Out}(q,w,f)$ is the collusion condition for the nonselected group. $h_{In}(q,w,f)$ and $h_{Out}(q,w,f)$ together constitute the retailers' individual rationality constraint.

Now the supplier wants to maximize $\pi_S = \frac{M[q(w-c)+f]}{1-\delta}$ by choosing w and f. The two collusion conditions (incentive constraints) for the retailers are:

$$\begin{aligned} &(1-\delta)[(a-bqM-w)q-f] + \delta\frac{M}{N}[(a-bqM-w)q-f] \\ &\geq (1-\delta)\frac{1}{4b}[a-b(M-1)q-w]^2 - (1-\delta)f + \delta\max\left\{\frac{(a-w)^2}{b(N+1)^2} - f,\ 0\right\} \end{aligned} \tag{In}$$

for the selected, and

$$\begin{aligned} &\delta\frac{M}{N}[(a-bqM-w)q-f] \\ &\geq (1-\delta)\frac{1}{4b}(a-bMq-w)^2 - (1-\delta)f + \delta\max\left\{\frac{(a-w)^2}{b(N+1)^2} - f,\ 0\right\} \end{aligned} \tag{Out}$$

for the nonselected.

Let collusion condition (In) be rewritten as $h_{In}(q,w,f) \geq 0$. In other words, let $h_{In}(q,w,f) \equiv (1-\delta)[(a-bqM-w)q-f] + \delta\frac{M}{N}[(a-bqM-w)q-f] - (1-\delta)\frac{1}{4b}[a-b(M-1)q-w]^2 + (1-\delta)f - \delta\max\left\{\frac{(a-w)^2}{b(N+1)^2} - f,\ 0\right\}$.

[2] $\binom{r}{k} = \frac{r!}{k!(r-k)!}$.

Let collusion condition (Out) be rewritten as $h_{Out}(q, w, f) \geq 0$. In other words, let $h_{Out}(q, w, f) \equiv \delta \frac{M}{N}[(a - bqM - w)q - f] - (1 - \delta)\frac{1}{4b}(a - bMq - w)^2 + (1 - \delta)f - \delta \max\left\{\frac{(a-w)^2}{b(N+1)^2} - f,\ 0\right\}$.

First the supplier chooses a pair (w, f) as the contract offer, then the N retailers decide on a pair (M, q), where M is the number of retailers randomly selected to participate in each period, and q is the agreed upon per-period quantity purchased by each individual retailer. Each player maximizes the value of a discounted stream of profits going into the future. The supplier makes her decision at only one point in time, whereas the retailers first make a collective decision on the values of M and q, then each retailer individually purchases his own quantity in each period.

Even though a closed-form solution to the supplier's optimization problem is complicated to obtain in the asymmetric case, we can still reach some meaningful conclusions by analyzing how the supplier would choose the fixed fee f for any per-unit price w. M being endogenous makes this analysis more complex than in the symmetric case, but in what follows, I show that even without a closed-form solution, we can still prove that the main results are robust.

Given a w, Lemmas 12 - 15 show the dynamics of the collusion conditions caused by a changing fixed fee. Understanding these dynamics will be helpful to analyzing both the supplier and the retailers' incentives in the asymmetric collusion setting. With this understanding, I will then go as far as I can to characterize the players' equilibrium behavior, as relevant to the robustness results. Recall that the retailers respond to an offer of (w, f) by choosing M and q simultaneously. This means an increase in individual purchase quantity does not necessarily boost the supplier's profit, since it could be accompanied by a change in M. Lemmas 12 - 15 are presentations of the dynamics of the individual collusion conditions in response to a changing fixed fee, while holding both w and M constant. What we will be able to deduce from these results eventually is a functional relationship between the individual retail quantity and the number of participating retailers M in a collusive equilibrium.

The case where $M = N$ is the same as the previous case with retail symmetric collusion. Thus, it suffices to show the robustness of the main results for all $M < N$.

Lemma 12. *If $M < N$, then for any given w, when $f < f_0 = \frac{(a-w)^2}{b(N+1)^2}$, increasing f loosens individual collusion condition* (In)*, by enlarging the set of supportable collusive quantities $\Theta_{In}(w, f) \equiv \{q : h_{In}(q, w, f) \geq 0\}$.*[3]

Proof. When $f < f_0 = \frac{(a-w)^2}{b(N+1)^2}$, $\max\left\{\frac{(a-w)^2}{b(N+1)^2} - f,\ 0\right\} = \frac{(a-w)^2}{b(N+1)^2} - f$. Thus, condition (In) can be written as

$$h_{In}(q) = \kappa_1 + \delta\left(1 - \frac{M}{N}\right) f \geq 0\,, \tag{In:1}$$

where $\kappa_1 = (1 - \delta + \delta\frac{M}{N})(a - bqM - w)q - (1 - \delta)\frac{1}{4b}[a - b(M - 1)q - w]^2 - \delta\frac{(a-w)^2}{b(N+1)^2}$ is independent of f. $h_{In}(q)$ is a quadratic in q, whose graph opens downward. Since $\delta(1 - \frac{M}{N}) > 0$, increasing f loosens the individual collusion condition. □

Lemma 13. *For any given w, when $f \geq f_0 = \frac{(a-w)^2}{b(N+1)^2}$, increasing f tightens individual collusion condition* (In)*, by shrinking the set of supportable collusive quantities $\Theta_{In}(w, f) \equiv \{q : h_{In}(q, w, f) \geq 0\}$.*

Proof. When $f \geq f_0 = \frac{(a-w)^2}{b(N+1)^2}$, $\max\left\{\frac{(a-w)^2}{b(N+1)^2} - f,\ 0\right\} = 0$. Thus, condition (In) can be written as

$$h_{In}(q) = \kappa_2 - \delta\frac{M}{N} f \geq 0\,, \tag{In:2}$$

where $\kappa_2 = (1 - \delta + \delta\frac{M}{N})(a - bqM - w)q - (1 - \delta)\frac{1}{4b}[a - b(M - 1)q - w]^2$ is independent of f. $h_{In}(q)$ is a quadratic in q, whose graph opens downward. Since $-\delta\frac{M}{N} < 0$, increasing f tightens the individual collusion condition. □

[3] In the trivial case where $M = N$, for any given w, when $f < f_0 = \frac{(a-w)^2}{b(N+1)^2}$, increasing f does not change the individual collusion condition.

Lemma 14. *For any given w, when $f < f_0 = \frac{(a-w)^2}{b(N+1)^2}$, increasing f loosens individual collusion condition* (Out)*, by enlarging the set of supportable collusive quantities $\Theta_{Out}(w, f) \equiv \{q : h_{In}(q, w, f) \geq 0\}$.*

Proof. When $f < f_0 = \frac{(a-w)^2}{b(N+1)^2}$, $\max\left\{\frac{(a-w)^2}{b(N+1)^2} - f,\ 0\right\} = \frac{(a-w)^2}{b(N+1)^2} - f$. Thus, condition (Out) can be written as

$$h_{Out}(q) = \kappa_3 + \left(1 - \delta\frac{M}{N}\right) f \geq 0\,, \tag{Out:1}$$

where $\kappa_3 = \delta\frac{M}{N}(a - bqM - w)q - (1-\delta)\frac{1}{4b}(a - bMq - w)^2 - \delta\frac{(a-w)^2}{b(N+1)^2}$ is independent of f. $h_{Out}(q)$ is a quadratic in q, whose graph opens downward. Since $1 - \delta\frac{M}{N} > 0$, increasing f loosens the individual collusion condition. □

Lemma 15. *For any given w, when $f \geq f_0 = \frac{(a-w)^2}{b(N+1)^2}$, increasing f would:*

- *loosen individual collusion condition* (Out)*, by enlarging the set of supportable collusive quantities $\Theta_{Out}(w, f) \equiv \{q : h_{In}(q, w, f) \geq 0\}$, if $M < \frac{1-\delta}{\delta}N$;*
- *tighten individual collusion condition* (Out)*, by shrinking the set of supportable collusive quantities $\Theta_{Out}(w, f) \equiv \{q : h_{In}(q, w, f) \geq 0\}$, if $M > \frac{1-\delta}{\delta}N$; or*
- *not affect individual collusion condition* (Out)*, if $M = \frac{1-\delta}{\delta}N$.*

Proof. When $f \geq f_0 = \frac{(a-w)^2}{b(N+1)^2}$, $\max\left\{\frac{(a-w)^2}{b(N+1)^2} - f,\ 0\right\} = 0$. Thus, condition (Out) can be written as

$$h_{Out}(q) = \kappa_4 + \left(1 - \delta - \delta\frac{M}{N}\right) f \geq 0\,, \tag{Out:2}$$

where $\kappa_4 = \delta\frac{M}{N}(a-bqM-w)q-(1-\delta)\frac{1}{4b}(a-bMq-w)^2$ is independent of f. $h_{Out}(q)$ is a quadratic in q, whose graph opens downward. The sign of the coefficient $(1-\delta-\delta\frac{M}{N})$ depends on the value of M. If $1-\delta-\delta\frac{M}{N} > 0$, or $M < \frac{1-\delta}{\delta}N$, then increasing f loosens the individual collusion condition; if $1 - \delta - \delta\frac{M}{N} < 0$, or $M > \frac{1-\delta}{\delta}N$, then increasing f tightens the individual collusion condition; if $1 - \delta - \delta\frac{M}{N} = 0$, or $M = \frac{1-\delta}{\delta}N$, then changing f does not affect the individual collusion condition. □

For any given M, increasing the fixed fee from zero to the Cournot-Nash profit f_0 makes both groups of retailers better able to collude, where the individual collusion condition for the inactive retailers loosens at a faster rate than that for the active retailers. To understand this effect, note that in a cooperative period, an inactive retailer would only have to pay the fixed fee if he chooses to deviate. Thus, increasing a small fixed fee makes an inactive retailer more willing to collude, so as to avoid a larger fee. As for an active retailer, increasing a small fixed fee also makes him more willing to collude, because with $M < N$, a selected retail who chooses to collude also expects to save the fixed fee in the future. Once f exceeds f_0, the collusion condition for the active retailers begins to tighten, for the same reason we previously discussed in the symmetric case: a fixed fee exceeding f_0 wipes out all of the Nash profit, in which case the punishment profit becomes zero because exiting the market would serve a retailer better than staying and paying a hefty fixed fee. On the other hand, once f exceeds f_0, the individual collusion condition for the inactive retailers could either loosen or tighten, depending on the value of M. The following are the three possible scenarios:

1. If $M < \frac{1-\delta}{\delta}N$, then further increasing the fixed fee above the threshold f_0 only works to further loosen the individual collusion condition for the nonselected retailers. In this case, the binding individual collusion condition would be h_{In}, and the supplier would keep increasing f until $h_{In} = 0$.

2. If $M = \frac{1-\delta}{\delta}N$, then further increasing the fixed fee above the threshold f_0 does not affect the individual collusion condition for the nonselected retailers. In this case, the binding individual collusion condition would still be h_{In}, and the supplier would keep increasing f until $h_{In} = 0$.

3. If $M > \frac{1-\delta}{\delta}N$, then further increasing the fixed fee above the threshold f_0 tightens the individual collusion condition for the nonselected retailers. In this case,

> it is not immediately clear whether (In) or (Out) would be the binding individual collusion condition. But note that for the purpose of proving robustness of the main results, it is enough to know that one of (In) and (Out) would bind.

On the one hand, $M < N$ implies a strictly positive benefit of colluding: retailers can expect to save some fixed fees in at least some periods. This is the force that expands the retailers' set of supportable collusive quantities when the fixed fee increases. On the other hand, increasing the fixed fee above the Cournot-Nash profit impacts the retailers' punishment profile, and thus reduces the set of supportable collusive quantities, for any M chosen by the retailers. Which effect is stronger depends on how big M is relative to N. If M is small, then the fixed-fee saving effect dominates (Scenario 1); if M is close to N, then the collusion restricting effect dominates (Scenario 3).

Proposition 10 is robust to retailers adopting the asymmetric collusive scheme. This result is summarized below in Propositions 17 and 18.

Proposition 17. *When confronted with asymmetric retail collusion where the number of participating retailers in the market are collectively decided by the cartel, a monopolist supplier still prefers offering a two-part tariff contract to offering a linear pricing contract.*

Proof. See Appendix D.

□

Next, I investigate finer characteristics of $f^*(w)$ under asymmetric retail collusion. In the case of symmetric retail collusion, the number of retailers N was fixed, and we were able to fully characterize the supplier's choice of w and f in symmetric collusive equilibrium. In the case of asymmetric retail collusion, the added difficulty lies in the fact that the number of participating retailers M and the individual collusive quantity q both respond to the supply contract terms simultaneously. To tackle this difficulty, in Proposition 18, I first let M be exogenously given, then prove a result that further characterizes the fixed fee and the total quantity. I then argue that because the result holds for any M, we know that its implication is meaningful in equilibrium even without explicitly solving for M.

Proposition 18. *Under asymmetric retail collusion, a monopolist supplier offering a two-part tariff chooses* $(w, f^*(w))$ *such that* $f^*(w) > f_0(w) = \frac{(a-w)^2}{b(N+1)^2}$. *As a result, the total quantity in equilibrium exceeds the retail monopoly quantity under linear pricing* $Q^{RM}(w) = \frac{a-w}{2b}$.

Proof. Let M be exogenously given. Under Assumption 1, $f(w) \in [0, f_0(w))$ cannot be in equilibrium, since the supplier can always do better by adding $\epsilon > 0$ to $f(w)$.

For $f(w) \in [f_0(w), \infty)$, the punishment profile is no longer the Cournot-Nash profile, but a profile where all retailers exit the market and obtain zero profit. This is the mechanism through which an appropriately set fixed fee that is high enough can restrict retail collusion. For any given M, the supplier would keep increasing f beyond the Nash profit threshold $f_0(w)$, until the aggregate set of supportable collusive quantities, $\bar{\Theta}_{Asym}(w, f, M) \equiv \{Mq : h_{In}(q, w, f, M) \geq 0 \text{ and } h_{Out}(q, w, f, M) \geq 0\}$, becomes a singleton. This is because when $\bar{\Theta}_{Asym}(w, f, M)$ becomes a singleton, either $h_{In}(q, w, f, M) = 0$ with a single quantity $\hat{\hat{q}}_{A,In}$[4], or $h_{Out}(q, w, f, M) = 0$ with a single quantity $\hat{\hat{q}}_{A,Out}$[5]. When $h_{In}(q, w, f, M) = 0$ at $q = \hat{\hat{q}}_{A,In}$, each participating retailer purchases

$$\hat{\hat{q}}_{A,In} = \frac{(a-w)\left(1-\delta+\delta\frac{M}{N}\right) + \frac{1-\delta}{2}(a-w)(M-1)}{2bM\left(1-\delta+\delta\frac{M}{N}\right) + \frac{1-\delta}{2}b(M-1)^2};$$

when $h_{Out}(q, w, f, M) = 0$ at $q = \hat{\hat{q}}_{A,Out}$, each participating retailer purchases

$$\hat{\hat{q}}_{A,Out} = \frac{(a-w)\delta\frac{1}{N} + \frac{1-\delta}{2}(a-w)}{2b\delta\frac{M}{N} + \frac{1-\delta}{2}bM}.$$

[4] $q = \hat{\hat{q}}_{A,In}$ is the maximizer of $h_{In}(q, w, f, M)$.
[5] $q = \hat{\hat{q}}_{A,Out}$ is the maximizer of $h_{Out}(q, w, f, M)$.

Recall that the retail monopoly quantity is $Q^{RM}(w) = \frac{a-w}{2b}$. The following can be shown mathematically:

$$Q^{RM}(w) < M\hat{\hat{q}}_{A,In} < M\hat{\hat{q}}_{A,Out}\,, \tag{2.2}$$

for any $\delta \in (0,1)$.[6] This result says that the retailers' ability to sustain the downstream monopoly quantity with an asymmetric collusive scheme can be eliminated by a supplier demanding a fixed fee higher than the Nash threshold. The supplier is self-incentivized to pick such a high fixed fee, since such a high fee also induces a large total quantity in equilibrium.

The above argument holds for all values of M. Hence, in equilibrium, it must be the case that $f^*(w) > f_0(w) = \frac{(a-w)^2}{b(N+1)^2}$, and $Q^*(w) > Q^{RM}(w)$.

□

In the one-shot setting, retailers compete. Charging (w_c^*, f_c^*) perfectly coordinates the supply channel, and rewards the supplier the entire monopoly profit. Denote the one-shot total quantity Q_c^*. In the repeated-game setting with symmetric collusion, charging (w_c^*, f_c^*) would leave the retailers with complete autonomy to collude at a total quantity smaller than Q_c^*, hurting the surplus of the supplier, and that of society. For this reason, a supplier facing symmetric collusion downstream would charge a unit price lower than the one-shot price, and a fixed fee higher than the one-shot fixed fee, as shown in Proposition 14. Doing this would not restore the supplier's surplus to the one-shot level, but it curtails her surplus loss due to downstream collusion. The supplier's choice to lower the unit price and raise the fixed fee also works to curtail surplus loss for society. In this regard, the supplier's interest is aligned with the society's. Now the question is: If the retailers engage in an asymmetric collusive scheme, can we expect the supplier to respond also by lowering

[6]Note that in the case where $M = N$, inequality (2.2) reduces to the symmetric case $Q^{RM} < N\hat{q}(w)$.

the per-unit price and raising the fixed fee from the one-shot level? The answer is affirmative. I put this result in the following proposition.

Proposition 19. *When facing asymmetric collusion downstream, the supplier would still charge $w < w_c^*$, and $f > f_c^*$.*

The following explains how the result in Proposition 19 can be understood.

Under an asymmetric collusive scheme, the retailers can choose a number M ranging from 1 to N. It suffices to show that for any M, a supplier earns a higher profit charging $w < w_c^*$ and $f > f_c^*$ than charging (w_c^*, f_c^*).

Let's first suppose that M is exogenously given before the game play. The supplier's per-period profit when facing retail collusion is

$$\pi_S = M[q(w - c) + f] \, .$$

Read this against the supplier's profit when she charges (w_c^*, f_c^*) while facing retail collusion:

$$\pi_{S,c} = M[q_c^*(w_c^* - c) + f_c^*] \, .$$

Note that $f_c^* = f_0(w_c^*)$. According to Proposition 18, raising the fixed fee above f_c^* can lead to a higher collusive quantity, by virtue of an effective restriction on the set of supportable collusive quantities. This means charging $f > f_c^*$ would lead to $q > q_c^*$, even without changing the per-unit price w_c^*. With $w = w_c^*, f > f_c^*, q > q_c^*$, we already have $\pi_S > \pi_{S,c}$. Now if the supplier further decreases the unit price w below w_c^*, the unit price becomes closer to the marginal cost of production c. This helps to further align the incentives of the supplier and the colluding retailers who act as a single entity, and creates a bigger economic pie, from which the supplier can extract more surplus by further increasing the fixed fee. Therefore, charging $f > f_c^*$ and $w < w_c^*$ could benefit the supplier under retail collusion.

The above argument applies to any M. Hence regardless of how the retailers may choose the number M in their collusive scheme, the supplier would always do better charging a higher fixed fee and a lower per-unit price than the one-shot level.

2.6 Concluding Remarks

Vertical contracting is commonly understood as a tool to leverage upstream monopoly power downstream. Yet it is more powerful than that. If downstream firms form a cartel, vertical contracting can be used strategically by an upstream monopolist to curtail its economic loss due to downstream collusion. The upstream monopolist would use nonlinear pricing to achieve this outcome, under both symmetric and asymmetric downstream collusion.

In ongoing related research, I study an extended model with an arbitrary number of upstream and downstream firms, where the downstream firms form a cartel. A preliminary result is presented in Chapter 3 as the basis for an empirical prediction.

Chapter 3

The Relation Between Upstream and Downstream Competition: Evidence from the Maritime Shipping and Shipbuilding Industries

Acknowledgement: Material in this chapter is joint work with Xuan Ding.

This paper establishes an empirical relationship between upstream and downstream competition for the shipbuilding and shipping industries. We find evidence of a negative and significant effect of upstream competition on downstream competition. Our result is robust to two alternative measures of competition. This result provides empirical support to the theoretical models in Chapters 1 and 2.

3.1 Introduction

In this paper, we examine the relation between competition in an upstream input market and competition in a downstream product market. While there is a general agreement among economists that vertical relations have consequences in both upstream and downstream competition, we do not know of any existing work on a possible direct linkage between upstream and downstream competition within a vertical structure. This paper provides a first empirical test to determine if such a linkage may exist.

Numerous theoretical and empirical works have studied vertical relations and market power.[1] The standard argument focuses on how a vertical practice alters market participants' incentives in ways that change market power[2]. Typically, cartel theory is not invoked, unless the argument considers cartelization as an ex post effect (for example, [CR07]). Chapters 1 and 2 of this dissertation model a vertical structure with a pre-existing downstream cartelization motive, and find a "restrained collusive" effect that promotes market efficiency.[3] Derivative of the model in the two chapters, we make a theoretical prediction that an increase in market power (decrease in competition) in the upstream industry causes a decrease in market power (increase in competition) in the downstream industry, assuming we live in a world where collusion (or conscious parallelism) is adopted whenever it is sustainable and profit-enhancing.[4] In this article, we test this hypothesis. If found to be true, such

[1] For theoretical works, see, for example, [BGM02], [CW02], [Che01], [CR00]. For empirical works, see, for example, [Bhu05], [BMO$^+$10], among many others.

[2] The definition of market power is a firm's ability to profitably raise price above cost. In this article, we take the view that a higher gross profit margin across an industry is indicative of more market power and less competition in the industry.

[3] In a way, this work (admittedly remotely) echoes the question raised by [Nic96]: "Are people right to think that competition improves corporate performance?" Chapters 1 and 2 take aim at the question: "Are people right to think that collusion is definitely costly to society?"

[4] Although the equilibrium market outcomes derived in Chapters 1 and 2 are technically "collusive" outcomes for the downstream firms, they in fact promote market efficiency. For this reason, such outcomes would empirically be observed as ones manifesting little market power (much competition) downstream.

a hypothesis would suggest that competition policy aimed at an upstream industry can have real competitive effects on a downstream industry.

We investigate the (causal) linkage between upstream and downstream competition by examining the global maritime shipping and shipbuilding industries. Shipbuilders supply vessels to shipping companies, who then use these vessels to provide shipping services to their customers. Over the years, both the shipbuilding industry and the ocean shipping industry have experienced changes in their respective product market competition. We empirically study how competition levels in these two industries are related, using publicly available financial data from 9 of the biggest public shipbuilding companies and 14 of the biggest public shipping companies over the period 2003 to 2015. For each year, to measure competition of an industry, we compute the average gross profit margin across all firms in that industry in our dataset. Controlling for downstream demand for shipping services using the China Containerized Freight Index (CCFI) and world seaborne trade data, both obtained from Clarkson's Shipping Intelligence Network, we find evidence that competition in the shipbuilding industry has a negative and significant effect on competition in the shipping industry. We find the same result when using an alternative measure of competition, where we weight each firm's gross profit margin by the firm's share of total sales in our dataset.

The remainder of this paper is organized as follows. Section 2 describes the industry backgrounds of ocean shipping and shipbuilding. Section 3 derives a theoretical result, which is the basis of our empirical prediction. Section 4 describes the data and the empirical methodology. Section 5 presents the results. In Section 6, we discuss causality and propose next steps in expanding the scope of this study. Section 7 concludes.

3.2 Institutional Background

The shipbuilding industry is increasingly concentrated. Nowadays, it is dominated by several large shipyards. Since the early 20th century, the industry leadership has changed from Europe to Asia. Currently, the main leaders are South Korea, China and Japan. According to data from Clarkson Research, in 2015, the three largest shipbuilders in terms of orderbooks were Daewoo Shipbuilding & Marine Engineering, Hyundai Heavy Industries, and Samsung Heavy Industries, all South Korean companies. World yard data in 2009 showed that the four largest shipbuilders made up 63% of the world market, and the seven largest shipbuilders made up 82% of the world market.

The shipping industry is also experiencing a trend of increasing consolidation, though it remains a relatively fragmented sector. Consolidation of liner shipping has mainly been strategic alliancing, enhanced by mergers and acquisitions. Our data collected from Alphaliner[5] show an increase in concentration in liner shipping for the past two decades. European and Asian shipping companies make up the top ten[6], which account for 71.2% of the worldwide liner shipping market as of May 2017.[7]

As we know, the supply chain begins with shipbuilders producing vessels and selling them to shipping companies. A shipping company (shipowner) can choose to operate a ship and sell shipping services for some freight rates; it can also choose to lease out a ship on a time charter basis.

Shipbuilding is a complex and sophisticated production process. It typically begins with signing of a contract at the shipyard. Then, production design takes place, at which stage the hull form and detailed arrangements of the ship are decided.

[5] https://www.alphaliner.com/

[6] According to Alphaliner, the latest top ten in market share (based on TEU, a unit of cargo capacity) are: APM-Maersk, MSC, CMA CGM, COSCO, Hapag-Lloyd, Evergreen, OOCL, NYK Line, Yang Ming Marine Transport Corporation, Hamburg Süd Group. Alphaliner - Top 100 Operated fleets as per 03 May 2017.

[7] A previous long-time member of the top ten, Hanjin Shipping, was declared bankrupt in February 2017.

Next, the shipbuilder will purchase all material and equipment needed to build the ship, lay out a production plan, and start cutting the steel. Because the steel cutting forms the shapes of a ship's hull and decks, it is considered a very important step, and the buyer would usually send their own supervisors to the shipyard to monitor and advise the process. Then, after a long period of assembly and adjustment work, the ship will finally be launched, finished up at the quay, and go on a sea trial. If all goes well, the ship will be delivered on time to the buyer at a ceremony where the ship is named. The entire process typically takes about one to two years.[8] Our research design accounts for this period of time for strategic response when estimating the effects of upstream competition on downstream competition.

The price of the ship is listed in the contract. It is paid in several installments. Immediately after signing the contract, the buyer makes the first payment, which is usually a small percentage of the total price. Then, a few small payments are made at various stages of production, starting from the steel cutting phase. It is only upon delivery of the ship that the bulk of the total price is paid. Adjustment of the contract price can occur, but usually only in cases of unsatisfactory or early delivery[9].

Many factors influence the shipbuilding industry's profitability: health of the global economy, credit conditions, geopolitical factors, government subsidies, material and labor costs, et cetera. Competition of the industry, however, could be impacted by other factors: for example, tendencies and traditions of firms in the industry to engage in conscious parallelism, if not blatant collusion; toughness of competition policies in various jurisdictions; antitrust enforcement patterns of different countries, in regards to not just penalizing collusive behavior, but also decisions to approve or

[8] To be more precise, the length of time it takes to build a ship depends on the ship's classification, which takes into account a ship's type, size, and area of operation. For example, a ship meant to pass through a particular canal may require extra design efforts to ensure the correct dimensions. Currently, for most of the active cargo ships, a typical length of building time is from one to two years.

[9] The buyer is entitled to reduction in price if delivery is delayed, or if a delivered ship is in deficient conditions (e.g. insufficient speed, excessive fuel consumption). Sometimes a contract would specify a bonus amount the shipbuilder is entitled to in the case of early delivery.

block mergers and acquisitions[10].

Competition of the shipping industry is more interesting. Historically, liner shipping has benefited from the formation of liner conferences, which engage members in rate and route discussions, and price fixing. These liner conferences have enjoyed antitrust exemption globally, and still do in many maritime jurisdictions. The rationale for granting this block exemption typically includes cost and utilization efficiencies, which are presumed to be passed on to customers in terms of better services and higher coverage of ports[11], as well as avoidance of "ruinous competition" and unstable rates[12]. However, maritime regulations have evolved overtime—in 2008, the liner conference exemption was repealed from the EU Competition Law. The European Council and the European Commission have also been actively advancing the removal of price fixing exemptions for liner conferences in other jurisdictions.[13] Another example of a competition policy shock in liner shipping would be the implementation of Hong Kong's Competition Ordinance in December 2015, which at the time of implementation did not include liner exemption, and caused an immediate response from the Hong Kong Liner Shipping Association to seek block exemption for shipping agreements.[14]

The research design of this paper allows us to establish consistency between the theory proposed in the previous two chapters and empirical observations. We exploit China Containerized Freight Index and world seaborne trade data to control for some confounding factors related to consumer demand.

[10]In a way, the percentage of M&A proposals that are approved may be suggestive of a government's assessment of the competition of the industry, and thus can potentially be used as a proxy to industry competition. An example of an exception may be China's governmental support for its two largest state-owned shipbuilders—the China State Shipbuilding Corporation and the China Shipbuilding Industry Corporation. Shipbuilding is considered a strategic industry for China.

[11]See [EU15].

[12]See [ABA07]. Note, however, that the apocalyptic effects of free competition in liner shipping are debatable.

[13]See [EU15].

[14]The Hong Kong Shippers' Council was against this exemption application. In September 2016, the Hong Kong Competition Commission proposed a liner shipping block exemption.

3.3 A Theoretical Result

In this section, we extend the model in Chapter 1, and demonstrate that increasing the number of upstream suppliers generally makes it more difficult to restrict downstream collusion.

Suppose, instead of having one monopolist upstream supplier, we now have N_S upstream suppliers. These N_S suppliers would do best by colluding in setting contract terms with the downstream retailers. For simplicity, we assume the suppliers collude symmetrically among themselves, and we ask the question: Does the increase in the number of upstream suppliers (decrease in upstream market power) weaken the restrictive power of vertical contracting over downstream collusion?

According to Table B.2 in Chapter 1, in a collusive period, each of the N_S colluding suppliers obtains

$$\pi^{Coll} = \frac{(a-c)^2}{4b} \cdot \lambda_S \cdot \frac{1}{N_S} \,.$$

This collusive profit is achieved if all suppliers charge a per-unit price $w^{**} = c + (a - c)\frac{1-\delta}{4-2\delta} \in (c, \frac{a+c}{2})$, and a fixed fee $f^{**} = \frac{(a-c)^2}{4b} \cdot \frac{(3-\delta)^2}{(2-\delta)^2(9-\delta)} > 0$. A deviant supplier can slightly undercut either the per-unit price or the fixed fee, and obtain the total collusive profits of

$$\pi^{Dev} = \frac{(a-c)^2}{4b} \cdot \lambda_S \,.$$

In a punishment period, all suppliers compete, and the contract terms would be brought down to $w = c$, $f = 0$, rendering each supplier's profit zero. So we have

$$\pi^{Pun} = 0 \,.$$

To sustain upstream collusion, each supplier faces the following incentive constraint:

$$\pi^{Coll} \geq (1-\delta)\pi^{Dev} + \pi^{Pun}\,. \tag{3.1}$$

As in Chapter 1, we take δ as given. Condition 3.1 above then comes down to:

$$N_S \leq \frac{1}{1-\delta}\,. \tag{3.2}$$

Thus, if $N_S \leq \frac{1}{1-\delta}$, then the N_S upstream firms together can effectively restrict downstream collusion, and sustain the upstream monopolist result $Q^{**} = \frac{a-c}{b} \cdot \frac{(3-\delta)^2}{(2-\delta)(9-\delta)}$[15] on the equilibrium path.

Note that if a downstream firm deviates in a period (by purchasing more units from the upstream firms), then from the next period onwards, Cournot competition is expected in the downstream market. Under downstream Cournot competition, upstream cartelization becomes even more profitable, since the upstream cartel can guarantee themselves the entire one-tier monopoly profit by pricing nonlinearly (e.g., using two-part tariff). In this case, the upstream firms' incentive constraint is condition 3.1 with $\pi^{Coll} = \frac{(a-c)^2}{4b} \cdot \frac{1}{N_S}$, $\pi^{Dev} = \frac{(a-c)^2}{4b}$, and $\pi^{Pun} = 0$, which after simplification is the same as condition 3.2.

Hence, if $N_S \leq \frac{1}{1-\delta}$, then the upstream firms enjoy a price-cost margin of $PCM_{U1} = \frac{a+c}{a+3c} > 0$ on the equilibrium path.[16]

If $N_S > \frac{1}{1-\delta}$, does there exist an equilibrium where the N_S upstream firms sustain a quantity different (smaller) than Q^{**}? The answer is no. If the upstream firms, unable to sustain Q^{**}, tried to sustain a smaller quantity that still gives the upstream group a large profit, then they would have to do it by together making the fixed fee lower than f^{**}, and increasing the per-unit price to a level higher than w^{**}. In that situation, a deviant firm's best strategy is to go just a little further

[15] See Proposition 3 in Chapter 1.

[16] The upstream firms' price-cost margin is Profit/(Profit + Total Cost) $= (w^{**}Q^{**} + 2f^{**})/(w^{**}Q^{**} + 2f^{**} + cQ^{**}) = \frac{a+c}{a+3c}$. See Propositions 2 and 3 in Chapter 1 for values of w^{**}, f^{**} and Q^{**}.

than its collusive counterparts in lowing the fixed fee and increasing the per-unit price, so as to profit from selling to the entire upstream market. The punishment profit for the upstream firms would still be zero. In essence, the way deviation and punishment work with $N_S > \frac{1}{1-\delta}$ is exactly the same as that with $N_S \leq \frac{1}{1-\delta}$. Hence, for $N_S > \frac{1}{1-\delta}$, simply no upstream collusive equilibrium exists, and all upstream firms would compete until they earn zero profit, or their price-cost margin $PCM_{U2} = 0$. We thus see that $PCM_{U1} > PCM_{U2}$.

From the above analysis, we find that for any given δ, there is a threshold for the number of upstream firms to be able to reach an upstream collusive outcome. If the number of upstream firms does not exceed the threshold, then the first-best upstream collusive outcome Q^{**} can be sustained. But if the number of firms exceeds the threshold, then the upstream firms would simply compete away all of their surplus. An implication is that when $N_S \leq \frac{1}{1-\delta}$, the upstream price-cost margin is larger than when $N_S > \frac{1}{1-\delta}$.

When $N_S \leq \frac{1}{1-\delta}$, the two colluding downstream firms' price-cost margin is[17]

$$PCM_{D1} = \frac{(a-c)\delta(1-\delta)}{2a(2-\delta)(9-\delta) - 2(a-c)(3-\delta)^2}.$$

When $N_S > \frac{1}{1-\delta}$, the two colluding downstream firms' price-cost margin is[18]

$$PCM_{D2} = \frac{a-c}{a+c}.$$

Therefore, $PCM_{D1} < PCM_{D2}$. We thus observe that a decrease in the upstream price-cost margin is associated with an increase in the downstream price-cost margin. Because we use the average price-cost margin[19] to measure competition of an industry, the above result leads to the following prediction:

[17]The downstream profit is $\frac{(a-c)^2}{b} \cdot \frac{\delta(3-\delta)^2(1-\delta)}{2(2-\delta)^2(9-\delta)^2}$. The downstream revenue is $P(Q^{**})Q^{**}$.
[18]The downstream profit is $\frac{(a-c)^2}{4b}$. The downstream revenue is $\frac{(a+c)(a-c)}{4b}$.
[19]Gross profit margin without consideration of the financial cost.

Prediction 1. *A change in competition of the upstream market leads to a change in competition of the downstream market in the opposite direction.*

In the next two sections, we empirically test this prediction.

3.4 Data and Methodology

3.4.1 Econometric Specification

Our measure of an industry's product market competition in a given year is the average of the gross profit margins of the representative firms in that year:

$$LIU_t = \frac{1}{N_U} \sum_{i \in U} LI_{it} \tag{3.3}$$

for the upstream (shipbuilding) industry, and

$$LID_t = \frac{1}{N_D} \sum_{i \in D} LI_{it} \tag{3.4}$$

for the downstream (shipping) industry, where

$$LI_{it} = \frac{\text{operating profit}_{it}}{\text{sales}_{it}} \tag{3.5}$$

is an individual firm i's gross profit margin in year t. Our measure of a firm's gross profit margin is similar to the price-cost margin (or Lerner Index) used by [ABB$^+$05] in their calculation of their competition measure.[20]

[20] Our measure differs by omitting the financial cost. [ABB$^+$05] note that their result is robust to excluding the financial cost from the Lerner measure, principally because it is relatively small and constant over time for the firms in their data set spanning seventeen industries. In this paper, because the composition of firms that constitute the bulk of the market does not vary significantly over the periods in our study, we use the same firms for each year. As such, we make the assumption that the financial cost is relatively constant overtime. Under this assumption, our result also would not be significantly affected by exclusion of the financial cost.

In order to make robust inference on the effect of upstream competition on downstream competition, we analyze the relationship between the two tiers of competition[21]:

$$LID_t = \alpha + \beta LIU_t + \epsilon_t\,. \tag{3.6}$$

Through reading sample shipbuilding contracts, we find that it typically takes at least one year to build a vessel. We also observe that although payment for a vessel is spread out over the course of production, the last installment upon delivery of the vessel is the largest (typically more than 50% of the total payment). Therefore, it is necessary to account for this lag in firms' strategic responses. We thus use LIU_{t-1} as our explanatory variable. Undoubtedly, other factors can also affect the downstream (shipping) industry's competition. The most obvious one is demand for shipping services. In order to control for shipping demand, we exploit the China Containerized Freight Index (CCFI) and world seaborne trade data (WST). The equation we estimate is of the following form:

$$LID_t = \alpha + \beta LIU_{t-1} + \gamma Log(CCFI)_t + \sigma Log(WST)_t + \epsilon_t\,. \tag{3.7}$$

Our choice of empirical specification finds its basis in models of cyclical behavior of prices[22]. The basic idea is that freight rates respond to shocks in shipping demand.[23] Therefore, some demand information is embedded in freight rates. Although freight

[21]Many previous studies measured collusion using the conjectural variation parameter, where a high conjectural variation (close to 1) indicates a situation close to "perfect" collusion, although it is acknowledged that this approach ignores the inherently static nature of the conjectural variation model. Some authors have proposed alternative measures of collusion (e.g. [Dic82]). However, there is a general consensus that market power, as measured by the Lerner Index, partially depends on the degree of collusion (as well as on the price elasticity of demand and market concentration). Our study follows previous authors in using the Lerner index to help measure industry competition. We have not directly measured collusion, but have derived a testable implication on competition from the cartel theoretical model in Chapter 1.

[22]In macroeconomics, see [CO91], [RW99], et cetera. In industrial organization, see [GP84], [RS86], [SR90], et cetera.

[23]In various oligopolistic models, implicitly colluding firms respond strategically in pricing to demand shocks. For example, [GP84] show price wars when demand is low (unexpectedly), while [RS86] show price wars when demand is high.

rates in period t may be related to shipping competition in the same period, the relation between freight rates and shipbuilding competition would be more remote. Specifically, freight rates in period t are independent of the shipbuilding competition in period $t-1$. This independence allows us to have a meaningful interpretation of the effect of upstream (shipbuilding) competition. The world seaborne trade data are quantity data of the global shipping trade. Clearly, they are closely related to the shipping demand. We find no evidence of correlation between CCFI and WST, and no evidence of correlation between WST and our explanatory variable: upstream competition with a one-year lag. Thus, we use world seaborne trade as another control variable. Finally, as a robustness check, we estimate our model again with LID1 (shipping competition with a one-year lag) as an additional regressor, to address the possibility that past competition may have an effect on current competition.

3.4.2 Data and Descriptive Statistics

The first data set contains yearly operating incomes and revenues of 9 shipbuilding companies and 14 shipping companies over the period 2003 to 2015. All firms in this data set are publicly held: the operating profits and sales were read from the firms' annual reports.[24] For each of the two industries, we have chosen a set of public companies that have consistently been the industry leaders in terms of market share over the period of our study. In each industry, the companies we have selected serve the majority of the market collectively, and we use information on these companies' financial statuses to infer market competition. For each year, the average gross profit margins of the upstream shipbuilding industry and the downstream shipping industry are calculated according to formulae 3.3 and 3.4.

The second data set contains information on market conditions of the global shipping industry—the China Containerized Freight Index (CCFI) and the world

[24]For conglomerates and companies engaged in multiple types of businesses, we only extracted information on the shipbuilding and shipping segments.

seaborne trade data (WST), collected from Clarkson's Shipping Intelligence Network, a global ship registry.

Table 3.1 provides summary statistics for the data used in this study.

Table 3.1: Summary Statistics

	Observations	Mean	SD	Min	Max	Description
LID	13	0.0207	0.0753	-0.1459	0.1264	Average gross profit margin in shipping
LIU	13	0.0278	0.0772	-0.1198	0.1124	Average gross profit margin in shipbuilding
CCFI	13	1057.846	94.8533	872	1171	China Containerized Freight Index
WST	13	8931.002	1229.364	6961.77	10812.35	World seaborne trade in million tonnes

The sample consists of 13 yearly observations for the two industries over the period 2003 to 2015.

Figures G.1 and G.2 in the appendix show how the distributions of the Lerner indexes evolved for the two industries.

Before presenting our estimation results, we graph the Lerner indexes[25] of the shipbuilding and shipping industries together in Figure 3.1, and observe the correlation between them. Note that the upstream Lerner index is graphed with a one-year lag, to be consistent with our estimated equation.

[25]In this paper, we use the terms "Lerner index", "gross profit margin", "price-cost margin" interchangeably, because we leave out consideration of financial costs, as explained earlier in the paper.

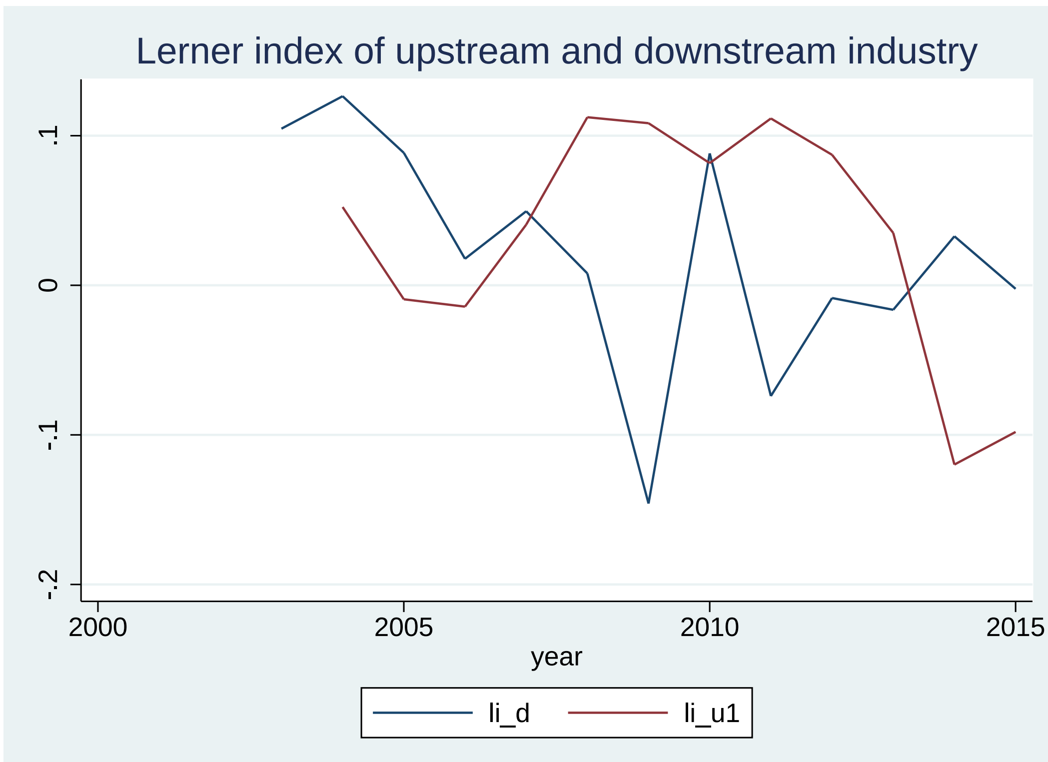

Figure 3.1: Upstream and Downstream Lerner Indexes

3.5 Results

Our results are reported in Table 3.2. Column 1 shows the result of the basic model specification (3.6). Column 3 shows the result of the fuller model specification (3.7), where we control for consumers' demand for shipping services to the maximum extent possible with our current available data. The key result is that the estimated coefficient for LIU1 (the one-year lagged Lerner index of the shipbuilding industry) is negative (-0.5239) and significant at the 5% level: upstream competition is found to be negatively correlated with downstream competition. This result is consistent with our prediction.

Table 3.2: OLS Regressions: Main Result

	(1) LID	(2) LID	(3) LID	(4) LID
LIU1	-0.2737	-0.4002*	-0.5239**	-0.5791**
	(0.2841)	(0.1947)	(0.1813)	(0.2024)
LID1				-0.1646
				(0.2300)
Log(CCFI)		0.5633***	0.5184***	0.4851**
		(0.1562)	(0.1382)	(0.1500)
Log(WST)			-0.2276*	-0.2989*
			(0.1165)	(0.1562)
Constant	0.0225	-3.8939***	-1.5047	-0.6177
	(0.0233)	(1.0860)	(1.5475)	(2.0213)
Observations	12	12	12	12
R^2	0.08	0.63	0.75	0.76

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In Table G.1 in the appendix, we report some related regression results. We do not observe a significant effect of downstream competition in a year on that of the previous year, or a significant correlation between our control variables and the explanatory variable—upstream competition.

We then show that our main result is robust to a share-weighted competition measure: instead of taking the average of all Lerner indexes as in formulae 3.3 and 3.4, for each industry, we weight the Lerner index of a firm by the firm's share of total sales in the dataset. Table 3.3 reports this result.

Table 3.3: OLS Regressions: Robustness

	(1) LIDW	(2) LIDW	(3) LIDW	(4) LIDW
LIUW1	-0.3854	-0.5576**	-0.5585**	-0.5945**
	(0.2805)	(0.1727)	(0.1888)	(0.1877)
LIDW1				-0.2176
				(0.1894)
Log(CCFI)		0.4394***	0.4390***	0.3938**
		(0.1012)	(0.1088)	(0.1137)
Log(WST)			-0.0018	-0.0504
			(0.0877)	(0.0958)
Constant	0.0279	-3.0225***	-3.0033**	-2.2410
	(0.0198)	(0.7025)	(1.1884)	(1.3411)
Observations	12	12	12	12
R^2	0.16	0.73	0.73	0.77

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

3.6 Discussion

We see this paper as the first step to a larger project to look into a general result. We want to investigate whether the negative correlation between upstream and downstream competition persists when we look into a variety of industries. To do that, we will first significantly increase the number of observations on shipping and shipbuilding, then collect competition data for additional upstream-downstream industry pairs that are generally perceived to be susceptible to explicit or implicit collusion. There are a few more things we can do to expand the scope of this paper. The following are some preliminary ideas and considerations.

Historically, antitrust immunity has been given to the global shipping industry, but from time to time, regulators in some jurisdictions would grow skeptical about the economic justification for such a widely applied antitrust exemption, and implement a repeal. There are also cases where a competition law has just been formally established in a jurisdiction, and the antitrust immunity is not immediately granted to the shipping industry without lengthy discussions and solicitation of public opinion. As a result, there are observable policy shocks that may influence the shipping industry's competition. We can control for these shocks for better identification.

To more convincingly establish causality, we can consider using regulatory policy variables specific to the upstream industry as instruments for upstream competition. Finding such instruments is not without its challenges, as governments' positions on competition and regulation often impact multiple industries at the same time. However, there are some viable policy-related variables we can exploit. For instance, the number of antitrust cases prosecuted in a year for a specific industry is likely to influence competition in that industry more than competition in other industries.[26]

3.7 Conclusion

In this paper, we investigate the relationship between competition of an upstream input market and competition of a downstream product market, using data on the shipbuilding and shipping industries. We find preliminary evidence that upstream competition has a negative impact on downstream competition. Our finding proves

[26] Another possible direction to look for instrumental variables is the cost components of upstream firms. Presumably, a change in cost would affect the firms' gross profit margins, and thus affect the competition measure. However, we are skeptical about using upstream costs as instruments for upstream competition, because changes in costs can be passed through to the downstream market, which can also affect downstream firms' gross profit margins, thus downstream competition.

to be robust to two alternative measures of competition. This result lends empirical support to the theoretical models of Chapters 1 and 2 of this dissertation.

This study is the beginning of a larger project to further explore the linkage between upstream and downstream competition. In the next step, we plan to do the following: (1) control for downstream competition policy; (2) exploit industry specific policy variables as instruments for upstream competition; (3) expand the database to include more industries over a longer period.

3.8 Acknowledgement

Chapter 3 is material co-authored with Xuan Ding. I would like to thank Xuan for giving me permission to include this material in my dissertation.

Appendix A

Some Proofs for Chapter 1

PROOF OF PROPOSITION 1:

Both $\pi^{Coll}(q, w, f)$ and $h(q, w, f)$ are quadratic functions in q that open downwards, as shown in Figures 1.1 - 1.3.

The solution to the retailers' problem (R) is

$$\tilde{q}(w, f) = \underset{q \in \Theta(w,f)}{\arg\max}\, \pi^{Coll}(q, w, f)\,.$$

If $\hat{q}(w) \in \Theta(w, f)$, then $\tilde{q}(w, f) = \hat{q}(w)$. If $\hat{q}(w) \notin \Theta(w, f)$, then

$$\tilde{q}(w, f) = \underset{q \in \Theta(w,f)}{\arg\min} \left| q - \hat{q}(w) \right|.$$

$\hat{q}(w) = \frac{a-w}{4b}$, and $\hat{\hat{q}}(w) = \frac{a-w}{b} \cdot \frac{3-\delta}{9-\delta}$. Because $\delta \in (0, 1)$, we have $\hat{q}(w) < \hat{\hat{q}}(w)$.

Note that $\pi^{Coll}(q, w, f) \geq h(q, w, f)$ for all $q \in \Theta(w, f)$. This is because $h(q, w, f)$ represents the per-period average gain in profit from colluding rather than deviating, and thus cannot be larger than $\pi^{Coll}(q, w, f)$, the per-period average profit from colluding, for sustainable collusive quantities.

Further, we know that in equilibrium, $\frac{\partial h(q,w,f)}{\partial f} = -\delta < 0$. So as f increases, $\Theta(w, f)$ becomes a smaller set, and $\inf \Theta(w, f)$ becomes larger (exceeding $\hat{q}(w)$). This means that before $\Theta(w, f)$ reduces to a singleton, the supplier always has an incentive to increase f, since doing that not only brings in additional revenue from a higher fixed fee, but also increases colluding retailers' purchase quantities.

When $\Theta(w, f)$ becomes a singleton, $\tilde{q}(w) = \hat{\hat{q}}(w)$, and $h(\hat{\hat{q}}(w), w, f^*(w)) = 0$, from which $f^*(w)$ can be solved.

We can verify that the supplier does not have any incentive to further raise f above $f^*(w)$—if she does, then $\Theta(w, f)$ becomes empty, which means retail collusion breaks down. Since $f^*(w) > f_0(w)$, the Cournot-Nash profit threshold, the retailers will simply exit the market in response. Retailers leaving the market would lead to zero profit for the supplier. Knowing this, the supplier would not want to deviate from $f = f^*(w)$.

By definition, $q^*(w)$ solves (R) when the contract terms are $(w, f^*(w))$. So $q^*(w) = \hat{\hat{q}}(w)$.

PROOF OF PROPOSITION 2:

$$\frac{\partial \pi_S}{\partial w} = \frac{2}{1-\delta}\left[\frac{\partial q}{\partial w} \cdot (w - c) + q + \frac{\partial f}{\partial w}\right] = 0$$

$$\Longrightarrow \; w^{**} = c + (a - c)\frac{1-\delta}{4-2\delta} \in \left(c, \frac{a+c}{2}\right).$$

Correspondingly,

$$f^{**} = \frac{(a - w^{**})^2}{4b\left[2 + \frac{1-\delta}{4}\right]} = \frac{(a-c)^2}{4b} \cdot \frac{(3-\delta)^2}{(2-\delta)^2(9-\delta)} > 0\,.$$

PROOF OF PROPOSITION 3:

$$
\begin{aligned}
Q^{**} &= 2\hat{\hat{q}}(w^{**}) \\
&= \frac{2(a-w^{**})}{b} \cdot \frac{3-\delta}{9-\delta} \\
&= \frac{a-c}{b} \cdot \frac{(3-\delta)^2}{(2-\delta)(9-\delta)}\,.
\end{aligned}
$$

When the supplier uses linear pricing, and the two retailers compete, in equilibrium, the supplier sets the industry monopoly price $P^M = \frac{a+c}{2}$, and the resulting total quantity is $Q^{RC} = \frac{a-c}{3b}$. Because $\frac{(3-\delta)^2}{(2-\delta)(9-\delta)} > \frac{1}{3}$, it follows that $Q^{**} > Q^{RC}$.

PROOF OF LEMMA 3:

$$
Q^{**} = \frac{a-c}{b} \cdot \frac{(3-\delta)^2}{(2-\delta)(9-\delta)}\,.
$$

Hence,

$$
\frac{\partial Q^{**}}{\partial \delta} = \frac{a-c}{b} \cdot \frac{(3-\delta)(5\delta-3)}{(2-\delta)^2(9-\delta)^2}\,.
$$

Thus, when $\delta < \frac{3}{5}$, we have $\frac{\partial Q^{**}}{\partial \delta} < 0$; when $\delta = \frac{3}{5}$, $\frac{\partial Q^{**}}{\partial \delta} = 0$; and when $\delta > \frac{3}{5}$, $\frac{\partial Q^{**}}{\partial \delta} > 0$.

PROOF OF PROPOSITION 4:

$$
\frac{\partial w^{**}}{\partial \delta} = \frac{-(a-c)}{2(2-\delta)^2} < 0\,,
$$

$$
\frac{\partial f^{**}}{\partial \delta} = \frac{-2(a-w^{**})\frac{\partial w^{**}}{\partial \delta}[2+\frac{1-\delta}{4}] - (a-w^{**})^2(-\frac{1}{4})}{4b[2+\frac{1-\delta}{4}]^2} > 0\,.
$$

Appendix B

Tables for Chapter 1

Table B.1: Equilibrium Comparison

Contract	**Setting**	w	f	Q
Linear Pricing	one-shot	[3] $\frac{a+c}{2}$	-	[2] $\frac{a-c}{3b}$
	repeated/collusion	[3] $\frac{a+c}{2}$	-	[1] $\frac{a-c}{4b}$
Two-Part Tariff	one-shot	[2] $\frac{a+3c}{4}$	[1] $\frac{(a-c)^2}{16b}$	[4] $\frac{a-c}{2b}$
	repeated/collusion	[1] $c+(a-c)\frac{1-\delta}{4-2\delta}$	[2] $\frac{(a-c)^2}{4b}\cdot\frac{(3-\delta)^2}{(2-\delta)^2(9-\delta)}$	[3] $\frac{a-c}{b}\cdot\frac{(3-\delta)^2}{(2-\delta)(9-\delta)}$ †

[1] The numbers in brackets reflect the relative sizes of the values in each column: they are order numbers from smallest to largest in each column. For example, two-part tariff in a repeated game setting gives the smallest equilibrium price w (denoted with [1]), while linear pricing gives the highest equilibrium w in both one-shot and repeated game settings (denoted with [3]).

†This result shows that restricted collusion with two-part tariff leads to a larger quantity than competition with linear pricing. In fact, $\frac{(3-\delta)^2}{(2-\delta)(9-\delta)}$ is very close to $\frac{1}{2}$ for all $\delta \in (0,1)$.

Table B.2: Welfare Comparison

Contract	Setting	Retailers	Supplier	R + S	Consumers	Total
Linear Pricing	one-shot	[3] $\frac{(a-c)^2}{b} \cdot \frac{1}{18}$	[2] $\frac{(a-c)^2}{b} \cdot \frac{1}{6}$	[2] $\frac{(a-c)^2}{b} \cdot \frac{2}{9}$	[2] $\frac{(a-c)^2}{b} \cdot \frac{1}{18}$	[2] $\frac{(a-c)^2}{b} \cdot \frac{5}{18}$
	repeated/collusion	[4] $\frac{(a-c)^2}{b} \cdot \frac{1}{16}$	[1] $\frac{(a-c)^2}{b} \cdot \frac{1}{8}$	[1] $\frac{(a-c)^2}{b} \cdot \frac{3}{16}$	[1] $\frac{(a-c)^2}{b} \cdot \frac{1}{32}$	[1] $\frac{(a-c)^2}{b} \cdot \frac{7}{32}$
Two-Part Tariff	one-shot	[1] 0	[4] $\frac{(a-c)^2}{b} \cdot \frac{1}{4}$	[4] $\frac{(a-c)^2}{b} \cdot \frac{1}{4}$	[4] $\frac{(a-c)^2}{b} \cdot \frac{1}{8}$	[4] $\frac{(a-c)^2}{b} \cdot \frac{3}{8}$
	repeated/collusion	[2] $\frac{(a-c)^2}{b} \cdot \lambda_R{}^{\ddagger}$	[3] $\frac{(a-c)^2}{b} \cdot \lambda_S{}^{\star}$	[3] $\frac{(a-c)^2}{b} \cdot (\lambda_R + \lambda_S)^{\diamondsuit}$	[3] $\frac{(a-c)^2}{b} \cdot \lambda_C{}^{*}$	[3] $\frac{(a-c)^2}{b} \cdot (\lambda_R + \lambda_S + \lambda_C)^{\wedge}$

[1] These are surplus values.

[2] The column "Retailers" shows the total surplus obtained by the two retailers.

[3] The column "R + S" shows the total surplus obtained by all three players.

[4] The numbers in brackets reflect the relative sizes of the values in each column: they are order numbers from smallest to largest in each column, the same way as in Table B.1.

$^{\ddagger}\lambda_R = \frac{\delta(3-\delta)^2(1-\delta)}{2(2-\delta)^2(9-\delta)^2}$, $0 < \lambda_R < 0.005$, λ_R is very close to zero for all $\delta \in (0,1)$.

$^{\star}\lambda_S = \frac{(3-\delta)^2}{2(2-\delta)(9-\delta)}$, $\frac{12}{49} \leq \lambda_S < \frac{1}{4}$, λ_S is very close to $\frac{1}{4}$ for all $\delta \in (0,1)$.

$^{\diamondsuit}\lambda_R + \lambda_S = \frac{(3-\delta)^2(9-5\delta)}{(2-\delta)^2(9-\delta)^2}$, $\frac{12}{49} < \lambda_R + \lambda_S < \frac{1}{4}$, $\lambda_R + \lambda_S$ is very close to $\frac{1}{4}$ for all $\delta \in (0,1)$.

$^{*}\lambda_C$ is very close to $\frac{1}{8}$. This can be implied from the result in Table B.1 that the equilibrium total quantity in the model is very close to the industry monopoly quantity.

$^{\wedge}\lambda_R + \lambda_S + \lambda_C$ is very close to $\frac{3}{8}$. This can be implied from the result in Table B.1 that the equilibrium total quantity in the model is very close to the industry monopoly quantity.

Appendix C

Graphs for Chapter 1

Upstream Two-Part Tariff Restricts Downstream Collusion.

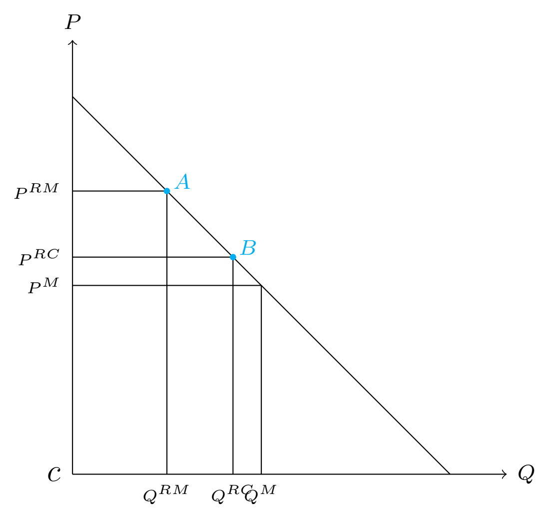

Figure C.1: Restricting collusion (1).

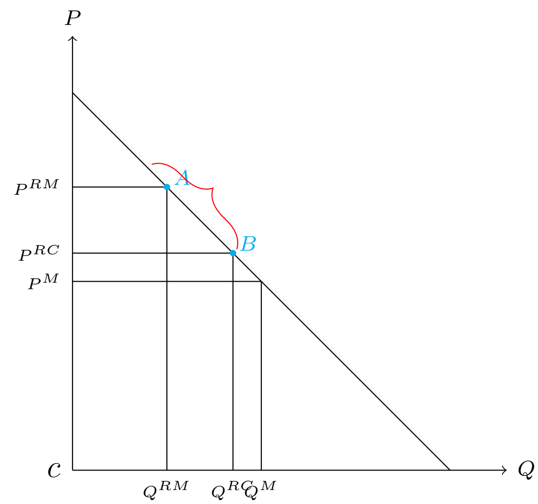

Figure C.2: Restricting collusion (2).

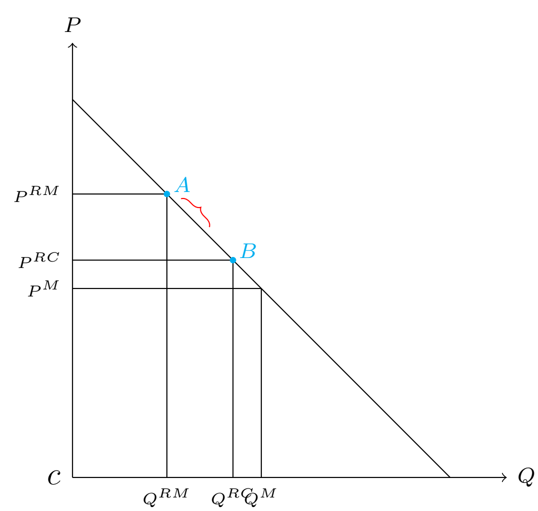

Figure C.3: Restricting collusion (3).

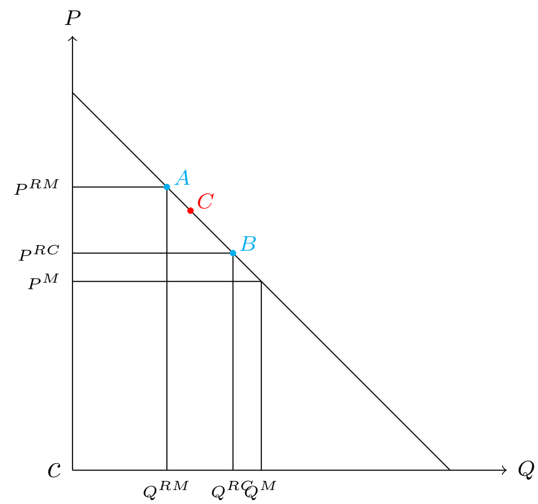

Figure C.4: Restricting collusion (4).

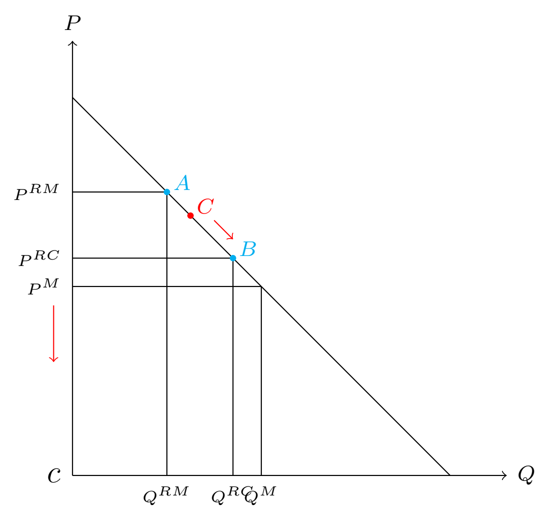

Figure C.5: Restricting collusion (5).

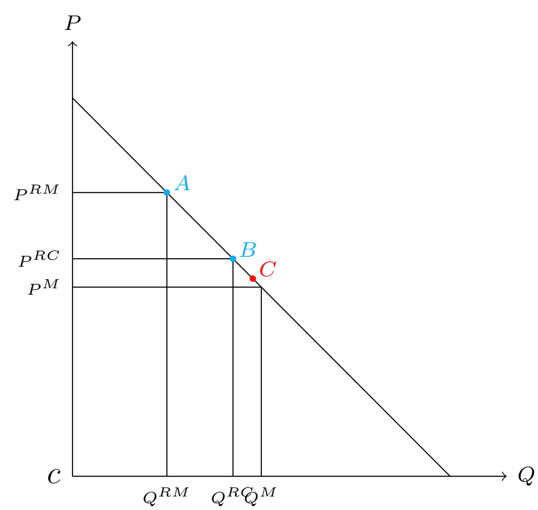

Figure C.6: Restricting collusion (6) - Equilibrium.

Appendix D

Some Proofs for Chapter 2

PROOF OF PROPOSITION 10:

Both $\pi^{Coll}(q, w, f)$ and $h(q, w, f)$ are quadratic functions in q that open downwards, as shown in Figures 1.1 - 1.3 in Chapter 1.

The solution to the retailers' problem (R) (described in Chapter 1 as an individual retailer's problem due to symmetry) is $\tilde{q}(w, f) = \arg\max_{q\in\Theta(w,f)} \pi^{Coll}(q, w, f)$. If $\hat{q}(w) \in \Theta(w, f)$, then $\tilde{q}(w, f) = \hat{q}(w)$. If $\hat{q}(w) \notin \Theta(w, f)$, then

$$\tilde{q}(w, f) = \arg\min_{q\in\Theta(w,f)} |q - \hat{q}(w)| .$$

$\hat{q}(w) = \frac{a-w}{2bN}$. $\hat{\hat{q}}(w) = \frac{a-w+\frac{1-\delta}{2}(a-w)(N-1)}{2bN+\frac{1-\delta}{2}b(N-1)^2}$. Because $\delta \in (0, 1)$, we have $\hat{q}(w) < \hat{\hat{q}}(w)$.

Note that $\pi^{Coll}(q, w, f) \geq h(q, w, f)$ for all $q \in \Theta(w, f)$, since $\pi^{Coll}(q, w, f) - h(q, w, f)$ represents the per-period average gain from colluding rather than deviating, and thus must be nonnegative for supportable collusive quantities.

Further, we know that $\frac{\partial h(q,w,f)}{\partial f} = -\delta < 0$. So as f increases, $\Theta(w, f)$ becomes smaller, and $\inf \Theta(w, f)$ becomes larger (surpassing $\hat{q}(w)$). This means that before $\Theta(w, f)$ reduces to a singleton, the supplier always has an incentive to increase f, since doing that not only brings in additional revenue from a higher fixed fee, but also increases colluding retailers' purchase quantities.

When $\Theta(w, f)$ becomes a singleton, $\tilde{q}(w) = \hat{\hat{q}}(w)$, and $h(\hat{\hat{q}}(w), w, f^*(w)) = 0$, from which $f^*(w)$ can be solved.

We can verify that the supplier does not have any incentive to further raise f above $f^*(w)$: If she does, then $\Theta(w, f)$ becomes empty, which means retail collusion breaks down. Since $f^*(w) > f_0(w)$, the Nash profit threshold, the retailers will simply exit the market in response. Retailers leaving the market would lead to zero profit for the supplier. Knowing this, the supplier would not want to deviate from $f = f^*(w)$.

By definition, $q^*(w)$ solves (R) when the contract terms are $(w, f^*(w))$. So $q^*(w) = \hat{\hat{q}}(w)$.

PROOF OF PROPOSITION 11:

$$\frac{\partial \pi_S}{\partial w} = \frac{N}{1-\delta}\left[\frac{\partial q}{\partial w} \cdot (w-c) + q + \frac{\partial f}{\partial w}\right] = 0$$

$$\Longrightarrow \; w^{**} = c + (a-c)\frac{(1-\delta)(N-1)}{2(1-\delta)(N-1)+2} \in \left(c, \frac{a+c}{2}\right).$$

Correspondingly,

$$f^{**} = \frac{(a-w^{**})^2}{4b\big[N + \frac{(1-\delta)(N-1)^2}{4}\big]} = \frac{(a-c)^2\left[\frac{(1-\delta)(N-1)+2}{2(1-\delta)(N-1)+2}\right]^2}{4b\big[N + \frac{(1-\delta)(N-1)^2}{4}\big]} > 0\,.$$

PROOF OF LEMMA 10:

First,

$$\begin{aligned}
N\hat{\hat{q}}(w^{**}) &= \frac{(a-w^{**})N}{b} \cdot \frac{1+\frac{1-\delta}{2}(N-1)}{2N+\frac{1-\delta}{2}(N-1)^2} \\
&= \frac{a-c}{b} \cdot \left[1 - \frac{(1-\delta)(N-1)}{2(1-\delta)(N-1)+2}\right] \cdot \frac{2N+(1-\delta)N(N-1)}{4N+(1-\delta)(N-1)^2} \\
&= \frac{(a-c)N}{b} \cdot \left[\frac{1}{2} + \frac{1}{2(1-\delta)(N-1)+2}\right] \cdot \frac{2+(1-\delta)(N-1)}{4N+(1-\delta)(N-1)^2}\,,
\end{aligned}$$

Using the above, we find

$$\begin{aligned}
\frac{\partial N\hat{\hat{q}}(w^{**})}{\partial \delta} = \frac{(a-c)N}{b} &\cdot \left\{(N-1)^2[2+(1-\delta)(N-1)][2-(1-\delta)(N+3)]\right\} \\
&\cdot \left\{2[1+(1-\delta)(N-1)]^2[4N+(1-\delta)(N-1)^2]^2\right\}^{-1}.
\end{aligned}$$

Thus, when $2-(1-\delta)(N+3)<0$, or $\delta < \frac{N+1}{N+3}$, we have $\frac{\partial N\hat{\hat{q}}(w^{**})}{\partial \delta} < 0$; when $\delta = \frac{N+1}{N+3}$, $\frac{\partial N\hat{\hat{q}}(w^{**})}{\partial \delta} = 0$; and when $\delta > \frac{N+1}{N+3}$, $\frac{\partial N\hat{\hat{q}}(w^{**})}{\partial \delta} > 0$.

PROOF OF PROPOSITION 13:

$$\frac{\partial w^{**}}{\partial N} = \frac{(a-c)(1-\delta)}{2[(1-\delta)(N-1)+1]^2} > 0\,,$$

$$\frac{\partial w^{**}}{\partial \delta} = \frac{-(a-c)(N-1)}{2[(1-\delta)(N-1)+1]^2} < 0\,,$$

$$\frac{\partial f^{**}}{\partial N} = \frac{-2(a-w^{**})\frac{\partial w^{**}}{\partial N}[N+\frac{(1-\delta)(N-1)^2}{4}] - (a-w^{**})^2[1+\frac{(1-\delta)(N-1)}{2}]}{4b[N+\frac{(1-\delta)(N-1)^2}{4}]^2} < 0\,,$$

$$\frac{\partial f^{**}}{\partial \delta} = \frac{-2(a-w^{**})\frac{\partial w^{**}}{\partial \delta}[N+\frac{(1-\delta)(N-1)^2}{4}] - (a-w^{**})^2(-1)\frac{(N-1)^2}{4}}{4b[N+\frac{(1-\delta)(N-1)^2}{4}]^2} > 0\,.$$

PROOF OF LEMMA 11:

$$N\hat{\hat{q}}(w^{**}) = \frac{(a-w^{**})N}{b} \cdot \frac{1+\frac{1-\delta}{2}(N-1)}{2N+\frac{1-\delta}{2}(N-1)^2}$$
$$= \frac{a-c}{b} \cdot \left[1 - \frac{(1-\delta)(N-1)}{2(1-\delta)(N-1)+2}\right] \cdot \frac{2N+(1-\delta)N(N-1)}{4N+(1-\delta)(N-1)^2}.$$

Hence,

$$\frac{\partial N\hat{\hat{q}}(w^{**})}{\partial N} = -\frac{a-c}{b} \cdot (1-\delta)[2+(1-\delta)(N-1)] \cdot \Big\{4N^2+(1-\delta)N(N-1)^2$$
$$+ [(1-\delta)(N-1)+1][4N+(1+\delta(N-1)^2]\Big\} \cdot \Big\{2[(1-\delta)(N-1)$$
$$+ 1]^2[4N+(1-\delta)(N-1)^2]^2\Big\}^{-1}$$
$$< 0.$$

PROOF OF PROPOSITION 17:

It suffices to show that for any per-unit price w, $f^*(w) > 0$ is true for any M. To do that, I argue that for any M, $f(w) = 0$ cannot be in equilibrium:

Suppose $f(w) = 0$. Then whatever M is, optimizing retailers must choose q such that $Mq = Q^{RM}(w) = \frac{a-w}{2b}$, where $Q^{RM}(w)$ is the retail monopoly quantity for a given w.[1] For any given w, the individual Cournot-Nash profit is $f_0(w) = \frac{(a-w)^2}{b(N+1)^2} > 0$. This Cournot-Nash profit is independent of M. Since $f(w) = 0$, each retailer obtains $f_0(w)$ in any punishment period. Due to Lemmas 12 and 14, the supplier could deviate to charging a positive fixed fee $f(w) \in (0, f_0(w))$ without affecting the retail cartel's choice of q. Such deviation would strictly increase the supplier's profit. Therefore, $f(w) = 0$ cannot be in equilibrium.

[1]Assumption 1 guarantees that the retailers are patient enough to sustain this collusive quantity.

Appendix E

Tables for Chapter 2

Table E.1: Equilibrium Comparison [$N > 1$ Retailers]

Contract	**Setting**	w	f	Q
Linear Pricing	one-shot	[3] $\frac{a+c}{2}$	-	[2] $\frac{a-c}{2b} \cdot \frac{N}{N+1}$
	repeated/collusion	[3] $\frac{a+c}{2}$	-	[1] $\frac{a-c}{4b}$
Two-Part Tariff	one-shot	[2] $\frac{a+c}{2} - \frac{a-c}{2N}$	[1] $\frac{(a-c)^2}{4b} \cdot \frac{1}{N^2}$	[3] $\frac{a-c}{2b}$
	repeated/collusion	[1] $c + (a-c)\frac{(1-\delta)(N-1)}{2(1-\delta)(N-1)+2}$	[2] $\frac{(a-c)^2\left[\frac{(1-\delta)(N-1)+2}{2(1-\delta)(N-1)+2}\right]^2}{4b\left[N+\frac{(1-\delta)(N-1)^2}{4}\right]}$	[> 1] $N\hat{\hat{q}}(w^{**})^\dagger$

[1]The numbers in brackets reflect the relative sizes of the values in each column: they are order numbers from smallest to largest in each column. For example, two-part tariff in a repeated game setting gives the smallest equilibrium price w (denoted with [1]), while linear pricing gives the highest equilibrium w in both one-shot and repeated game settings (denoted with [3]).

$^\dagger w^{**} = c + (a-c)\frac{(1-\delta)(N-1)}{2(1-\delta)(N-1)+2}$. Refer to Proposition 1.

Table E.2: Welfare Comparison [$N > 1$ Retailers]

Contract	Setting	Retailers	Supplier	R+S	Consumers	Total
Linear Pricing	one-shot	[2] $\frac{(a-c)^2}{4b} \cdot \frac{N}{(N+1)^2}$	[2] $\frac{(a-c)^2}{4b} \cdot \frac{N}{N+1}$	[2] $\frac{(a-c)^2}{4b} \cdot \frac{N^2+2N}{(N+1)^2}$	[2] $\frac{(a-c)^2}{4b} \cdot \frac{N^2}{2(N+1)^2}$	[2] $\frac{(a-c)^2}{4b} \cdot \frac{3N^2+4N}{2(N+1)^2}$
	repeated/collusion	[3] $\frac{(a-c)^2}{4b} \cdot \frac{1}{4}$	[1] $\frac{(a-c)^2}{4b} \cdot \frac{1}{2}$	[1] $\frac{(a-c)^2}{4b} \cdot \frac{3}{4}$	[1] $\frac{(a-c)^2}{4b} \cdot \frac{1}{8}$	[1] $\frac{(a-c)^2}{4b} \cdot \frac{7}{8}$
Two-Part Tariff	one-shot	[1] 0	[3] $\frac{(a-c)^2}{4b}$	[3] $\frac{(a-c)^2}{4b}$	[3] $\frac{(a-c)^2}{4b} \cdot \frac{1}{2}$	[3] $\frac{(a-c)^2}{4b} \cdot \frac{3}{2}$
	repeated/collusion	[> 1] $\frac{(a-c)^2}{4b} \cdot \lambda_R{}^{\ddagger}$	[> 1] $\frac{(a-c)^2}{4b} \cdot \lambda_S{}^{\star}$	[> 1] $\frac{(a-c)^2}{4b} \cdot (\lambda_R + \lambda_S)$	[> 1] $\frac{(a-c)^2}{4b} \cdot \lambda_C{}^{*}$	[> 1] $\frac{(a-c)^2}{4b} \cdot (\lambda_R + \lambda_S + \lambda_C)^{\wedge}$

[1] These are surplus values.

[2] The column "Retailers" shows the total surplus obtained by all N retailers.

[3] The numbers in brackets reflect the relative sizes of the values in each column: they are order numbers from smallest to largest in each column, the same way as in Table B.1.

‡ The value of λ_R depends on δ and N, but we know $\lambda_R > 0$, as implied by Proposition 1. Also see Figure **??**.

⋆ The value of λ_S depends on δ and N, but we know $\lambda_S > \frac{1}{2}$, as implied by Corollary 1.

⁎ The value of λ_C depends on δ and N, but we know $\lambda_C > \frac{1}{8}$, as implied by Proposition 1.

^ The value of $(\lambda_R + \lambda_S + \lambda_C)$ depends on δ and N, but we know $\lambda_R + \lambda_S + \lambda_C > \frac{7}{8}$, as implied by Proposition 1.

Appendix F

Graphical Summary for Chapter 2

Define the total payment by all retailers to the supplier as $C(Q)$ and the retailers' total revenue as $R(Q) = P(Q) \cdot Q$. In Figure F.3, $\bar{\Theta}_{Sym}(\bar{w}, \underline{f}, N) \equiv \{Nq : h(q, \bar{w}, \underline{f} \geq 0\}$. In Figure F.6, Q_L^{Coll} denotes the retail collusive quantity under wholesale linear pricing.

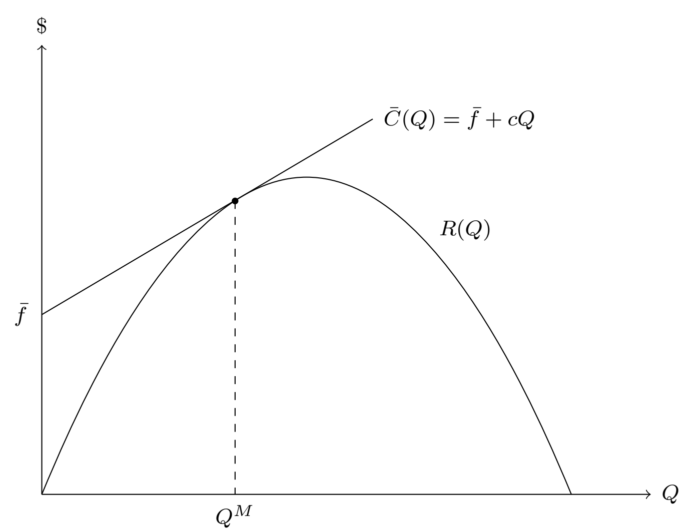

Figure F.1: Optimal Two-Part Tariff When $N = 1$.

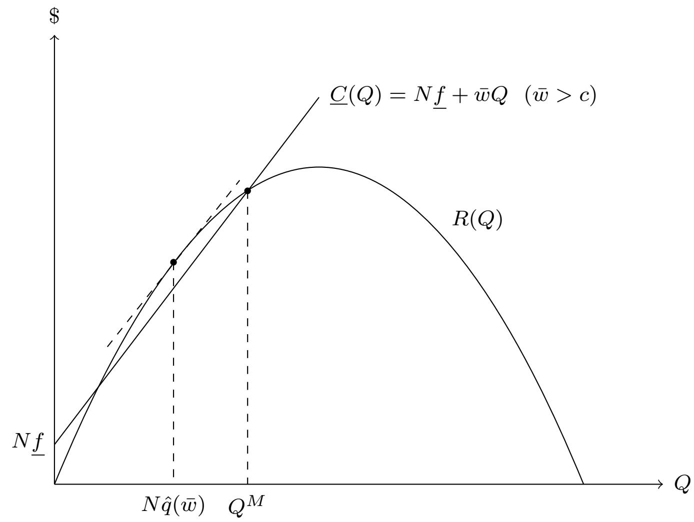

Figure F.2: Optimal Two-Part Tariff When $N > 1$, Without Collusion.

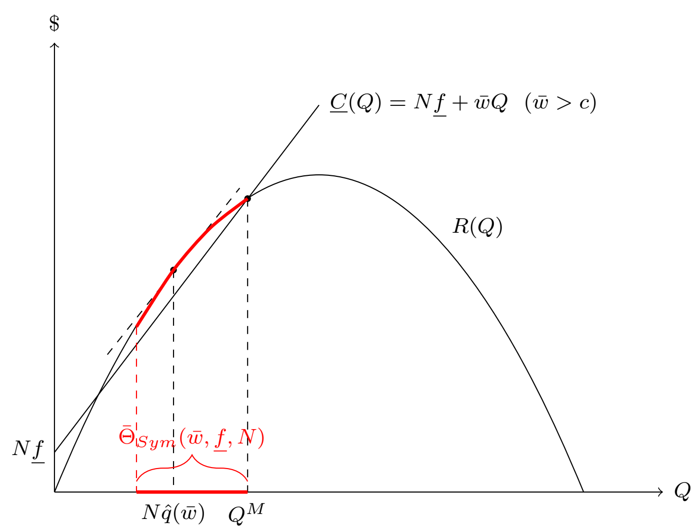

Figure F.3: Optimal Two-Part Tariff When $N > 1$, Without Collusion.

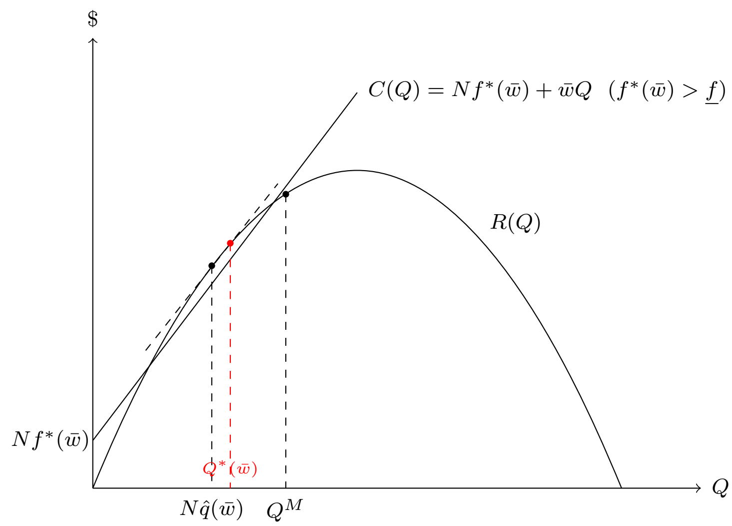

Figure F.4: Optimal Two-Part Tariff When $N > 1$, $w = \bar{w}$, with Collusion.

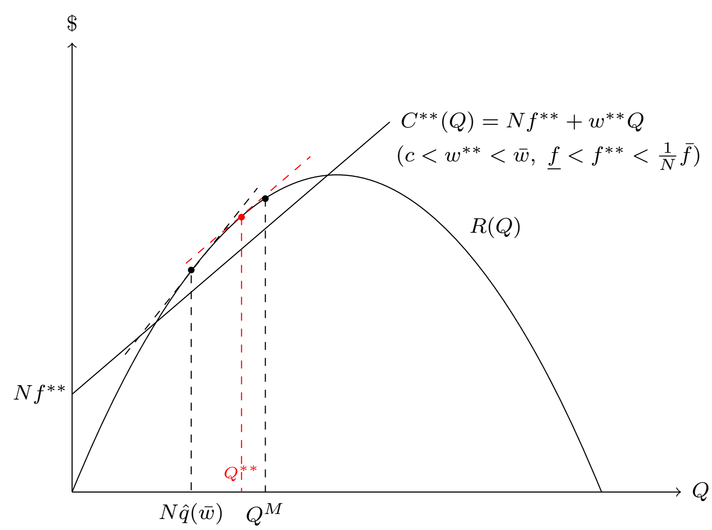

Figure F.5: Optimal Two-Part Tariff When $N > 1$, with Collusion, $\delta < 1$.

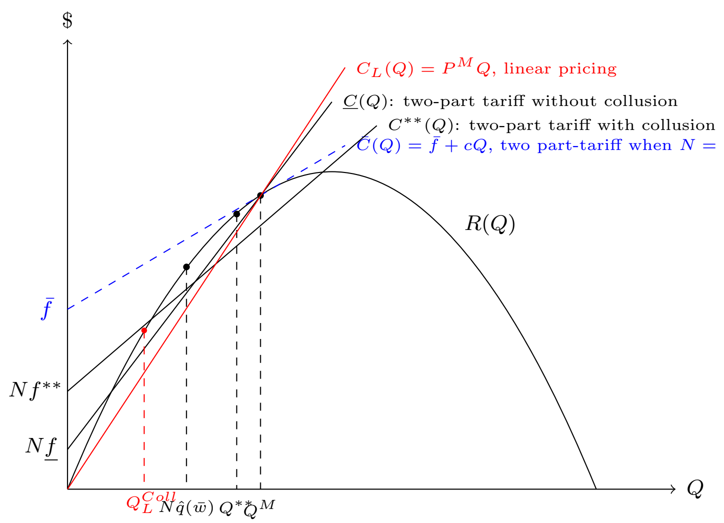

Figure F.6: Summary: Equilibrium Comparison.

Appendix G

Appendix for Chapter 3

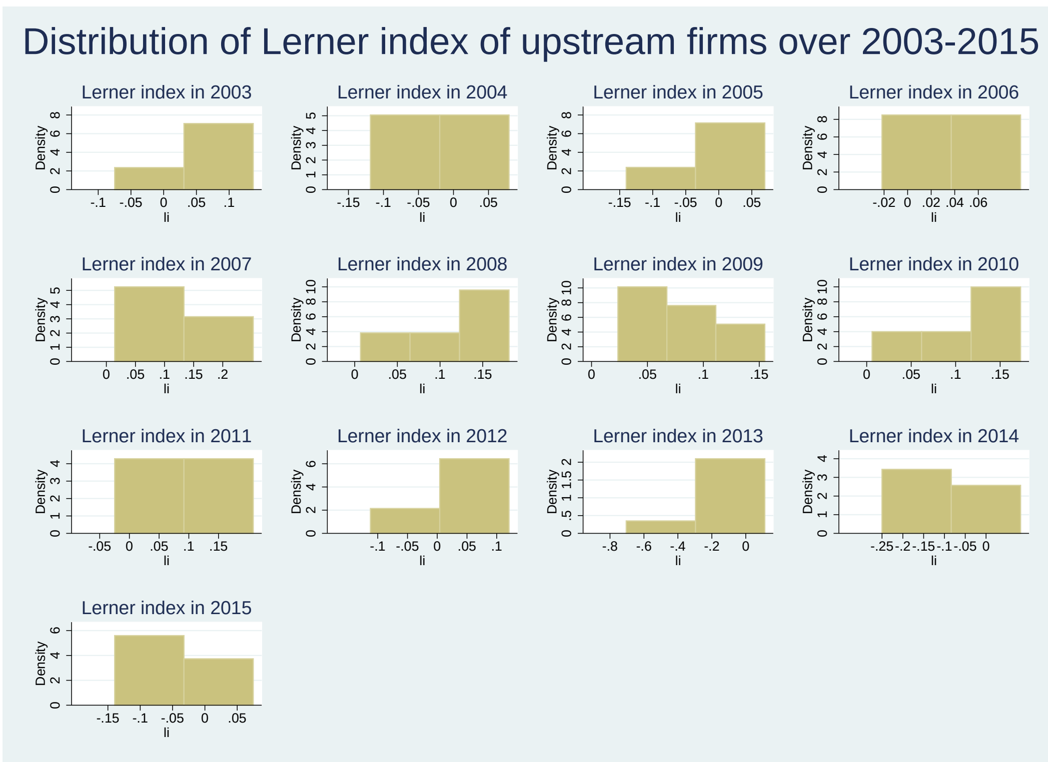

Figure G.1: Upstream Lerner Index

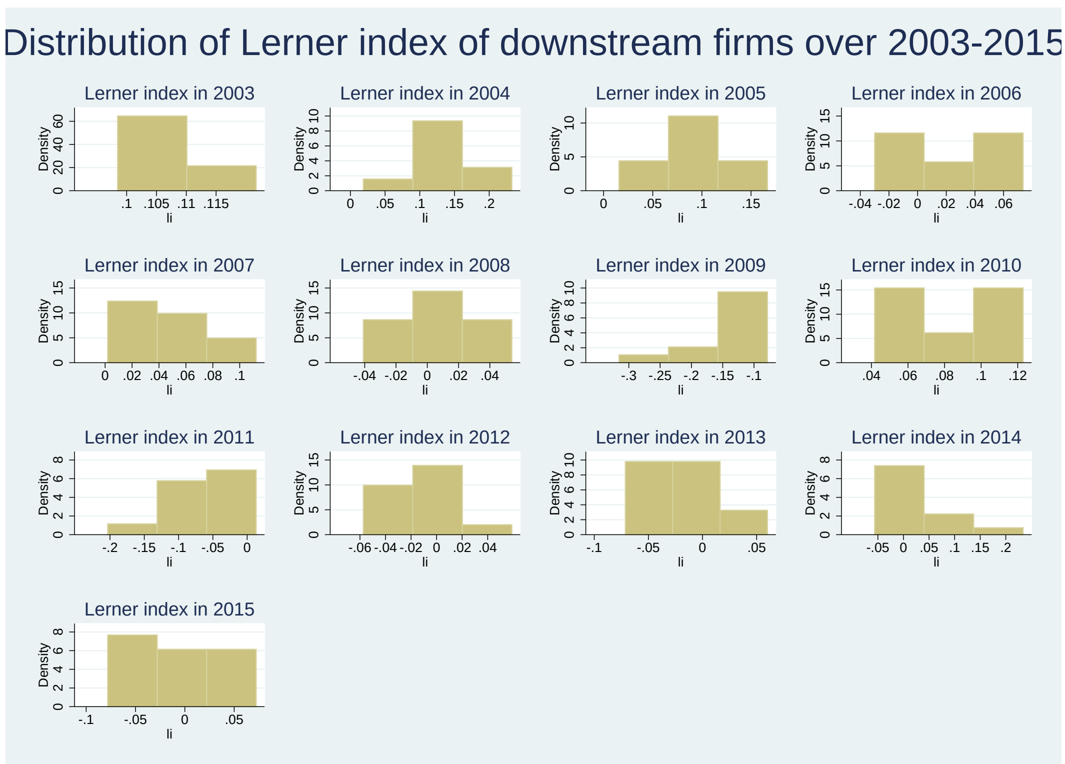

Figure G.2: Downstream Lerner Index

Table G.1: Supplementary OLS Regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	LID	LID	LID	Log(CCFI)	LIU	LIU1	LIU	LIU1
Log(CCFI)	0.5074**				-0.0386	0.1445		
	(0.1864)				(0.2470)	(0.2495)		
Log(WST)		-0.2353	-0.4602*	-0.1295			-0.2196	-0.2387
		(0.1474)	(0.2186)	(0.2008)			(0.1541)	(0.1868)
LIU1			-0.5942*					
			(0.2989)					
LID1			-0.3951					
			(0.3230)					
Constant	-3.5105**	2.1589	4.2338*	8.1368***	0.2967	-0.9732	2.0237	2.2061
	(1.2974)	(1.3399)	(2.0002)	(1.8252)	(1.7192)	(1.7368)	(1.4010)	(1.7021)
Observations	13	13	12	13	13	12	13	12
R^2	0.40	0.19	0.41	0.04	0.00	0.03	0.16	0.14

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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