The Anticompetitiveness of a
Private Information Exchange of Prices[*]

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Abstract

Competitors privately sharing *price intentions* is universally prohibited under antitrust/competition law. In contrast, there is no common well-accepted treatment of competitors privately sharing *prices*. This paper is the first to show that a private exchange of prices can result in higher prices for consumers. Conditions relevant to determining when such an information exchange is anticompetitive are identified.

Keywords: infomaton exchange, collusion

1 Introduction

The canonical collusive practice involves private communication among competitors that results in them agreeing on the prices they will charge buyers. Contrary to that description, there are a number of episodes for which firms communicated about prices different from those that buyers would pay. Some cartels privately communicated list prices - as in high fructose corn syrup,[1] urethane,[2] and cement[3] - and others communicated surcharges (or component prices) - as in air freight,[4] air passenger,[5] and railroads[6]. While list prices and surcharges may ultimately affect final (or transaction) prices, they are distinct from those prices. A second departure from that canonical collusive practice is that cartel members' communications may not involve agreeing on price but instead only comprise an exchange of prices. This paper explores the possible anticompetitive harm when both of those elements are present: firms privately exchange non-transaction prices such as list prices and surcharges.

Competition law is unequivocal in prohibiting firms from agreeing on prices, whether they are final prices, list prices, or surcharges. It is unlawful by the per se rule in the United States (under Section 1 of the Sherman Act) and by object in the European Union (under Article 101 of the Treaty of the Functioning of the European Union).[7] There is not, however, a common position with respect to firms sharing prices. In the U.S., the exchange of prices - and even an agreement among firms to exchange prices - is not outright prohibited:

> The exchange of price data ... among competitors does not invariably have anticompetitive effects; indeed such practices can in certain circumstances increase economic efficiency and render markets more, rather than less, competitive. For this reason, we have held that such exchanges of information do not constitute a per se violation of the Sherman Act.[8]

The sharing of prices is evaluated under the rule of reason. In the market for corrugated containers, firms were found guilty because the sharing of prices was shown to have an effect on prices.[9] In the EU, the exchange of prices comes under Article 101 as a concerted practice. To establish a concerted practice,

> it suffices for those concerned to inform each other of the amount of charges actually imposed by them or contemplated for the future; for the object or effects of such contacts is to influence the level of the charges imposed by the competitor

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[1] *In Re: High Fructose Corn Syrup Antitrust Litigation*, No. 01-3565 (7th Cir. June 18, 2002)

[2] *In Re: Urethane Antitrust Litigation*, No. 13-3215 (10th Cir. Sep. 29, 2014)

[3] "Aggregates: Report on the market study and proposed decision to make a market investigation reference," Office of Fair Trading, OFT1358, August 2011.

[4] CASE AT.39258 - Airfreight, European Commission, 11 September 2010

[5] "Virgin Atlantic Airways immunity review," Office of Fair Trading, OFT 1398, December 2011

[6] *In re Rail Freight Surcharge Antitrust Litig.*, 587 F.Supp.2d 27, 30 (2008), U. S. District Court, District of Columbia. November 7, 2008

[7] For background information on the economics and law of price fixing, I refer the reader to Motta (2004) for the EU and Kaplow (2013) for the U.S..

[8] *United States v. United States Gypsum Co.*, 438 U.S. 422, 441 n. 16 (1978)

[9] *United States v. Container Corp. of Am.*, 393 U.S. 333 (1969).

or, at least, to eliminate uncertainty on the part of the competitor as to the level of charges imposed by the first party.[10]

The European Commission has taken the position that "mere attendance at a meeting where an undertaking discloses its confidential pricing plans to its competitors is likely to be caught by Article 101(1)."[11] This view has been put into their guidelines which state: "information exchange can constitute a concerted practice if it reduces strategic uncertainty ... because it reduces the independence of competitors' conduct and diminishes their incentives to compete."[12]

The lack of a common treatment of the sharing of prices is at least partly due to the absence of a well-established theory of harm. This missing theory of harm is exemplified by the EU's vague claim that the exchange of prices is potentially harmful because it "reduces strategic uncertainty." However, there are no theoretical or empirical analyses showing that less "strategic uncertainty" among firms results in higher prices for consumers. In the case of the U.S., an agreement to share prices is not per se illegal because courts claim there can be procompetitive benefits, though there are no economic studies showing those benefits. We then find judicial views on both sides of the Atlantic are unsubstantiated which calls for a rigorous economic analysis to deliver clarity.

The absence of a theory of harm is also problematic for the enforcement of competition law. For jurisdictions with the rule of reason (or by effect), understanding when a private exchange of prices is anticompetitive is essential to determining when such an exchange should be prohibited. For jurisdictions with the per se rule (or by object), a conviction on liability still leaves private litigants having to establish harm in order to collect damages.[13] Furthermore, the lack of an economic argument showing consumer harm from such an information exchange could result in a future court reversing a per se prohibition.[14] For all of these reasons, competition policy would be on more solid and stable ground if it was better understood when and how such information exchanges are anticompetitive.

These issues and challenges are exemplified by the recent trucks cartel case in the EU.[15] It was documented that executives of truck manufacturers regularly met and shared gross list prices. Absent the information exchange, gross list prices were only distributed internally and, in particular, were not shared with customers. Gross list prices were part of the pricing process that eventually determined the prices charged to dealers and final purchasers. While the European Commission ruled that the truck manufacturers were in violation of Article 101, private litigation is currently seeking to determine whether there was harm to final purchasers

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[10]Case 172/80, Zürchner v. Bayerische Vereinsbank, Judgment, E.C.R., 2027 (14 July 1981)

[11]Whish and Bailey (2018), p. 117.

[12]European Commission, "Guidelines on the Applicability of Article 101 of the Treaty on the Functioning of the European Union to Horizontal Co-operation Agreements," 2011, para. 61.

[13]"In damages cases, buyers must demonstrate a causal link between the infringement by producers and the associated harm to buyers. The claimants of damages often find it easier to sue if they can already build on a theory of harm established by a competition authority. Yet, in both the trucks and thread cartel cases, the European Commission remained vague when it came to presenting a theory of harm." Boshoff and Paha (2021), p. 394.

[14]In the U.S., resale price maintenance and tying were moved from the per se rule to the rule of reason because it was concluded the per se prohibition was not justified by economic theories and evidence.

[15]Commission Decision of 19.7.2016 relating to a proceeding under Article 101 of the TFEA and Article 53 of the EEA Agreement, AT.39824 - Trucks

and that could depend on what information was actually conveyed at those meetings. Claims range from executives *exchanging* gross list prices to *discussing* gross list prices to *agreeing* on gross list prices.

> All of the Addressees exchanged gross price lists and information on gross prices [which] constituted commercially sensitive information. ... [T]he Addressees participated in meetings involving senior managers of all Headquarters [where] ... the participants discussed and in some cases also agreed their respective gross price increases.[16]

While it is commonly recognized that there is harm if it can be shown they *agreed* on prices, that is not the case when all that can be shown is that they *exchanged* prices.

This research project addresses two questions. First, is it harmful to consumers when firms privately share their prices? Second, if it is harmful, should the sharing of prices be subject to the per se rule (by object) or rule of reason (by effect)? This paper addresses the first question by developing a theory of harm associated with the private sharing of prices and delivers conditions when such an information exchange raises prices. Thus, the first question is answered in the affirmative. The second question will be addressed in a companion policy paper where the following per se prohibition is proposed: *Competitors are prohibited from privately communicating prices relevant to transactions that have not yet occurred.*

In order to be able to draw general policy conclusions, it is important that the theory of harm is robust and relies on some general factors. Towards that end, a parsimonious model is developed with two distinctive features that I believe are ubiquitous and compelling. The first feature is that firms (or, more specifically, their executives) are not sharing transaction prices. They are instead sharing prices that may ultimately affect the prices that consumers pay but are not necessarily the final prices that are put before consumers. In the trucks case, manufacturers shared list prices, and list prices would be expected to affect dealer prices which would then affect the prices paid by final purchasers. If airlines shared fuel surcharges, one would expect those surcharges to affect final passenger prices delivered by the airline's pricing algorithm. And if executives of retail chains shared posted prices, the prices faced by consumers could be different through the offering of discount coupons or rebates. The critical property is that the prices shared may influence the transaction price but, at the time of the information exchange, those transaction prices are not yet determined. The second feature is that the executives who are sharing prices may be able to influence transaction prices but do not have full control over them. This feature differs from the standard economic model of the firm, which has a single decision-maker choosing prices, but is consistent with actual practice. Generally, prices are the result of a process within a firm involving various employees with different responsibilities. As this second feature is crucial to the theory of harm, Section 3 reviews some of the evidence supporting it.

The way those two features are encompassed in the model of this paper is stylized but the insight it yields is intuitive and robust (in the sense that it only relies on some general assumptions). The sharing of prices by firms is captured with a two-stage structure. Firms first choose prices and then, after sharing those prices, can change the price at some cost. To relate this structure to the trucks case, suppose an executive chooses a list price. In

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[16] *Ibid*, para. 46, 51.

the absence of sharing list prices, a list price would lead to some final prices for purchasers according to the firm's internal pricing process. When executives of truck manufacturers share their list prices, knowledge of other manufacturers' list prices may induce an executive to intervene in the internal process by which the list price affects the final purchaser prices. However, such intervention is costly to the executive as other employees must be convinced of the price change or be incentivized to make it. That cost to changing price captures the limited ability of the executive to influence final prices. Though the structure is stylized, in that it subsumes the internal pricing process through an adjustment cost for price, it has the appealing feature that it is not dependent on a particular modeling of that internal pricing process.

The main finding is that a private information exchange of prices by competitors is harmful to consumers when the cost of adjusting price is neither too small nor too large which can be interpreted as the colluding executives having some but not full control over the final price. The intuition is as follows. When executives privately share prices, they are given the opportunity to effectively change the prices they will be offering to consumers before consumers have an opportunity to transact. However, this sharing of prices would be of no consequence when it is near costless to change prices. In that case, the information exchange is basically cheap talk so each executive would simply set the final price to maximize profits regardless of what was learned about rivals' prices from the information exchange.[17] Sharing of prices would also have no effect when it is very costly to change prices. For example, suppose executives share list prices and, after sharing them, each executive is either unable to change its list price or finds it very difficult to intervene in the process determining the discounts provided off of the list price. Again, the information exchange would have no effect. However, when the executive has some limited control - as reflected in a moderately-valued adjustment cost to price - sharing prices is anticompetitive. When they have an agreement to share prices, an executive will set a supracompetitive price because the executive knows that, should it be learned that other firms have set lower prices, they will have the opportunity and means to respond by lowering price. This anticipation that other firms would respond to a low price incentivizes executives to select and share supracompetitive prices.

As will become clear, the theory is an adaptation of a well-understood strategic pricing mechanism exemplified by most-favored-customer clauses. From a purely theoretical perspective, the paper's contribution is modest. From the practical perspective of understanding firm conduct (why do firms privately exchange prices?) and providing guidance for courts (how should it rule regarding an information exchange?), the paper's contribution is more significant.[18]

Section 2 discusses related research. Section 3 offers some evidence regarding company pricing processes which motivates the model. (A reader who would like to skip that material can read the final paragraph of Section 3 and determine if they accept the conclusions from the case studies.) Section 4 provides the simplest structure for establishing that a

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[17]Of course, express communication which is cheap talk can allow coordination on prices. That is the usual avenue for harm and is interpreted as firms discussing and agreeing on prices. Our analysis focuses on when firms are only sharing prices.

[18]As some evidence of its practical relevance, the working paper comprising this theory (Harrington, 2020) was influential and widely quoted in a recent decision by the Amsterdam District Court (12 May 2021) which concluded there was harm to final purchasers from the trucks cartel.

private information exchange of prices can be harmful to consumers. Section 5 shows that the conclusions from that simple model are general as the anticompetitive effect of sharing prices holds for the canonical price game with differentiated products. For the case when firms share list prices, Section 6 provides a more explicit model which links list prices to the prices paid by consumers. A discussion of the practical application of the theory of harm is offered in Section 7, and Section 8 concludes.

2   Literature Review

The model of this paper assumes firms make sequential price decisions and, due to a cost to adjusting price, the initial price constrains the final price. This strategic pricing mechanism was originally identified in most-favored-customer (MFC) clauses where the "initial" price is the price charged to customers in one period and the "final" price is the price charged to customers in a later period (Cooper, 1986; Salop, 1986). A MFC clause binds a firm to charging all of its customers the lowest price that any of its customers receive. Thus, if a firm's later price is lower than its earlier price, it must reimburse the difference to its earlier buyers. That is the "cost" to setting a lower "final" price. As described later, the cost of changing price in our model has a different structure from that in the MFC clause literature.

There is some related research assuming a two-stage pricing structure in which list prices are chosen in stage 1 and final prices (or, equivalently, discounts off of list price) in stage 2. In García Díaz, Hernán González, and Kujal (2009), the selection of prices in stage 2 is assumed to be costless, while it is costly in this paper's model and that cost is crucial to the results. There are also some papers, such as Raskovich (2007) and Gill and Thanassoulis (2016), examining how list prices with discounts for some buyers can be used for purposes of price discrimination.[19] Price discrimination is not present in this paper's model. Lubensky (2017) and Harrington and Ye (2019) consider list (or manufacturer recommended) prices as cheap talk signals of cost where transaction prices are retail prices and negotiated prices, respectively. List prices affect search which then impacts transaction prices. In contrast, the model here is one of complete information without search.

There are two papers that find firms privately sharing prices is procompetitive. Myatt and Ronayne (2019) considers a variant of the model in Varian (1980) with list and final prices. It is shown that an information exchange of list prices - so each firm know its rival's list price at the time it chooses its final price (which is its list price less the discount) - can lower average transaction prices. Though sharing list prices does benefit consumers, this theory is *not* an argument against prohibiting the private sharing of list prices. For if there was such a prohibition, the firms could avoid it by instead *publicly* sharing their list prices and the same procompetitive effect arises. Myatt and Ronayne (2019) then provide a rationale for allowing firms to publicly share list prices.

Andreu, Neven, and Piccolo (2020) considers a duopoly setting in which each firm comprises two levels: an upper division which is interested in maximizing the firm's profit, and a lower division which is interested in maximizing a weighted average of profit and output. The list price comes out of the upper division and, after learning the list price, the lower

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[19]In related work, Gill and Thanassoulis (2009) examine a quantity setting in which there is a posted price and discounts. However, firms do not choose the posted price; it is instead set by the Cournot auctioneer.

division decides on the discount to offer. Consumers do not observe list prices. When firms share their list prices - so a lower division knows its rival's list price when it chooses the discount - average discounts can be higher compared to the absence of such an information exchange. From this result, the authors conclude: "agreements according to which firms disclose list prices to their competitors should be presumed neither as anticompetitive nor as pro-competitive."[20] Undermining this conclusion is that the theory rests on some unorthodox and unrealistic modelling assumptions. First, it is assumed list prices are determined by an arbitrary stochastic process rather than being optimally selected by firms. Second, a consumer's purchasing decision depends on a firm's discount and not on the price that a consumer would actually pay which results in the counterfactual property that a firm with a *higher net price* would have *more demand* than its rival as long as the firm's discount is higher. For these reasons, the theory is probably not a sound basis for drawing conclusions about the effect of a private information exchange.

Finally, Janssen and Karamychev (2021) is closely related to the current paper, and is discussed at the end of Section 5.

3 Evidence on the Internal Pricing Process

Our approach is rooted in two implicit assumptions. First, the colluding executives have a large influence on the prices that they will be sharing. In our model, this will be approximated by assuming they have full control over them. Second, after sharing prices, those executives have limited influence when it comes to either changing the prices that were shared or influencing the internal pricing process that translates those prices (such as list prices) into the prices faced by consumers (which encompass any discounts off of the list price). In our model, this second assumption is modelled by assuming an executive can change the subsequent prices but only at a cost. This cost captures having to go outside of standard protocol - such as changing the list price which the firm had already decided upon - or exerting pressure on other employees who have more authority over the subsequent pricing process - such as sales managers who control discounts. Towards substantiating these claims about the internal pricing process, we draw on several case studies. While our theory does not exclusively pertain to when executives share list prices, that is the most likely application of it and industrial markets have been the focus of the studies we have been able to find. Consequently, our discussion will consider the internal process by which list prices and discounts are determined.

"Research indicates that the pricing of products is a costly and complex activity"[21] because it encompasses many employees from different parts of the organization who bring in different expertise and information.

> One approach that many companies find effective is to establish a multidisciplinary pricing council as a venue for offering input, discussing issues, and setting policies. Such a council, typically headed by the executive leading the pricing organization, may include representatives from different functions, geographies,

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[20]Quotation is from the abstract of Andreu, Neven, and Piccolo (2020).
[21]Hallberg (2017), p. 179.

business units, product lines, or any other stakeholder group that plays a significant role in pricing.[22]

Authority over the list price may reside at a high level where the marketing division plays an important role, while discounts are apt to be controlled by the sales division.

> The pricing activities were run by a vice president [and] the pricing director and the sales director worked for him. The pricing director managed the pricing manager and several pricing analysts who prepared the price list and reviewed pricing decisions in the field. The sales director managed the sales force ... As in many industrial settings, the firm used both list and negotiated prices, so the pricing process worked sequentially from marketing to sales. Pricing activities began with a price list, which was set annually ... The marketing group set list prices, standard discount structures, and procedures for handling exceptions. The sales group then negotiated discounts for individual bids.[23]

That this pricing process is costly in terms of resources is well documented. The following statement refers to the adjustment of price that occurs on a routine (e.g., annual) basis.

> The managerial costs of price adjustment increase with the size of the adjustment because the decision and internal communication costs are higher for larger price changes. First, the increased costs occur because more people are involved. ... Second, the increased costs occur because larger price changes lead to more internal discussions. ... Third, the increased cost occurs because larger price changes lead to more attention and controversy.[24]

The determination of a list price can take several months which means that an executive could find it difficult, though still possible, to change the list price. The executive may have the authority to do so but find it costly because it means going outside of standard protocol. Again, the reference in the ensuing passage is to the routine change in the list price.

> Changing the list price takes place over a period of several months. ... Once the list-price changes are determined, they must be communicated to the sales force. This requires group meetings with members of the pricing team, senior managers, territory managers, and the field sales force. ... The internal communication costs, therefore, involve the time and the effort for pricing managers need to spend informing the sales force about the motives behind the price change.[25]

Given the length of time to decide on a new list price and then inform and explain it to other company employees, it could be a costly task for an executive to subsequently change it.

If an executive believed that the firm's new list price was not competitive, an alternative to lowering the list price is to have larger discounts off of the list price. However, it could prove costly for the executive to make such a change when the standard operating procedure gives authority over discounts to other members of the organization.

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[22]Simonetto et al (2012), p. 845.

[23]Zbaracki and Bergen (2010), p. 958.

[24]Zbaracki et al (2004), p. 524.

[25]Zbaracki et al (2004), pp. 517, 519,

> [T]wo key dimensions of the organizational structure of pricing authority [are] the vertical delegation of authority over tactical pricing decisions within sales and the horizontal dispersion of authority over strategic pricing decisions across sales, marketing, and finance.[26]

> Three different set-ups regarding pricing authority were identified: (1) pricing authority held by a sales and marketing manager, (2) pricing authority held by key account managers or internal sale reps, and (3) pricing authority held by external sales reps.[27]

> [In our sample], 61% of the firms [gave] limited pricing authority to their salespeople. Here, salespeople are allowed to set prices within a pre-specified range. ... 11% [gave] their salespeople with full pricing authority. In these cases, salespeople are given the freedom to set any price above marginal cost.[28]

There are two takeaways from these case studies. First, list prices are determined by a lengthy process involving various employees. While it is quite plausible that a high-ranking executive would have a large influence on the list price, it would be difficult, though presumably possible, for them to later change the list price which emerged from that process. Second, the authority for setting discounts off of the list price often lies with employees who are distinct from those involved in the setting of list prices. It could then be difficult, though presumably possible, for a high-ranking executive to intervene in the setting of discounts.

4   Illustrative Model with Two Prices

This section offers the simplest model for conveying the mechanism by which an information exchange of prices is anticompetitive. The generality of the mechanism is established in the ensuing section where a modification of a standard oligopoly model is considered.

Consider a duopoly in which firms offer differentiated products and choose prices. $\pi_i(p_1, p_2)$ denotes the profit of firm $i \in \{1, 2\}$ where prices are (p_1, p_2). Departing from the standard formulation, p_i is to be interpreted as the price that is to be shared. If that price proves to be the price that consumers face then it is consistent with the standard formulation. However, p_i could instead be, say, a list price, and the price at which consumers transact may be that list price or something less due to the offering of discounts. In that case, $\pi_i(p_1, p_2)$ is to be interpreted as the profit that firm i expects to receive when firms' list prices are (p_1, p_2). Hence, $\pi_i(p_1, p_2)$ implicitly embeds the process by which a list price is translated into the price a consumer faces. A more foundational approach would explicitly model that process but, in doing so, generality would be lost because results would be tied to the particular specification of that process. In order to derive general results appropriate for drawing policy recommendations and judicial guidance, I have sought to derive results based on a minimal set of assumptions.

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[26]Homburg, Jensen, and Hahn (2012), p. 49

[27]Hallberg (2017), p. 185.

[28]Hansen, Joseph, and Krafft (2008), p. 95.

Suppose each firm has two possible prices, $\{L, H\}$, and $H > L$. The profit function is symmetric across firms:

$$\pi_1 \left(p', p'' \right) = \pi_2 \left(p'', p' \right), \ \forall \left(p', p'' \right) \in \{L, H\}^2.$$

The low price strictly dominates the high price:

$$\pi_1 \left(L, p_2 \right) > \pi_1 \left(H, p_2 \right), \ \forall p_2 \in \{L, H\},$$

but each firm earns higher profit when both price high compared to when both price low: $\pi_1 \left(H, H \right) > \pi_1 \left(L, L \right)$. Finally, the profit function has increasing differences:[29]

$$\pi_1 \left(H, H \right) - \pi_1 \left(L, H \right) > \pi_1 \left(H, L \right) - \pi_1 \left(L, L \right). \tag{1}$$

As each firm has a dominant strategy, the unique Nash equilibrium is for both firms to set a low price. That is the competitive outcome when there is no information exchange.

Let us now modify the game so that firms share prices. In the first stage, firms simultaneously choose *initial* prices, where the initial price for firm i is denoted $p_i^I \in \{L, H\}$. In the second stage, firms share their initial prices and then simultaneously choose *final* prices, denoted p_i^F for firm i. Consumers' transactions are based on the final price. If firms are sharing posted (retail) prices then the initial price is the posted price and the final price is the posted price less any discount or rebate. The interpretation is more subtle when firms are sharing list prices in a market where prices are negotiated. In that situation, the list price influences transaction prices but is not itself the transaction price. We can think of the initial price as the original list price selected by the firm. After executives share those list prices, an executive can choose to effectively change its list price where the final price selected in stage 2 is the new "effective" list price. This could mean literally changing the list price or, in situations where the executive is incapable of changing the list price, intervening in the internal pricing process that maps the list price to the price faced by a consumer so it is "as if" the list price equalled the final price.[30] Whether the executive is changing the list price or altering the process mapping the list price into the transaction price, it is assumed this price adjustment is costly to the executive. $k > 0$ is the cost incurred when the final price differs from the initial price. The implicit assumption is that the executive who largely determined the choice of the initial price does not have as much control over the subsequent pricing process but can influence it at a cost. This cost to changing the price is the critical departure from previous models and is motivated by the evidence reviewed in Section 3.

Firm 1's payoff function is

$$\begin{cases} \pi_1 \left(p_1^F, p_2^F \right) & \text{if } p_1^F = p_1^I \\[2mm] \pi_1 \left(p_1^F, p_2^F \right) - k & \text{if } p_1^F \neq p_1^I \end{cases}$$

[29] This property commonly holds for price games with differentiated products. See Chapter 6 in Vives (1999).

[30] In the context of surcharges, one could imagine price H corresponds to the addition of a surcharge (perhaps to some standard base price, as in the railroad case) and price L to when no surcharge is added. Having adopted a surcharge in stage 1, an executive could try to intervene in stage 2 by influencing the setting of the base price and thereby causing price to go from H to L. In this example, the final price is the price faced by consumers.

with firm 2's payoff function analogously defined. Gross profit $\pi_1\left(p_1^F, p_2^F\right)$ depends only on final prices, with net profit also depending on the adjustment cost when final prices differ from initial prices. This structure gives substance to the idea that, at the time that executives share prices, there is some level of commitment to those prices - as captured by the cost k to changing them - but the prices faced by consumers are not yet determined - in that the price which affects a firm's demand and profits can be changed.[31]

For the two-stage game, first note that it is a subgame perfect equilibrium (SPE) outcome for both firms to set low and final initial prices. Given low initial prices, it is strictly dominant for a firm to set a low final price. Turning to the initial stage and given firm 1 expects $p_2^I = L$, its payoff is $\pi_1\left(L, L\right)$ from $p_1^I = L$ and is $\max\left\{\pi_1\left(L, L\right) - k, \pi_1\left(H, L\right)\right\}$ from $p_1^I = H$, which is strictly lower. Thus, as in the case when initial prices are not shared, it is an equilibrium outcome for both firms to set low final prices.

Under certain conditions, it is also a SPE outcome for both firms to choose high initial prices. Consider the following symmetric strategy profile: i) $p_1^I = H$; ii) $p_1^F = H$ if $\left(p_1^I, p_2^I\right) = (H, H)$, and $p_1^F = L$ if $\left(p_1^I, p_2^I\right) \neq (H, H)$. Thus, a firm sets a high initial price and does not change it when both firms set high initial prices, but chooses a low final price otherwise (and, in particular, when the other firm chose a low initial price).

In establishing conditions whereby this strategy pair is a SPE, consider the four possible stage 2 subgames.

1. $\left(p_1^I, p_2^I\right) = (H, H)$. $\left(p_1^F, p_2^F\right) = (H, H)$ is a stage 2 Nash equilibrium (NE) if and only if (iff) $\pi_1\left(H, H\right) \geq \pi_1\left(L, H\right) - k$ which, after rearranging, is $k \geq \pi_1\left(L, H\right) - \pi_1\left(H, H\right)$.

2. $\left(p_1^I, p_2^I\right) = (L, H)$. Given $\left(p_1^F, p_2^F\right) = (L, L)$, firm 1's price is trivially optimal and firm 2's price is optimal iff $\pi_2(L, L) - k \geq \pi_2(L, H)$ or $\pi_2(L, L) - \pi_2(L, H) \geq k$. By symmetry, this condition is equivalent to $\pi_1(L, L) - \pi_1(H, L) \geq k$. The analysis is the same when $\left(p_1^I, p_2^I\right) = (H, L)$.

3. $\left(p_1^I, p_2^I\right) = (L, L)$. $\left(p_1^F, p_2^F\right) = (L, L)$ is trivially a NE.

Combining the conditions in cases #1 and #2, the strategy projection is a NE for all subgames iff:

$$\pi_1\left(L, H\right) - \pi_1\left(H, H\right) \leq k \leq \pi_1\left(L, L\right) - \pi_1\left(H, L\right). \tag{2}$$

Re-arranging (1), one can see that the right-hand side expression of (2) strictly exceeds the left-hand side expression and, furthermore, the left-hand side expression is strictly positive. Hence, there is a set of values for k such that (2) is satisfied.

Turning to stage 1, given $p_2^I = H$, $p_1^I = H$ yields firm 1 a payoff of $\pi_1\left(H, H\right)$ and $p_1^I = L$ yields a payoff of $\pi_1\left(L, L\right)$. Thus, $p_1^I = H$ is optimal because $\pi_1\left(H, H\right) > \pi_1\left(L, L\right)$. By symmetry, it applies as well to firm 2. We conclude that if k satisfies (2) then the strategy pair is a SPE.

Summarizing, both firms choosing a low initial and final price is always a SPE outcome. If k is moderate in value, so that (2) is satisfied, then it is also a SPE outcome for both

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[31] As we are modelling the incentives of the executive, this payoff specification is appropriate if the executive's compensation is proportional to profits.

firms to choose a high initial and final price.[32] What sustains an outcome of high prices is that a firm which instead charges a low initial price expects the other firm to reduce its price in stage 2 to match it. Matching the lower price is optimal as long as the cost of adjusting price is sufficiently low: $k < \pi_1(L, L) - \pi_1(H, L)$. However, this raises the possibility that, should both firms set high initial prices, a firm may find it optimal to undercut its rival with a low final price. That will not be profitable as long as the cost of adjusting price is sufficiently high: $k > \pi_1(L, H) - \pi_1(H, H)$. As, by increasing differences, $\pi_1(L, L) - \pi_1(H, L) > \pi_1(L, H) - \pi_1(H, H)$, it is then more profitable to match a rival's low price than to undercut a rival's high price. If the cost of adjusting price is neither too high nor too low then high prices are consistent with equilibrium. If k is too high then a firm with a high initial price would not lower its final price in response to its rival having a low initial price, in which case firms would initially set a low initial price. If k is too low then, when both firms have set high initial prices, a firm would find it optimal to set a low final price and undercut its rival's price. In anticipation, firms would set low initial prices.

When there are two equilibria, a slight modification of the game allows us to use forward induction and weak dominance to select the equilibrium with high prices. Append the two-stage game with a stage 0 in which firms simultaneously decide whether or not to propose sharing prices. If one or both firms choose *do not share prices* then the ensuing game is the one-stage game in which they choose prices and realize profits. If both choose *share prices* then the ensuing game is the two-stage game in which they choose initial prices and then, after having shared those prices, decide on their final prices. Assume each firm incurs a small cost $z > 0$ when both choose *share prices*, perhaps due to possible litigation.[33]

By choosing *do not share prices*, firm i expects to earn $\pi_i(L, L)$ because firms will be engaging in the one-stage game. If a firm chose *share prices* and anticipates that (L, L) would ensue - either because it expects the other firm to choose *do not share prices* or to choose *share prices* and then price at L - then its payoff is $\pi_i(L, L) - z$ which is less than when it chooses *do not share prices*. If it instead anticipates the other firm choosing *share prices* and then pricing at H, it expects to earn $\pi_i(H, H) - z$ which exceeds $\pi_i(L, L)$ (due to z being small). Hence, by forward induction, firm j can infer from firm i having chosen *share prices* that firm i will price at H in the event that firm j also chose *share prices*. Of course, *do not share prices* is (weakly) optimal if a firm expects the other firm to choose *do not share prices*. More specifically, a SPE outcome for this three-stage game is *do not share prices* and price at L. However, action *share prices* weakly dominates action *do not share prices*. By choosing *share prices*, a firm earns $\pi_i(H, H) - z$ when the other firm chooses *share prices* and earns $\pi_i(L, L)$ when the other firm chooses *do not share prices*, while by choosing *do not share prices*, it earns $\pi_i(L, L)$ whether the other firm chooses *share prices* or *do not share prices*. We conclude that, when they have the opportunity to share prices, firms will do so and subsequently set high prices.

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[32]It can also be shown that there are no other SPE outcomes.

[33]All that is required for the forward induction argument is $0 < z < \pi_i(H, H) - \pi_i(L, L)$.

5 General Model and Analysis

The theory of harm derived in the previous section tells the following story. Executives of competing companies are sharing prices such as list prices or surcharges. Such prices influence the prices that consumers pay. After conducting the information exchange, it is costly but feasible for an executive to either change the price that was shared or to change how that price determines the prices faced by consumers. Due to the anticipation of sharing prices and that rival firms are able, to some limited extent, to respond to the prices that are shared, firms are incentivized to choose supracompetitive prices and, consequently, consumer pay supracompetitive prices. Having shown such an information exchange is anticompetitive for the simple case when there are just two prices, I now extend it to the canonical price-setting duopoly game with differentiated products. Proofs are in the Appendix.

5.1 Firms Do Not Share Prices

Consider a standard symmetric duopoly setting in which firms choose prices and have differentiated products. Firm i's profit function is $\pi_i(p_1, p_2) : [0, \overline{p}]^2 \to \Re_+$ where $\overline{p}$ is sufficiently great so as not to constrain equilibrium prices. $\pi_i(p_1, p_2)$ is assumed to be twice continuously differentiable, strictly concave in p_i, increasing in p_j, increasing differences in (p_1, p_2), and the marginal effect of own price is more sensitive to own price than to the rival's price:

$$\frac{\partial^2 \pi_i(p_1, p_2)}{\partial p_i^2} < 0 < \frac{\partial^2 \pi_i(p_1, p_2)}{\partial p_i \partial p_j} < \left| \frac{\partial^2 \pi_i(p_1, p_2)}{\partial p_i^2} \right|.$$

A firm's best response function is represented by $\psi_i(p_j)$ and is increasing when it delivers an interior optimum:

$$\psi_i'(p_j) = -\frac{\partial^2 \pi_i / \partial p_i \partial p_j}{\partial^2 \pi_i / \partial p_i^2} \in (0, 1).$$

Since $(\psi_1(p_2), \psi_2(p_1)) : [0, \overline{p}]^2 \to [0, \overline{p}]^2$ is a contraction mapping, there is a unique (symmetric) fixed point: $p^N = \psi_i(p^N)$.

The standard model represents the case when firms do not share prices. Thus, $\pi_i(p_1, p_2)$ is the profit that firm i can expect to earn when prices are (p_1, p_2). For example, suppose these are list prices (or base prices possibly with a surcharge). Then, in the absence of sharing prices, each firm will choose a list price of p^N, and consumers will pay the transaction prices that are the consequence of a list price of p^N. While the properties assumed on $\pi_i(p_1, p_2)$ are standard ones, those assumptions are typically made presuming prices are transaction prices. It is not immediate that they should hold when, say, prices are list prices for then π_i embeds an unspecified relationship between list and transaction prices. In order to address this issue, I could have developed a specific structure for how list and transaction prices are connected. However, rather than be tied to a particular specification, I've chosen this more general but reduced form approach. In Section 6, a model is provided which explicitly makes the connection between list and transaction prices, and I show that the assumptions made on $\pi_i(p_1, p_2)$ are satisfied.

5.2 Firms Share Prices

As in Section 4, the extensive form has two stages. In stage 1, firms simultaneously choose initial prices, where recall p_i^I is firm i's initial price. In stage 2, initial prices are shared, and firms can, at some cost, have its final price, p_i^F, be below its initial price, $p_i^F \leq p_i^I$.[34] It is assumed that the cost of lowering price is a linear function of the extent of the price reduction, and is represented by $g\left(p_i^I - p_i^F\right)$ where $g > 0$.[35] Thus, the firm's payoff is $\pi_i\left(p_1^F, p_2^F\right) - g\left(p_i^I - p_i^F\right)$.[36]

To solve for the subgame perfect equilibria of this two-stage game, we begin by analyzing the stage 2 game. Given initial prices $\left(p_1^I, p_2^I\right)$ from stage 1, firm 1's stage 2 problem is:

$$\max_{p_1^F} \pi_1\left(p_1^F, p_2^F\right) - g\left(p_1^I - p_1^F\right) \text{ subject to } p_1^F \leq p_1^I.$$

Consider firm 1's optimal stage 2 price when the constraint $p_1^F \leq p_1^I$ is not binding. The associated best response function, $\phi_1(\cdot)$, is defined by the first-order condition:

$$\frac{\partial \pi_1\left(\phi_1(p_2^F), p_2^F\right)}{\partial p_1} + g = 0.$$

Note that

$$\phi_i'(p_j) = -\frac{\partial^2 \pi_i / \partial p_i \partial p_j}{\partial^2 \pi_i / \partial p_i^2} \in (0, 1).$$

Let p^* denote the symmetric Nash equilibrium price when both firms' constraints are not binding, $p^* = \phi_1(p^*)$, or

$$\frac{\partial \pi_1\left(p^*, p^*\right)}{\partial p_1} + g = 0. \tag{3}$$

Totally differentiating (3) with respect to the price adjustment parameter, we find

$$\frac{\partial p^*}{\partial g} = -\left(\frac{\partial^2 \pi_1\left(p^*, p^*\right)}{\partial p_1^2} + \frac{\partial^2 \pi_1\left(p^*, p^*\right)}{\partial p_1 \partial p_2}\right)^{-1} > 0.$$

Thus, p^* is higher when the cost of adjusting price is higher. Since $g = 0$ implies $p^* = p^N$, it follows that $p^* > p^N$ when $g > 0$.

Figure 1 depicts the best response function without the price adjustment cost, $\psi_i(p_j)$, and when the price adjustment cost is present and operative, $\phi_i(p_j)$. The latter is just a shifting

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[34]I assume the final price cannot exceed the initial price so that the model applies to settings in which the initial price is a posted price which, in practice, is an upper bound on the price that consumers face; the transaction price can be lowered through discounts and rebates but cannot be raised. At the end of this section, it is explained that our main result is robust to allowing the final price exceed the initial price.

[35]At the end of this section, we argue that linearity is not necessary, though it does simplify the analysis.

[36]To relate this structure to the MFC clause literature, let p_1^I (p_1^F) represent the period 1 (2) price. According to a MFC clause, if firm 1 lowers its price in period 2 then all those consumers who bought in period 1 are reimbursed the difference. Hence, the cost to firm 1 from lowering its price is $D_1\left(p_1^I, p_2^I\right)\left(p_1^I - p_1^F\right)$ where $D_1\left(p_1^I, p_2^I\right)$ is firm 1's period 1 demand. In our setting, the cost is instead $g\left(p_1^I - p_1^F\right)$. The difference in functional form does require working out the paper's main results and there are some new findings related to the parameter g.

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out of $\psi_i(p_j)$. Also depicted are the one-stage Nash equilibrium p^N, and the equilibrium price p^* when firms are incurring the price adjustment cost at a final price of p^*.

With that benchmark, we can solve the stage 2 game. The stage 2 best response function is defined by:

$$\phi_1^F\left(p_2^F, p_1^I\right) \equiv \arg\max_{p_1^F} \pi_1\left(p_1^F, p_2^F\right) - g\left(p_1^I - p_1^F\right) \text{ subject to } p_1^F \leq p_1^I$$

which, by strict concavity of $\pi_1\left(p_1^F, p_2^F\right) - g\left(p_1^I - p_1^F\right)$, takes the form:

$$\phi_1^F\left(p_2^F, p_1^I\right) = \min\left\{\phi_1(p_2^F), p_1^I\right\}.$$

$\left(\phi_1^F\left(p_2^F, p_1^I\right), \phi_1^F\left(p_1^F, p_2^I\right)\right) : \left[0, p_1^I\right] \times \left[0, p_2^I\right] \to \left[0, p_1^I\right] \times \left[0, p_2^I\right]$ is a contraction mapping and thus has a unique fixed point.

Figure 1: Best Response Functions with and without Price Adjustment Cost
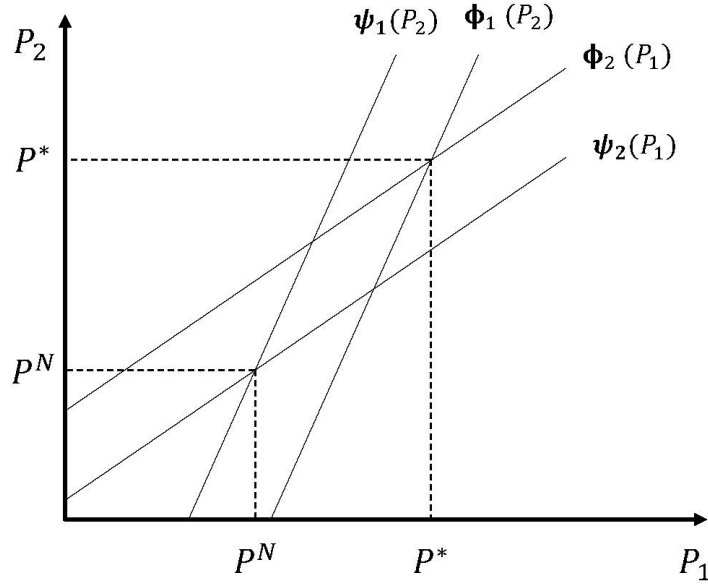
Lemma 1 shows that a property of subgame perfect equilibrium (SPE) is that a firm's initial and final prices are equal. This is not surprising given that a firm can anticipate what initial price a rival firm will charge.

Lemma 1 *A necessary condition for a SPE outcome is:* $\left(p_1^F, p_2^F\right) = \left(p_1^I, p_2^I\right).$

The first result is that the two-stage game always has a SPE in which firms price at p^N. Thus, sharing prices need not affect firms' prices.

Theorem 2 $\left(p_1^I, p_2^I\right) = \left(p_1^F, p_2^F\right) = \left(p^N, p^N\right)$ *is a SPE outcome for the two-stage game.*

The next theorem is the main result. It provides sufficient conditions for it to be a SPE outcome for firms to price at p^*.[37]

Theorem 3 *If*

$$\frac{d^2\pi_1\left(p_1,\phi_2\left(p_1\right)\right)}{dp_1^2} < 0 \ \forall \left(p_1,p_2\right) \tag{4}$$

then $\exists \overline{g} > 0$ *such that if* $g \in (0,\overline{g}]$ *then* $\left(p_1^I, p_2^I\right) = \left(p_1^F, p_2^F\right) = \left(p^*, p^*\right)$ *is a SPE outcome for the two-stage game where* $p^* > p^N$.

If there is strict concavity of $\pi_1\left(p_1, \phi_2\left(p_1\right)\right)$ (note that it takes into account how a firm's initial price affects the rival firm's final price) then sharing of prices can result in higher prices when it is not too costly to adjust prices (g is not too high). In Section 6, (4) is shown to hold for a version of the standard duopoly model with linear demand and cost functions.

Let us explain the proof of Theorem 3 and thereby convey the intuition behind why higher prices emerge in the two-stage structure. Begin by considering the situation faced by firms in stage 2 given their initial prices are p^*. Putting aside any price adjustment cost, p^* exceeds a firm's best response to its rival pricing at p^*: $\psi_i(p^*) > p^*$ (see Figure 1). Hence, a firm may be inclined to set its final price below its initial price of p^*. By the construction of p^*, the marginal profit gain from setting its final price below p^*, $\partial\pi_1\left(p^*, p^*\right)/\partial p_1$, equals the marginal cost of adjusting price, g; see (3). Thus, given the rival's final price is p^*, it is optimal for a firm to have its final price at its initial price of p^*. Now consider the situation faced in stage 1. Given the rival's initial price is p^*, the marginal profit from firm 1 changing its initial price is:

$$\frac{d\pi_1\left(p^*, p^*\right)}{dp_1^I} = \frac{\partial\pi_1\left(p^*, p^*\right)}{\partial p_1} + \left(\frac{\partial\pi_1\left(p^*, p^*\right)}{\partial p_2}\right)\left(\frac{\partial\phi_2\left(p^*\right)}{\partial p_1}\right). \tag{5}$$

The first term is negative (because lowering price raises profits holding fixed firm 2's price) and the second term is positive (because lowering the initial price causes firm 2 to lower its final price which then reduces firm 1's profit). The second term captures the ability of a rival firm to respond to a firm having set and shared a low price. Given that the first term equals $-g$ by (3) and the second term is bounded above zero, (5) is positive as long g is sufficiently small. Hence, a firm's profit would decline by marginally lowering its initial price from p^* because of how its rival will react. (4) ensures that this local disincentive to lower price applies globally.

We conclude this section with four remarks. First, as argued in Section 4, forward induction and weak dominance can be used to select the SPE with price p^*. Second, Theorem 3 is robust to allowing the final price to exceed the initial price. With both firms having set the initial price above p^N, each firm's initial price exceeds its best response to the other firm's initial price (putting aside the cost of changing price). Thus, in stage 2, there is no incentive to raise price, only to possibly lower it. It follows that a firm will not want to set its final price above its initial price. What may not be robust is Theorem 2. If a firm can set its final price above its initial price, a firm may want its initial price to exceed p^N,

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[37]In the Online Appendix, it is shown that there are no other SPE outcomes.

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given its rival's initial price is p^N, in order to induce its rival to raise its final price in stage 2 (according to the usual price leader logic). The key takeaway is that the anticompetitiveness of sharing prices is robust to allowing the executive to either raise or lower price after the information exchange.

Third, the linearity of the price adjustment cost function is not essential for Theorem 3. In equilibrium, price is not adjusted so what matters is the marginal cost of adjusting price at a price change of zero. Consider a general price cost adjustment function $\rho\left(p_i^I - p_i^F\right)$: $\Re_+ \to \Re_+$ which is differentiable and increasing. As long as second-order conditions are satisfied, results are expected to go through by replacing g with $\rho'(0)$. The critical property is not linearity but rather that the marginal cost of adjusting price at a price change of zero is positive: $\rho'(0) > 0$.

The final remark explains the difference between Theorem 3 and the finding of Section 4. When a firm could only choose from two prices, it was shown there is an equilibrium with high prices if and only if the cost of adjusting price is neither too small nor too large. That result differs from Theorem 3 which only requires the adjustment cost is not too large. In the two-price model, if the adjustment cost was small then a firm finds it profitable to set a low final price after having set a high initial price, which undermines having high equilibrium prices. Given a fixed gain in profit from setting a final price below the initial price, it becomes profitable to do so when the adjustment cost is small enough. By comparison, in the many-price model of this section, the equilibrium initial price declines as the adjustment cost is reduced. As a result, the additional profit earned from lowering price in stage 2 is lessened, which compensates for the lower adjustment cost, and thus makes it unprofitable to set the final price below the initial price. Still, as in the two-price setting, the harm from sharing prices is greatest when the adjustment cost is moderate. When it is high, prices are unaffected. When it is low, prices are higher but the amount is small (as equilibrium prices are close to competitive prices when g is close to zero).

In concluding this section, let me offer a comparison with Janssen and Karamychev (2021) which was produced subsequent to this paper. It has a similar two-stage duopoly structure though with two different modelling choices. First, a firm commits to a range of prices in the first stage (rather than a single price) and there is a cost to the stage 2 price being outside of the stage 1 range. Second, the adjustment cost function is allowed to have a fixed component as well as a variable component. These changes prove secondary because the symmetric equilibrium of Theorem 3 is also present in that model. Where the analysis differs is that they also characterize an asymmetric equilibrium in which only one firm shares price and the other firm best responds in the second stage. Prices are also higher with that equilibrium compared to when there is no information exchange. While the asymmetric equilibrium is interesting, it strikes me as counterfactual in that there is not evidence of only some firms sharing prices. For example, it appears all firms shared list prices in the EU trucks case. Furthermore, when the model is generalized to the case of n firms, the asymmetric equilibrium has all but one firm sharing prices (with the final firm best responding). Thus, when the number of firms is not small, the asymmetric equilibrium is not that different from the symmetric equilibrium.

6 Analysis with List and Transaction Prices

In this section, we consider a simple model that presumes the initial and final prices are list prices, and specify how list prices are related to the prices paid by consumers. It is shown that the conditions associated with Theorem 3 are satisfied.

Suppose there are multiple submarkets which can vary in terms of their demand and the amount of discount off of the list price. Given list price p_i^L for firm i, $\lambda^h\left(p_i^L\right)$ is the net price that firm i charges in submarket $h \in \{1, ..., H\}$, so $p_i^L - \lambda^h\left(p_i^L\right)$ is the discount. For example, one submarket comprises small buyers who pay list price and another submarket comprises large buyers who receive a discount. For the executives who are choosing the list price, suppose they treat $\lambda^h\left(\cdot\right)$ as exogenous because other individuals in the organization control discounts. Assume λ^h is twice continuously differentiable, $\lambda^h \in (0,1]$, and $\partial\lambda^h/\partial p_i^L > 0$. Symmetry is maintained in that λ^h is common to both firms.

Assume submarket demand is linear, so firm i's demand in submarket h is

$$a^h - b^h \lambda^h\left(p_i^L\right) + e^h \lambda^h\left(p_j^L\right),$$

and $0 < e^h < b^h$. Firm i's profit function is:

$$\pi_i\left(p_1^L, p_2^L\right) = \sum_{h=1}^{H}\left(a^h - b^h \lambda^h\left(p_i^L\right) + e^h \lambda^h\left(p_j^L\right)\right)\left(\lambda^h\left(p_i^L\right) - c\right).$$

In the Online Appendix, it is shown that the assumptions imposed on the profit function in Section 4 hold when $\partial^2\lambda^h/\partial\left(p_i^L\right)^2$ is small enough. To further simplify the analysis, assume the discount schedules are linear: $\lambda^h\left(p_i^L\right) = \lambda^h p_i^L$, $i \in \{1,2\}$. In the Online Appendix, it is shown that (4) in Theorem 3 holds. Thus, our main findings hold for this model.

With this additional structure, we can engage in some further analysis. It is straightforward to derive:

$$p^N = \frac{\displaystyle\sum_{h=1}^{H}\left(a^h + b^h c\right)\lambda^h}{\displaystyle\sum_{h=1}^{H} 2b^h\left(\lambda^h\right)^2 - \sum_{h=1}^{H} e^h\left(\lambda^h\right)^2}, \quad p^* = \frac{g + \displaystyle\sum_{h=1}^{H}\left(a^h + b^h c\right)\lambda^h}{\displaystyle\sum_{h=1}^{H} 2b^h\left(\lambda^h\right)^2 - \sum_{h=1}^{H} e^h\left(\lambda^h\right)^2}.$$

Assume the submarkets are identical, $b^h = b, e^h = e \; \forall h$. Note that $e \in [0, b]$ where $e = 0$ when products are independent and $e = b$ when products are homogeneous. Recalling that $\overline{g}$ is the maximal value for the price adjustment cost parameter such that an equilibrium with p^* exists, it can be shown:

$$\overline{g} = \left(\sum_{h=1}^{H}\lambda^h\right)\left(\frac{e^2(a - (b-e)c)}{4b^2 - 2be - e^2}\right).$$

Given p^* is increasing in g, an upper bound on the anticompetitive distortion in list prices

due to the information exchange is measured by $p^*(g = \bar{g})/p^N$.

$$\frac{p^*(g = \bar{g})}{p^N} = \frac{\bar{g} + (a + bc)\sum_{h=1}^{H} \lambda^h}{(a + bc)\sum_{h=1}^{H} \lambda^h} = \frac{(2b - e)\left(2cb^2 + 2ab - ce^2\right)}{(a + bc)\left(4b^2 - 2be - e^2\right)}.$$

The overcharge $(p^*(g = \bar{g})/p^N)$ is increasing in e, which is shown in Figure 2 for when $a = 100, b = 1, c = 10$. As products become more substitutable, the distortion rises and at an increasing rate. When $e = b$, $p^*(g = \bar{g})/p^N = 2$. Thus, the price distortion is bounded above by 100%.[38]

Figure 2: List Price Overcharge from Information Exchange
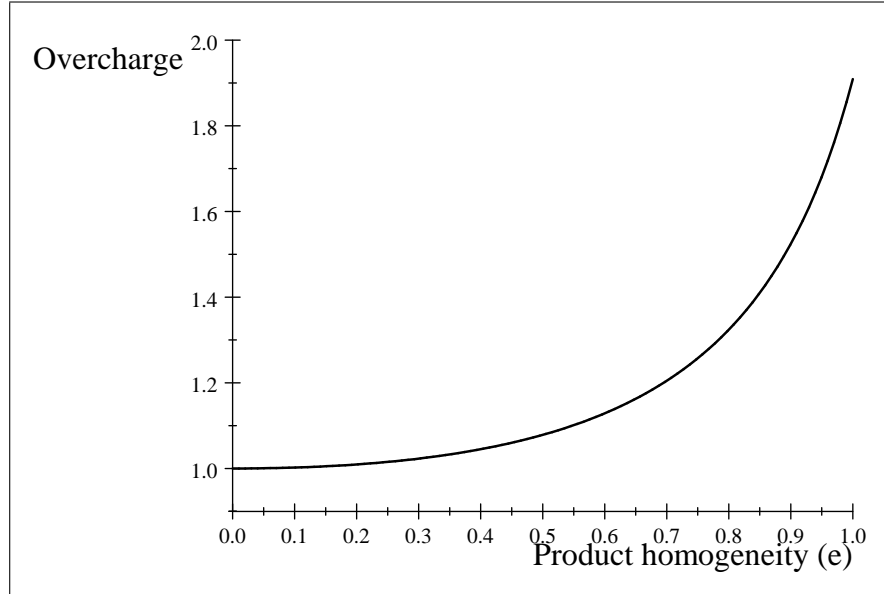
7   Discussion

Rather than modelling a firm's internal pricing process, the approach of this paper has been to represent it as a cost faced by the colluding executive to changing the price that was shared or to intervening in the subsequent stages of the pricing process in order to influence how the shared price affects final transaction prices. The approach's appeal is its parsimony and generality for it is not limited to any particular internal pricing process. It does come with some limitations, however, which are discussed here.

An advantage to getting into the black box of that adjustment cost is that an explicit model of the internal pricing process could identify additional relationships and implications. For example, the implicit assumption in the model is that a firm's final price is determined by, for example, its list price. However, it could be the case that the final price is also affected

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[38]To be clear, this is the distortion in list prices. The distortion in transaction prices depends on the mapping between list prices and transaction prices.

by the rival firm's list price. For suppose the colluding executive chooses the list price and a sales representative chooses the discount for a particular customer. A sales representative might offer a higher discount when the rival firm's list price is lower. Thus, in response to sharing list prices, a colluding executive that learns its rival's list price is low could expect their sales representative to offer a higher discount though it could still be the case that the executive might want to engage in the costly process of lowering the firm's list price in order to remain competitive. There may then be a richer set of predictions from modelling the internal pricing process.

A second limitation comes from how the main deliverable of the paper is stated: A private sharing of prices is anticompetitive when the cost of adjusting price faced by a colluding executive is neither too low nor too high. It is not clear what exactly "too low" or "too high" means in terms of observables. Towards shedding light on that issue, let me offer some thoughts for operationalizing this theory of harm.

Consider a situation in which firms' employees are sharing prices that are not final prices. This exchange is occurring through private communications or semi-privately at, say, trade association meetings which are not regularly attended by buyers; hence, we can confidently dismiss informing buyers as the reason for the information exchange. There are three steps associated with determining the relevance of the theory of harm put forth here.

- Step 1: Document and describe firms' internal pricing processes. What are the stages of that process and the associated prices determined at those stages? Which individuals in the firm are involved in each stage? What is the procedure used to make a decision at each stage? How long does this process take to finally yield transaction prices?

- Step 2: Locate the colluding employees and shared prices in that process. Which stage(s) are those employees involved in setting prices? Which price is shared between competitors?

- Step 3: Evaluate the control and influence of the colluding employees in that process. At the stage where the shared price is determined, does the employee have full control? is s/he a member of a committee? is s/he the senior manager on that committee? Is the employee routinely involved in the stages subsequent to where the share price is set? How complex are those stages in terms of the data and methods used?

With that framework in mind, let me put forth some general scenarios that would correspond to the adjustment cost being moderate (so the information exchange is harmful) or low or high (so it is not).

If the colluding employees fully or near-fully control both the shared price (e.g., list price) and the price faced by buyers (e.g., list price less a discount) then the adjustment cost is low in which case the theory of harm would not be applicable. If the firms are small with all pricing decisions at one level, one employee is likely to have significant control over the entire pricing process. In that case, the information exchange may be part of more standard collusive practices. If colluding employees are sharing list prices or surcharges and they can easily change them after the information exchange, it is possible the shared prices are

actually just proposed prices and the communication may be intended for firms to coordinate on the levels of those list prices or surcharges.[39]

Suppose the internal pricing process is complex, technical, and regimented. In that case, it could be difficult for a high-level executive, who might have significant influence in setting a list price or adding a surcharge, to intervene in later stages when they are not typically engaged in that protocol. For example, suppose prices are set according to an algorithm as occurs in airlines and many online retailers. A colluding executive may be able to adopt a surcharge but could find it difficult to intervene in the subsequent pricing process if it means changing a pricing algorithm that is typically controlled by pricing managers with technical expertise. This situation corresponds to when the adjustment cost is high so again the theory of harm is not applicable. The sharing of list prices or surcharges in that setting could be occurring as part of a standard collusive arrangement in which the information exchange is the monitoring of previously agreed-upon list prices or surcharges but where documentation of communications associated with that agreement are absent.

Finally, let us consider a set of conditions for which the theory of harm is relevant. Suppose the colluding employee is the senior manager on a committee that is setting the shared price. Thus, the employee is likely to have considerable influence in setting that price. However, later changing price requires reconvening the committee and that could be costly and require justification which would mean using reputational capital. Next suppose the shared price is part of a pricing process that spans multiple divisions - e.g., senior management and sales - where pricing authority over different prices is delegated over those divisions. If the senior manager has authority over the manager in charge of the sales division, they could in principle intervene in the pricing process at the sales division though it would mean overruling the sales manager. Intervention is possible but outside of the standard protocol. We then have an internal pricing process in which the colluding employee has considerable control over the shared price but it is difficult, though feasible, for them to change that shared price or intervene in the subsequent stages of the pricing process. This is a scenario for which the theory of harm would be applicable.

8   Concluding Remarks

For courts to be convinced that a private information exchange of prices is anticompetitive, there needs to be a general and intuitive narrative. I believe such a narrative is offered here. The private sharing of prices by competitors gives each firm an opportunity to lower its price should it learn that its rival's price is relatively low. In anticipation of the information exchange and such a possible response by rival firms, a firm is incentivized to set and share a supracompetitive price, which could be in the form of a high list price or the addition of a surcharge. Notably, it is the information exchange agreement that creates harm for it is the anticipation of sharing prices that induces firms to initially set higher prices. While there is no agreement on prices, there is an agreement to share prices and there lies the unlawful agreement.

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[39]In that case, the theory of harm in Harrington and Ye (2019) is relevant for it has firms coordinating list prices.

For economists to be convinced that a private information exchange of prices is anticompetitive, there needs to be a well-grounded rigorous theory which produces that narrative. The theory put forth rests on two key assumptions: 1) it is possible but costly for a colluding executive to change the firm's prices after prices have been shared with competitors; and 2) the increasing difference property of price games with differentiated products. The latter assumption delivers the property that a firm finds it more profitable to lower its price in order to be competitive with a rival's low price than it is to lower its price in order to undercut a rival's high price. The former assumption provides some level of commitment to the prices that are shared but not so much that a firm is locked into that price. As a result of these two assumptions, firms can independently set supracompetitive prices and, upon sharing them, each firm find it optimal to maintain that supracompetitive price as long as rival firms have priced at a supracompetitive level but, should a rival firm have set a lower price, it is optimal to respond by decreasing price.

Though supracompetitive prices emerge without repeated interaction (as in the MFC clause literature), repetition may be required to induce truthful sharing of information, for there could be an incentive for a firm to misreport its price at the information exchange. However, as long as the true price is revealed in a timely manner and firms interact sufficiently frequently, the usual argument of repeated games can be applied to incentivize firms to truthfully report their prices. While, by the theory of this paper, supracompetitive prices do not arise if the information exchange is cheap talk (i.e., it is costless for an executive to change price), such an information exchange is still harmful and unlawful by the usual argument that firms discussing prices is the basis for them coordinating their prices. The theory we offer is a complement to that standard argument for condemning communications among firms about their prices.

9 Appendix

Proof of Lemma 1.   Contrary to the lemma, suppose $p_1^F < p_1^I$ and $p_2^F \leq p_2^I$. As these are stage 2 NE prices, it follows that $p_1^F = \phi_1\left(p_2^F\right)\left(< p_1^I\right)$. Consider firm 1 choosing a slightly lower stage 1 price, $p_1^I - \varepsilon$, so that its stage 2 pricing constraint still does not bind: $\phi_1\left(p_2^F\right) < p_1^I - \varepsilon$. Hence, the stage 2 NE prices are unchanged: firm 1 prices at $\phi_1\left(p_2^F\right)$ and firm 2 prices at p_2^F. Given that firm 1's payoff has increased by the reduction in adjustment costs, $g\left(p_1^I - \phi_1\left(p_2^F\right)\right) - g\left(p_1^I - \varepsilon - \phi_1\left(p_2^F\right)\right) = g\varepsilon$, we have a contradiction that the original stage 1 prices were equilibrium prices. ∎

Proof of Theorem 2.   Consider a symmetric strategy profile in which a firm prices at p^N in stage 1. If both firms price at p^N in stage 1, it is immediate that the unique stage 2 Nash equilibrium is for both to price at p^N in stage 2. That is because p^N is a firm's best response to p^N when it is unconstrained and faces no price adjustment costs. Thus, it is also the best response when the constraint is not binding $(p^N \leq p_i^I)$ and there are price adjustment costs from setting a price below p^N. Thus, if $\left(p_1^I, p_2^I\right) = \left(p^N, p^N\right)$ then firm 1 expects profit of $\pi_1\left(p^N, p^N\right)$. The only way in which firm 1's payoff could rise with $p_1^I \neq p^N$ is if it caused firm 2 to raise its stage 2 price. However, that is not possible as firm 2 is pricing in stage 2 at the highest feasible level given $p_2^I = p^N$. Thus, $p_1^I = p^N$ is the unique best reply to $p_2^I = p^N$.
∎

Proof of Theorem 3.   First note:

$$\frac{d^2 \pi_1\left(p_1^I, \phi_2\left(p_1^I\right)\right)}{d\left(p_1^I\right)^2}$$

$$= \frac{\partial^2 \pi_1\left(p_1^I, \phi_2\left(p_1^I\right)\right)}{\partial p_1^2} + 2\left(\frac{\partial^2 \pi_1\left(p_1^I, \phi_2\left(p_1^I\right)\right)}{\partial p_1 \partial p_2}\right)\left(\frac{\partial \phi_2\left(p_1^I\right)}{\partial p_1}\right)$$

$$+ \left(\frac{\partial^2 \pi_1\left(p_1^I, \phi_2\left(p_1^I\right)\right)}{\partial p_2^2}\right)\left(\frac{\partial \phi_2\left(p_1^I\right)}{\partial p_1}\right)^2 + \left(\frac{\partial \pi_1\left(p_1^I, \phi_2\left(p_1^I\right)\right)}{\partial p_2}\right)\left(\frac{\partial^2 \phi_2\left(p_1^I\right)}{\partial p_1^2}\right)$$

Towards proving the theorem, we'll need the following partial characterization of Nash equilibria for the stage 2 game. First note that, when $p^* \leq p_1^I$ and $p^* \leq p_2^I$, it is immediate that the unique stage 2 NE is $\left(p_1^F, p_2^F\right) = (p^*, p^*)$. Next we claim that if $p_i^I < p^* \leq p_j^I$ then the unique stage 2 NE is $\left(p_i^F, p_j^F\right) = \left(p_i^I, \phi_j\left(p_i^I\right)\right)$. Given $\phi_j\left(p^*\right) = p^* \leq p_j^I$ and $p_i^I < p^*$, it follows from ϕ_j being an increasing function that $\phi_j\left(p_i^I\right) < p_j^I$. Thus, $\phi_j^F\left(p_i^I\right) = \phi_j\left(p_i^I\right)$. In stage 2, p_i^I is a best reply to firm j choosing $\phi_j\left(p_i^I\right)$ iff $p_i^I \leq \phi_i\left(\phi_j\left(p_i^I\right)\right)$. Note that

$$\frac{\partial \phi_i\left(\phi_j\left(p_i\right)\right)}{\partial p_i} = \phi_i'\left(\phi_j\left(p_i\right)\right)\phi_j'\left(p_i\right) \in (0, 1)$$

because $\phi_i'\left(p_j\right), \phi_j'\left(p_i\right) \in (0, 1)$. Hence, $p_i^I - \phi_i\left(\phi_j\left(p_i^I\right)\right)$ is increasing in p_i^I. Given $p^* - \phi_i\left(\phi_j\left(p^*\right)\right) = 0$, it follows from $p_i^I < p^*$ that $p_i^I - \phi_i\left(\phi_j\left(p_i^I\right)\right) < 0$.

Now let us prove the theorem. Suppose $p_2^I = p^*$. If $p_1^I > p^*$ then stage 2 NE prices are still $\left(p_1^F, p_2^F\right) = (p^*, p^*)$ - so product market profits are unchanged - but price adjustment

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costs rise by $g\left(p_1^I - p^*\right)$. Hence, firm 1's payoff is lower with $p_1^I > p^*$ compared to $p_1^I = p^*$. Thus, $p_1^I = p^*$ is preferred to $p_1^I > p^*$.

Next consider $p_1^I < p^*$. Given $p_2^I = p^*$, it was previously shown (for $p_2^I \geq p^*$) that the stage 2 NE is $\left(p_1^F, p_2^F\right) = \left(p_1^I, \phi_2\left(p_1^I\right)\right)$. Hence, firm 1's stage 1 payoff is $\pi_1\left(p_1^I, \phi_2\left(p_1^I\right)\right)$. Take the total derivative of it with respect to p_1^I:

$$\frac{d\pi_1\left(p_1^I, \phi_2\left(p_1^I\right)\right)}{dp_1^I} = \frac{\partial\pi_1\left(p_1^I, \phi_2\left(p_1^I\right)\right)}{\partial p_1} + \left(\frac{\partial\pi_1\left(p_1^I, \phi_2\left(p_1^I\right)\right)}{\partial p_2}\right)\left(\frac{\partial\phi_2\left(p_1^I\right)}{\partial p_1}\right),$$

and evaluate it at $p_1^I = p_2^I = p^*$:

$$\frac{d\pi_1\left(p^*, p^*\right)}{dp_1^I} = \frac{\partial\pi_1\left(p^*, p^*\right)}{\partial p_1} + \left(\frac{\partial\pi_1\left(p^*, p^*\right)}{\partial p_2}\right)\left(\frac{\partial\phi_2\left(p^*\right)}{\partial p_1}\right). \tag{6}$$

In order to show that a stage 1 price below p^* is not preferred to pricing at p^*, (6) must be non-negative so that firm 1's profit does not rise by reducing p_1^I below p^*.

Given that

$$\frac{\partial\pi_1\left(p^*, p^*\right)}{\partial p_1} + g = 0.$$

then (6) becomes:

$$\frac{d\pi_1\left(p^*, p^*\right)}{dp_1^I} = -g + \left(\frac{\partial\pi_1\left(p^*, p^*\right)}{\partial p_2}\right)\left(\frac{\partial\phi_2\left(p^*\right)}{\partial p_1}\right). \tag{7}$$

Since $\left(\partial\pi_1/\partial p_2\right)\left(\partial\phi_2/\partial p_1\right)$ is bounded above zero, the following property holds for (7):

$$\lim_{g\to 0}\frac{d\pi_1\left(p^*, p^*\right)}{dp_1^I} = \lim_{g\to 0} -g + \left(\frac{\partial\pi_1\left(p^*, \phi_2\left(p^*\right)\right)}{\partial p_2}\right)\left(\frac{\partial\phi_2\left(p^*\right)}{\partial p_1}\right) > 0.$$

Hence, if g is sufficiently small then (7) is positive, and firm 1's profit is reduced by marginally lowering its stage 1 price from $p_1^I = p^*$.

To complete the proof, we want to show that $p_1^I = p^*$ is preferred to any $p_1^I < p^*$. For when g is sufficiently small, a sufficient condition is

$$\frac{d^2\pi_1\left(p_1^I, \phi_2\left(p_1^I\right)\right)}{d\left(p_1^I\right)^2} < 0. \tag{8}$$

If (8) holds then $d\pi_1\left(p_1^I, \phi_2\left(p^*\right)\right)/dp_1^I > 0$ implies $d\pi_1\left(p_1^I, \phi_2\left(p_1^I\right)\right)/dp_1^I > 0$ when evaluated at $p_1^I < p^*$. ∎

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