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USING LIST PRICES TO COLLUDE OR TO COMPETE?*

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Collusion is deemed unlikely in wholesale markets where upstream suppliers and intermediate buyers privately negotiate discounts off list prices and sales quotas are unfeasible. However, many wholesale markets include both small and large buyers who compete in the retail market. We study the role of publicly announced list prices in this wholesale-retail setting, whether suppliers collude or compete. When suppliers collude, public announcements of list prices extend the possibility of collusion from small to large buyers (the multi-buyer contact effect). When suppliers compete, these announcements provide them with commitment to negotiate better terms with large buyers (the commitment effect).

Collusion in retail markets usually involves firms agreeing to charge prices above competitive levels and then monitoring prices for compliance. Collusion in wholesale markets also involves suppliers agreeing on prices, but, as noticed by Stigler (1964), compliance is more problematic because there are buyers who rarely pay posted prices or so-called list prices. They often buy at a substantial discount off the list price, which is privately negotiated. This explains why some cartels in these intermediate markets have also agreed to sales quotas (or some other market-segmentation scheme), and monitoring involved comparing actual sales with agreed-upon sales (see, e.g., Harrington and Skrzypacz, 2007; 2011; Marshall and Marx, 2012; Bernheim and Madsen, 2017).

It appears that coordinating on prices alone would not be possible in wholesale markets. However, as explained by Harrington and Ye (2019) and Boshoff and Paha (2021), this goes against recent allegations on both sides of the Atlantic of suppliers effectively coordinating on public announcements of list prices. A problem faced by courts when ruling on these cases is that defendants often claim that, due to pervasive secret discounts, any ostensible list price coordination cannot have anticompetitive effects. Here is what a member of the thread cartel explained in court:

> ...list prices have more of a political importance than a competitive one. Only very small clients pay the prices contained in the lists. As the official price lists issued by each competitor are based on large profit margins, customers regularly negotiate rebates, but no clear or fixed amount of rebates is granted....[T]he list prices are essentially 'fictitious' prices.
>
> (Commission of the European Communities, 14.09.2005, Case COMP/38337/E1/PO/Thread, 112, 159–60.)

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According to this cartel member, list prices would, not only constitute costless messages—cheap talk, using the language of Crawford and Sobel (1982)—but would also be uninformative. Courts have expressed different views on this matter. In the fibreglass cartel, for example, the Seventh Circuit Court indicated that list prices

> ...would be, to put it mildly, an awkward facilitator of price collusion because the industry practice of providing discounts to individual customers ensured that list price did not reflect the actual transaction price.
>
> (*Reserve Supply vs. Owens-Corning Fiberglas* 971 F. 2d 37 (7th Cir., 1992), para 62.)

By contrast, the Tenth Circuit Court commented regarding the polyurethane cartel that

> ...product price lists and parallel price-increase announcements — 'presumably established an artificially inflated baseline' for negotiations.
>
> (*In Re: Urethane Antitrust Litigation,* No. 13-3215 (10th Cir., 2014), p.7.)

In addition to these cases is a recent event that took place in Chile's wholesale fresh-egg market. Egg producers used to publish their list prices on a weekly basis—each Monday—in the country's main newspaper. By instruction of the competition authority, this publication was suddenly interrupted in October 2018.[1] After the newspaper ended their publication, suppliers continued communicating list prices, but asynchronously and in a more frequent (almost daily), decentralised and 'opaque' way, using the internet, emails and phone calls. As we document in Section 1 using detailed transaction-level data, the newspaper interruption had a significant impact on wholesale prices: list prices dropped by 15% and transaction prices paid by large buyers (e.g., supermarket chains) dropped by 4%. This implies that discounts off list prices also fell.

Since the fresh-egg market has many small buyers (e.g., independent grocery stores) who for the most part pay list prices, a natural explanation would be that suppliers were colluding, and that publicly sharing list prices was the vehicle supporting that. Does this imply that the only explanation for the drop in list prices is a collusive one? Any non-collusive explanation that could account for the fall in list prices should also explain why transaction prices for large buyers also fell, and why their fall was smaller than that of list prices.

Motivated by the aforementioned cases and the fresh-egg market, our goal in this paper is to contribute to our understanding of whether, how and to what extent public announcements of list prices can help suppliers sustain supra-competitive prices. We start our theoretical analysis in Section 2 by highlighting two elements in the fresh-egg market that are common to many other markets (see, e.g., Thomassen *et al.*, 2017, Ellickson *et al.*, 2020), namely, that the wholesale market is composed of buyers of varying bargaining powers and that these different buyers compete for final consumers in the retail market.

Building on the bargaining model of Horn and Wolinsky (1988), our theory considers two types of buyers, large and small, who bilaterally negotiate with suppliers over linear prices. Unlike large buyers, small buyers lack any bargaining power, so they pay whatever list prices are offered (or announced) by suppliers. Prices negotiated by large buyers often exhibit a discount off these list prices, although, under certain conditions, these discounts may vanish in equilibrium. What is important for our theory is not that small buyers pay list prices, but that they are price

[1] This instruction became publicly known only recently, in October 2023, during a settlement procedure (see footnote 37 for more details). Note that the newspaper also interrupted the publication of (wholesale) list prices concerning many other products, including cattle, fruits, vegetables, fertilisers, etc. Our empirical analysis focuses on the egg market primarily because of data availability.

takers. Small buyers may still get some discounts off list prices, as long as they are determined by suppliers following price discrimination motives, not a bargaining logic.[2]

Echoing Harrington (2022), our theory distinguishes list prices based on their disclosure: openly available to all, including rival suppliers and buyers, or shared less transparently, e.g., upon request. Publishing in local newspapers is an obvious way to ensure transparency and broad accessibility of these prices. But there are other instances in which this can be done, for example, using the website of the suppliers' trade association.

In terms of our theory, the difference between these two types of list prices is their timing. Prices (publicly) announced before negotiations with large buyers are called *public* list prices, and prices determined simultaneously with negotiations are called *private* list prices.[3] We believe this to be a plausible way to capture price transparency.[4]

The main message of our theory is that moving from private to public list prices allows suppliers to charge higher prices to both small and large buyers. This is true whether suppliers collude or compete. When suppliers collude, public list prices make it easier for suppliers to extend the possibility of collusion from small to large buyers. We refer to this as the *multi-buyer contact effect*.

To understand this effect, consider two extreme cases. Let us start with the case where only small buyers exist in the market. In this case, the distinction between public and private list prices vanishes, reducing the suppliers' collusive problem to a textbook example of collusion with price-taking buyers.

Consider now the case where only large buyers exist in the market. This is a context in which, not only list prices become irrelevant—since nobody pays them—but also means that collusion cannot emerge (recall that we are focusing on a setting in which suppliers can only resort to price agreements and not to market-segmentation agreements). What makes collusion fail in this case is the impossibility of satisfying the (large) buyers' incentive compatibility constraint while extracting rents from final consumers. In other words, suppliers have only one instrument at their disposal, the wholesale price, to accomplish two opposing goals as they bargain with buyers: extract rents from final consumers by means of higher wholesale prices, and share part of those rents with buyers by means of lower wholesale prices.[5]

Given their 'contact' in the downstream market, the presence of small buyers extends the possibility of collusion from small to large buyers.[6] By agreeing to charge higher list prices to

[2] For this reason, our theory extends equally well to a situation where final consumers have, not only the option to buy from large and small intermediaries, but also directly from suppliers. Increasing evidence of this hybrid sales model can be found in European Commission (2017) and Oliver-Wyman (2018).

[3] The use of private list prices to refer to prices that may not even exist on a list may seem odd to some readers. We do it to avoid any confusion. Small buyers, who lack any bargaining power, pay whatever prices suppliers offer them. There are occasions in which these offers are made public on a list before suppliers negotiate with large buyers. In other occasions these offers remain private, unknown to other buyers and suppliers at the time large buyers negotiate with suppliers. Whether these private offers actually exist on a list is immaterial for our theory. We still refer to them as list prices to differentiate them from negotiated prices, the prices paid by large buyers.

[4] One could also entertain an intermediate view, of 'semi-public list prices', where list price announcements are observed by large buyers before they initiate their negotiations, but not by rival suppliers. This case is not different from public list prices when suppliers compete (agents correctly conjecture the public-list-price play), but it is different when suppliers collude (for communication reasons).

[5] There are many wholesale markets, including the fresh-egg market, in which parties bargain over linear prices (e.g., Crawford and Yurukoglu, 2012; Noton and Elberg, 2018). In the Online Appendix we extend our model to the case in which parties bargain over two-part tariffs. Our main results remain qualitatively unchanged.

[6] To some readers this multi-buyer contact effect is reminiscent of the multi-market contact effect of Bernheim and Whinston (1990), but it is actually different. Markets are independent in Bernheim and Whinston (1990), while buyers are interdependent here.

small buyers, suppliers can in turn negotiate better terms with large buyers. The reason is that increasing the purchasing cost of small buyers reports extra profits to large buyers, some of which are bargained away from them by suppliers in the form of higher wholesale prices. This is an instance in which large buyers benefit from upstream collusion at the expense of small buyers and final consumers.

Do list prices being public or private make a difference for the success of the collusive agreement? It does, for two reasons. The first and most important is communication. Under private list prices, suppliers need to find a way to communicate to large buyers that the list prices they expect small buyers to pay in equilibrium are strictly higher than the prices they would pay in the otherwise non-collusive (i.e., static) equilibrium. Suppliers may be reluctant to share their collusive intentions with large buyers for obvious reasons, even if the latter benefit from such intentions. Buyers, in turn, may want to avoid being caught in a conspiracy to increase prices to final consumers.

The second reason relates to the sustainability of the agreement. It is easier for suppliers to sustain collusion under public list prices since any deviation from the agreed list prices is detected before suppliers bargain with large buyers, as opposed to when all prices are determined simultaneously.

For these reasons, moving from public to private list prices makes collusion less likely: it can terminate it altogether or force suppliers to transit to a less ambitious agreement. In either case, all buyers, large and small, will see the prices they pay fall.

Moreover, our theory predicts that small buyers will see their input prices fall more than large buyers will. This happens because the pass-through from list to negotiated prices is strictly less than one. The exact level of pass-through will ultimately depend on the cost-effectiveness of small buyers and the bargaining power of large buyers vis-à-vis suppliers. For example, we should expect a small pass-through (and, hence, large discounts) when small buyers play a minor role in the downstream market and large buyers enjoy a significant bargaining power against suppliers.

Moving from public to private list prices has implications, not only when suppliers attempt to collude, but also when they compete, which is when public list prices allow them to unilaterally (as opposed to cooperatively) commit charging higher prices to small buyers and, hence, to negotiate better terms with large buyers. By publicly communicating in advance—before bargaining with large buyers—the price to be charged to small buyers, suppliers solve a commitment problem akin to that in Hart and Tirole (1990), which is the temptation to offer better deals to small buyers after setting terms with large buyers. We refer to this as the *commitment effect*. And, for the same reasons laid out above, when suppliers compete and list prices move from public to private, all buyers, small and large, see their input prices drop.

At least two antitrust lessons emerge from our theory. First and foremost, price transparency—here, making list prices publicly available to everyone—unambiguously leads to higher prices, whether facilitating collusion or softening competition.

Second, it may prove difficult for an antitrust authority to separate collusive from competitive conduct by simply looking at how economic variables respond to changes in the economic environment; here, as we move from public to private list prices.[7] For the most part, what distinguishes one conduct from the other in our theory is a matter of magnitude: in both cases

[7] A seminal paper where this distinction is possible is Rotemberg and Saloner (1986), which exploits changes in the demand from final consumers.

suppliers take advantage of public list prices to obtain better terms from large buyers, only that in one case they do it in a coordinated fashion and in the other independently.

There are instances, however, in which our theory can be more informative about conduct. One is when small buyers are so efficient that suppliers agree not to serve them along the collusive path (but still use them off-path, as outside options), while they are always served under competition. Thus, a move from public to private list prices that results in a strong expansion of small buyers can only be consistent with collusive conduct when list prices were public.[8]

Another instance is when suppliers compete relatively intensely for small buyers, enough for the commitment effect to disappear. In this case, suppliers set list prices low enough that in equilibrium they stop negotiating discounts off list prices with large buyers, as if suppliers were competing by simultaneously setting a single price for small and large buyers, and thus eliminating any difference between public and private list prices. Therefore, observing the elimination of discounts as we move from public to private list prices makes collusion when list prices were public very likely.[9]

Our theory connects to three strands of the literature. The first is about the impact of price transparency on market performance. While there are empirical studies showing that price transparency can lead to higher prices (see, for example, Luco, 2019 for retail gasoline, and Albæk *et al.*, 1997 and Office of Fair Trading, 2011 for cement), others show the exact opposite (see, for example, Ater and Rigbi, 2023 for supermarkets). We add to this literature with new empirical evidence on the adverse effect of price transparency, and more importantly, we advance a theory with a price-increasing mechanism that can prove relevant in many wholesale-retail settings.

Our work also connects to the recent literature on how coordination on list price announcements can help suppliers to obtain better terms, in particular, Harrington and Ye (2019) and Harrington (2022). Our theory is based on elements absent from these papers and vice versa, so they apply to different settings. In Harrington and Ye (2019), for example, nobody pays list prices, but suppliers still use them to coordinate on high-cost signals before (large) buyers invite them to participate in their procurement auctions. In our setting suppliers and buyers negotiate bilaterally under complete information, so costless messages are never informative.

In Harrington (2022), on the other hand, offering discounts off list prices carries a disutility to the sales agents offering them, so they keep them smaller than what discounts would otherwise be. Thus, sharing list prices with rivals before discounts are set serves to credibly ‘inflate the baseline’ for such negotiations, much consistent with the third quotation above. We abstract from such organisational costs.

Finally, our work connects to models of retail market competition where retailers compete in both list prices and discounts off list prices. We share with them the anti-competitive concerns regarding discounts, but the mechanisms are very different. Raskovich (2007), for example, assumed that a fraction of consumers are given the (exogenous) opportunity to bargain with suppliers for discounts. When that fraction is big enough, the game accepts two equilibria in list prices: marginal cost pricing and monopoly pricing. Otherwise, the former is the unique equilibrium. What explains his result is that suppliers posting higher list prices have worse outside options and are therefore more attractive to bargaining consumers. Lubensky (2017), on

[8] In practice, such expansion should be reflected, not only in a significantly larger market share, but also in a more diversified purchasing pattern, leaning more toward the (large) suppliers taking part in the alleged collusive scheme.

[9] This elimination of discounts may also happen under heterogeneous suppliers with varying degrees of bargaining power.

the other hand, considered incomplete information, so final consumers must search for better prices. Announcements of list prices are informative in that they affect the direction of this search.

Closer to our paper is Gill and Thanassoulis (2016), who also studied the role of public list prices in a Hotelling retail setting with two types of price-taking consumers. An exogenous fraction of consumers, the ‘bargainers’, are offered the opportunity to get a discount off the list price with some exogenous probability. The discount is set by the firms. The remaining consumers, the ‘no-bargainers’, pay list prices (which is also the price paid by bargainers who did not get the discount). When list prices are publicly announced, that is, announced before firms decide on their discounted prices, equilibrium list and discounted prices are above the Hotelling price. In contrast, when list and discounted prices are decided simultaneously—as in our private-list-price setting—discounts disappear in equilibrium and all consumers pay the same price, the Hotelling price. As firms anticipate that higher list prices lead to higher discounted prices and that bargainers are more difficult to attract by rivals in expectation, firms can credibly use public announcements of list prices to set higher prices to all consumers.[10]

We share with Gill and Thanassoulis (2016) that public list prices allow suppliers to charge higher prices to all buyers, bargainers or otherwise, but we differ from them in several ways. One is in our focus on conduct screens, the extent to which the qualitative evolution of some economic variables (e.g., discounts) could help distinguish collusive from competitive conduct. The other is in results and the mechanism behind them. The latter is largely explained by our attention to wholesale settings with small and large downstream buyers who compete for final consumers. In Gill and Thanassoulis (2016) all consumers suffer as we move from private to public list prices, while in our setting only small buyers and final consumers do; large buyers strictly benefit from such a move, and more so if upstream firms collude.[11] The reason is that in our setting discounts are not unilaterally set by upstream suppliers, but endogenously determined through bilateral negotiations. Thus, and in sharp contrast to Gill and Thanassoulis (2016), there may be instances in which discounts do not emerge under public list prices and others in which they do under private list prices.

The rest of the paper is organised as follows. Evidence from the fresh-egg market is presented in Section 1. We present our model of public list prices in Section 2, in which we first cover the case in which suppliers compete and then in which they collude. In Section 3 we move from public to private list prices. In Section 4 we study under what conditions our theory can help separate collusive from competitive conduct. We conclude in Section 5. Proofs and some auxiliary results are relegated to the Appendix. Additional auxiliary results can be found in the Online Appendix.

1. Motivating Evidence

A recent event in Chile’s wholesale fresh-egg market provides a natural experiment to look at the impact of public announcements of list prices on market performance. Large egg producers used to publish their list prices on a weekly basis—each Monday—in the country’s main news-

[10] In a way, the authors’ mechanism is reminiscent of the taxonomy of Fudenberg and Tirole (1984): firms ‘invest’ in higher list prices in the first stage in anticipation of a softer competition in the second, discount stage. The taxonomy does not apply to our context because suppliers have only indirect control over discounts as they are determined in bilateral negotiations.

[11] Our connection to Gill and Thanassoulis (2016) extends to the study of collusion. We also find that moving from private to public list prices makes collusion easier to sustain for upstream firms, although for reasons different from theirs.

paper. Without any notice, this publication was suddenly interrupted in October 2018. After the interruption, suppliers continued communicating their list prices, but in a more frequent (almost daily), decentralised and 'opaque' way, using the internet, emails and phone calls.

The event we exploit here is that before the newspaper ended their weekly publication, list prices were publicly and readily available in a single place, where they were posted simultaneously, while afterwards they became more disperse and asynchronously informed to buyers. In connection to our theory, list prices posted before the newspaper interruption would correspond to *public* list prices and those posted after the interruption to *private* list prices.

We want to explore whether the newspaper publication had any effect, not only on list prices, but also on transaction prices, i.e., prices actually paid. We focus on large white eggs, the most popular fresh-egg category,[12] for which we have detailed transaction-level data from two of its largest suppliers. Together these two suppliers account for roughly 16% of sales during our sample period, which runs from December 2016 to August 2020.

We identify two types of buyers in our sample: single and multi-store buyers. An important fraction of buyers comprises independent, small grocery stores that, according to the data, pay transaction prices very close to list prices (at least before the newspaper interruption, when list prices were available). The remaining fraction corresponds to large buyers (e.g., supermarkets, retail chains) that, according to the data, pay transaction prices that are systematically below list prices. We want to compare wholesale prices paid by these two types of buyers before and after the newspaper interruption. Identification of its effect on wholesale prices comes from the assumption that the newspaper interruption was an unexpected event for both suppliers and buyers.[13]

We estimate the 'before-and-after' model

$$w_{ilt} = \alpha + \gamma Post_t + \beta Large_i + \phi Large_i \times Post_t + \mu' X_{ilt} + \delta' Y_t + \varepsilon_{ilt}, \tag{1}$$

where w_{itl} is the unit price paid by buyer i located in municipality l on day t,[14] $Post_t$ is an indicator that takes the value of one for days after the newspaper interruption and $Large_i$ is an indicator that takes the value of one if buyer i qualifies as large, i.e., as a supermarket or retail chain. Therefore, the omitted category of buyers is small buyers. We also add a set of controls. Vector X includes controls common to all specifications: day-of-the-week fixed effects, supplier fixed effects and municipality fixed effects. Vector Y, in contrast, includes controls that differ by specification. In the baseline specification, it includes only month-of-the-year fixed effects, while in the alternative specification it includes year fixed effects, month-of-the-year fixed effects and a proxy for costs of production (the corn wholesale price index provided by the National Bureau of Statistics, which is of monthly frequency). To control for any possible COVID-19 effect, we estimate (1) for two windows of data around the time of the newspaper interruption: one- and two-year windows before and after the event.

If having list prices posted in the local newspaper had any effects on list prices (i.e., prices paid by small buyers), this should be captured by the coefficient of *Post*, γ. Similarly, if it had any effect on the prices paid by large buyers, this should be captured by the sum of the coefficients of *Post* and *Large* $\times$ *Post*, $\gamma + \phi$. In addition, any discount off list prices received by large buyers

[12] White large eggs account for 40% of the fresh-egg market. Other categories include white extra-large, white medium, white small and colour in different sizes.

[13] It seems a reasonable assumption based on a series of conversations with industry personnel. Additional evidence supporting this assumption comes from a series of emails sent by the suppliers' trade association to the newspaper questioning the interruption of the publication of list prices.

[14] We truncated prices falling outside the 2nd and 98th percentiles.

Table 1. *Impact of the Newspaper Interruption on List and Transaction Prices.*

	(1)	(2)	(3)	(4)
Large	-18.114^{***}	-23.580^{***}	-18.172^{***}	-23.894^{***}
	(2.322)	(3.200)	(2.325)	(3.052)
Post	-11.678^{***}	-13.905^{***}	-13.142^{***}	-13.560^{***}
	(3.489)	(3.475)	(3.505)	(3.413)
Post × *Large*	8.691^{***}	10.894^{***}	8.520^{**}	11.317^{***}
	(3.279)	(3.207)	(3.506)	(3.207)
Corn price index			0.167^{***}	0.391^{***}
			(0.024)	(0.048)
Constant	108.224^{***}	113.327^{***}	92.440^{***}	75.350^{***}
	(2.045)	(2.952)	(3.478)	(6.135)
Observations	200,566	108,723	200,566	108,723
F-tests, *p*-values				
$\gamma + \phi = 0$	0.000	0.000	0.000	0.000

Notes: Dependent variable is effective prices charged by two suppliers for large white eggs, the most popular fresh-egg category in the market (truncated at the 2nd and 98th percentiles). Columns (1) and (2) show estimates of the baseline specification of (1) for two symmetric windows around the week of the newspaper interruption (third week of October 2018): 22 months before and after that week and 12 months before and after that week. Columns (3) and (4) show the same, but for the alternative specification (year and month-of-the-year fixed effects, and the corn price index). All models include fixed effects by day of the week, supplier and municipality. SEs, which are clustered at the municipality level, are shown in parentheses. The bottom of the table shows the results of the *F*-tests mentioned in the text. $^{**}p < 0.05$, $^{***}p < 0.01$.

before the newspaper interruption should be captured by a negative coefficient of *Large*, β, and after the interruption by a negative sum of the coefficients of *Large* and *Post* × *Large*, $\beta + \phi$.

Table 1 reports the results of our estimation of (1). Results are consistent across specifications and windows of estimation. The coefficient of *Large* is negative and statistically significant, confirming that discounts off list prices are common among large buyers. Given that the average list price observed in our sample is 92 pesos (13 US cents), discounts are around 20% before the newspaper interruption. The table also shows that the coefficient of *Post* is always negative and statistically significant, meaning that list prices fell with the interruption, by about 15%. Meanwhile, the coefficient of *Post* × *Large* is positive, statistically significant and smaller than that of *Post* in all specifications. This means that prices paid by large buyers fell as well with the interruption, but not as much as list prices. The *F*-tests at the bottom of the table indicate that these price falls were statistically different from zero. In all cases we reject the null of no fall in prices paid by large buyers. Ultimately, these tests imply that the gap between prices paid by small and large buyers shrank after the newspaper interruption.

It is clear that the weekly publication of list prices in the local newspaper helped suppliers set higher prices for small buyers who lack bargaining power and for the most part pay list prices. One potential explanation is a collusive one: the 'transparency' of posting list prices in a single place and at the same time would have facilitated the monitoring of compliance with a supposed collusive agreement.

But, even if this collusive explanation turns out to be correct, it is not clear how it would also serve to explain the evolution of prices paid by large buyers. Take, for instance, the numbers of column (1) in the table. Given an average list price for the entire period of our sample of 92 pesos, the coefficient of *Post* suggests that list prices fell from an average of 97.8 pesos before the cease of publication to an average of 86.2 pesos afterwards. According to the coefficients of *Large* and *Post* × *Large*, the discounts received by supermarkets before the newspaper interruption were 18.1 pesos on average, or 18.5% off list prices. After the interruption, these discounts dropped dramatically, to 9.4 pesos, or 10.9%. It is unclear how to explain the drop in prices paid by large buyers from 79.7 to 76.8 pesos associated with the interruption.

In looking for an explanation behind these numbers and, ultimately, behind the role of public list prices, we start by highlighting two elements in the fresh-egg market that are common to many other markets, namely, that the wholesale market is composed of buyers of varying bargaining powers and that these different buyers compete for final consumers in the retail market.[15] These two elements form the basis of the theory that we develop next.

2. A Model of Public List Prices

Our model extends the bargaining model of Horn and Wolinsky (1988) to the presence of small buyers. We discuss the choice of some of our modelling assumptions after presenting the model. There are two upstream suppliers, U_1 and U_2, of a homogeneous good with production costs normalised to zero, two large buyers or distributors, D_1 and D_2, and a continuum of small buyers.[16] Supplier U_i and buyer D_i $(i = 1, 2)$ are in an exclusive relationship with each other. Each small buyer is also in an exclusive relationship with one of the two suppliers.

The timing of the game is as follows. In the first stage suppliers simultaneously announce their list prices l_i and l_j, which are the prices at which small buyers will procure their units. Since small buyers lack any bargaining power, l_i and l_j can also be interpreted as the prices suppliers would negotiate with small buyers. In the second stage D_i has the option to skip negotiations and buy at the list price l_i or alternatively bargain with U_i over a wholesale price w_i. If D_i opts to bargain with U_i, she forgoes the option to ever buy at the list price. One can view l_i as the initial offer made by U_i in his negotiation with D_i, which will always be rejected by D_i in equilibrium. We assume that U_i and D_i bargain under equal bargaining weights.

Finally, in the third stage, and after observing list and negotiated prices, buyers, large and small, compete for final consumers by simultaneously setting quantities (and sending purchase orders to their suppliers accordingly). Final consumers see no horizontal differentiation across buyers and clear the market according to the (inverse) demand

$$p = a - \sum_{i=1,2} q_i - \sum_{i=1,2} q_i^F,$$

where q_i is the amount sold by D_i and q_i^F is the total amount sold by the fringe of small buyers who procure their units from U_i according to

$$q_i^F = \gamma(p - l_i), \tag{2}$$

[15] Thomassen *et al.* (2017) offered a detailed analysis of how large supermarkets adjust their pricing strategies to the presence of smaller stores carrying a reduced number of products (e.g., butchers, bakers, greengrocers, etc.). See also Ellickson *et al.* (2020).

[16] We model small buyers as a continuum of agents mainly for simplicity. More importantly, what ultimately distinguishes small from large buyers is not their size per se, but their ability to negotiate the prices effectively paid. This includes an understanding of the total surplus involved in the negotiation and how it may be split among the negotiating parties. Large buyers have account managers dedicated to these negotiations. Small buyers—very much like final consumers in the retail market—lack such an ability; they accept or reject whatever offer is presented to them. These offers may include small discounts off the list price, but they respond to a price-discrimination motive tailor-made by suppliers.

where $\gamma > 0$ captures how cost effective are the small buyers relative to the large buyers.[17] This three-stage game is repeated over an infinite number of periods under a per-period discount factor equal to $\delta \in (0, 1)$.

Modelling assumptions. Before proceeding, we offer some reflections on our modelling assumptions. To start, a general reflection: it proved fruitless to work with more general payoff functions. The reason is that the first-order condition associated with D_i-U_i's bargaining problem does not easily lend itself to comparative statics analysis and to the study of potential global deviations. This forced us to adopt tractable (i.e., linear) functional forms and other simplifying assumptions, but, as we discuss next, they are less restrictive than they appear.

Take, for instance, the assumption that D_i is an exclusive relationship with U_i. We relax this assumption in two passages of the paper. In Section I of the Online Appendix, we add an initial stage where we let large buyers decide which supplier to visit first (we recommend visiting the Online Appendix after seeing Proposition 1 below and its proof in Appendix A). We show that in equilibrium buyers approach different suppliers, as if they were in exclusive relationships.[18]

We also relax the exclusive-relationship assumption for small buyers. This is done in the main text (which borrows from Section II of the Online Appendix) by giving each of the small buyers the option to order from either supplier according to the specification of Shubik and Levitan (1980), which allows for any level of substitution between the two suppliers. This will also serve to better appreciate why and when discounts off list prices emerge in equilibrium.

Another assumption we relax in Section I of the Online Appendix is D_i's zero outside option in case of a negotiation breakdown (unlike U_i's, who always has the (outside) option to sell through the small buyers). In this case, and in the spirit of the Nash-in-Nash approaches of Ho and Lee (2019) and Chambolle and Molina (2023)—with threat of replacement or with previous competition for slots—we allow D_i to visit the other supplier and bargain for an offer. We allow this offer to vary from something prohibitively high (equivalent to having no outside option) to something similar to what D_i would have otherwise obtained from her initial supplier. This ample range of outside options is intended to capture different possible costs of initiating a second negotiation on short notice. Together with improving their bargaining positions, it is confirmed that in equilibrium large buyers approach different suppliers, as if they were in exclusive relationships, no matter their outside options.[19]

Besides its tractability, the assumption that D_i and U_i bargain over linear prices is, not only in Horn and Wolinsky (1988), but also has support in practice (e.g., Crawford and Yurukoglu, 2012; Noton and Elberg, 2018), including the fresh-egg market. We relax this assumption in Section III of the Online Appendix, where we allow parties to negotiate over two-part tariffs. The main result of the paper—that public list prices help suppliers to obtain better terms from all buyers—remains qualitatively unchanged. The result that is lost is that, under two-part tariffs, suppliers can still sustain some collusion even in the absence of small buyers.

[17] Think of the fringe of buyers as a unit mass of a continuum of heterogeneous buyers, each with demand $q_{ik}^F = \gamma_k(p - l_i)$, where $\int_0^1 \gamma_k dk = \gamma$. Note that, even if U_i could set different public list prices for different small buyers, he has no incentives to do so; he cares only about demand (2), the fringe's aggregate demand (see footnote 28 for a formal proof on this).

[18] To see large buyers buying from both suppliers in equilibrium, one could adopt the approach of Cussen (2021). He lets a large buyer's procurement costs to be decreasing in variety. Although the analysis gets cumbersome quite rapidly, he illustrates with the aid of numerical exercises that results do not qualitatively change.

[19] Note that what we cannot do is to let D_i buy at l_i in the case of a negotiation breakdown. If we do that, the boundary of U_i's and D_i's potential payoffs when they bargain over w_i would reduce to a (convex) set with a single price, $w_i = l_i$, rendering bargaining irrelevant. The exception to a singleton set is when l_i is sufficiently high, so both parties benefit from agreeing on $w_i < l_i$. But this possibility falls outside any relevant range of list prices that U_i would ever announce.

Two other assumptions that we relax without qualitative consequences for our main result are the Cournot competition in the downstream market and parties' symmetric bargaining weights. The former, which considers a linear setting of horizontally differentiated price setting distributors, is considered in Section IV of the Online Appendix. The latter is done in the main text (which borrows from material in Section II of the Online Appendix), as it helps to convey the intuition for some of our results, in particular, the emergence of discounts in equilibrium.

Finally, in Section 4 below we discuss the implications of introducing some upstream asymmetries, in particular, when only one supplier has access to public list prices or when U_1 and U_2 share the upstream market with smaller suppliers.

The rest of this section is organised as follows. We first characterise the competitive equilibrium, i.e., the equilibrium of the one-shot game. Since much of our theory builds on the fact that small buyers pay higher prices than large buyers, irrespective of their relative costs, we then devote a few lines to explain the factors that drive this price gap in equilibrium. We conclude the section with a characterisation of collusion.

2.1. *Competing with Public List Prices*

To find the equilibrium of the one-shot game, we proceed by backward induction. Suppose that in equilibrium l_1 and l_2 are large enough so buyers prefer to bargain with suppliers than to buy at those prices. Given wholesale prices paid by small and large buyers, l_i and w_i, respectively, the Cournot outcome in stage three is characterised by D_i's equilibrium output

$$q_i(w_i, w_j) = (\tilde{a} - (2w_i - w_j)(1 + 2\gamma))/3, \tag{3}$$

and clearing price

$$p(w_i, w_j) = (\tilde{a}/(1 + 2\gamma) + w_i + w_j)/3, \tag{4}$$

with $\tilde{a} = a + \gamma(l_i + l_j)$. Thus, D_i's profit is given by

$$\pi_{D_i}(w_i, w_j) = (p(w_i, w_j) - w_i)q_i(w_i, w_j) = q_i^2(w_i, w_j)/(1 + 2\gamma).$$

In the second stage, D_i and U_i bargain over w_i while forming some expectation about the price w_j that D_j and U_j will agree upon and anticipating the corresponding Cournot outcome (3) and (4) that would follow from such prices. If D_i and U_i agree to trade at some w_i, their on-path payoffs would be

$$\hat{\pi}_{D_i} = \pi_{D_i}(w_i, w_j),$$

and

$$\hat{\pi}_{U_i} = w_i q_i(w_i, w_j) + l_i\gamma(p - l_i),$$

respectively, whereas if they do not, their off-path payoffs would be $\bar{\pi}_{D_i} = 0$ and

$$\bar{\pi}_{U_i} = l_i\gamma(\bar{p} - l_i),$$

where

$$\bar{p} = a - q_i^F - q_j^F - q_j = (\tilde{a}/(1 + 2\gamma) + w_j)/2, \tag{5}$$

is the prevailing off-path price, which is obviously higher than the on-path price (4). Note that we are using an upper hat (respectively an upper bar) to denote on-path (respectively off-path) payoffs. Although parties are expected to reach an agreement in this complete-information environment, off-path payoffs are important for they determine the overall net surplus from trade.

We adopt the Nash bargaining solution as the outcome of the bargaining process. The solution is a pair of prices w_1 and w_2 such that w_1 is the Nash solution to the bargaining problem between D_1 and U_1, given that both expect w_2 to be agreed upon between D_2 and U_2. Thus, when D_i and U_i expect w_j to be the wholesale price agreed by the other pair, their Nash bargaining solution as a function of w_j is found by solving

$$\max_{w_i}(\hat{\pi}_{U_i} - \bar{\pi}_{U_i})(\hat{\pi}_{D_i} - \bar{\pi}_{D_i}),$$

which leads to

$$w_i^N(w_j) = \frac{a + (1+2\gamma)w_j + \gamma(4l_i + l_j)}{8(1+2\gamma)}, \tag{6}$$

which together with $w_j^N(w_i)$ yields

$$w_i^{NB}(l_i, l_j) = \frac{3a + \gamma(11l_i + 4l_j)}{21(1+2\gamma)}, \tag{7}$$

for $i = 1, 2$.

Equations (6) and (7) indicate that higher list prices allow suppliers to negotiate better (i.e., higher) terms with large buyers. The intuition is simple. An increase in l_i, while keeping w_i fixed, has a positive impact on D_i's net surplus, $\hat{\pi}_{D_i} - \bar{\pi}_{D_i}$, and a negative impact on U_i's net surplus, $\hat{\pi}_{U_i} - \bar{\pi}_{U_i}$. The positive impact on D_i's net surplus is easy to see: the reduction in competition from small buyers. The negative impact over U_i's net surplus is more difficult to see, as both $\hat{\pi}_{U_i}$ and $\bar{\pi}_{U_i}$ respond to changes in l_i in the same direction. However, since U_i's sales through small buyers are larger off path than on path, it turns out that $\bar{\pi}_{U_i}$ is more responsive to changes in l_i than $\hat{\pi}_{U_i}$ at any level of l_i.[20] Bargaining around these asymmetric impacts calls for a redistribution of surplus from D_i to U_i, which is done by increasing w_i. Later we see that this redistribution of surplus occurs regardless of the parties' bargaining powers.

Let us now move to the first stage of the game, when suppliers simultaneously announce list prices l_i and l_j. If U_i expects U_j to post a list price l_j that will invite D_j to bargain with him, then the payoff that U_i anticipates to receive from a list price l_i that will also invite D_i to bargain with him is equal to

$$\hat{\pi}_{U_i}(l_i, l_j) = w_i^{NB}(\cdot)q_i(w_i^{NB}(\cdot), w_j^{NB}(\cdot)) + l_i\gamma(p(w_i^{NB}(\cdot), w_j^{NB}(\cdot)) - l_i), \tag{8}$$

where $w_i^{NB}(\cdot) \equiv w_i^{NB}(l_i, l_j)$ is given by (7) and $p(w_i^{NB}(\cdot), w_j^{NB}(\cdot))$ is given by (4). Solving for the best response $l_i^*(l_j) = \arg\max_{l_i} \hat{\pi}_{U_i}(l_i, l_j)$ and imposing symmetry we arrive at the following proposition.

PROPOSITION 1. *The one-shot game with public (pb) list prices has a unique equilibrium in which suppliers* $i = 1, 2$ *announce list prices*

$$l_i^{pb} = \frac{43}{147 + 149\gamma}a,$$

[20] At low levels of l_i, both $\partial\hat{\pi}_{U_i}/\partial l_i$ and $\partial\bar{\pi}_{U_i}/\partial l_i$ are positive, which is when the price effect in U_i's profits from small buyers dominates the quantity effect, on and off path. At high levels of l_i, on the other hand, both $\partial\hat{\pi}_{U_i}/\partial l_i$ and $\partial\bar{\pi}_{U_i}/\partial l_i$ are negative, which is when the quantity effect dominates the price effect. In either case, however, $\partial\hat{\pi}_{U_i}/\partial l_i < \partial\bar{\pi}_{U_i}/\partial l_i$.

at stage one, and then negotiate wholesale prices

$$w_i^{NB}(l_i^{pb}, l_j^{pb}) \equiv w_i^{pb} = \frac{21 + 52\gamma}{(1 + 2\gamma)(147 + 149\gamma)} a < l_i^{pb},$$

with large buyers at stage two.

PROOF. Given that $w_i^{pb} < l_i^{pb}$, it is clear that D_i will prefer to bargain with U_i than to buy at l_i, confirming our initial guess. The rest of the proof, which is given in Appendix A, serves to (*i*) show uniqueness of equilibrium, and to rule out two other 'global' deviations, namely, (*ii*) that it is unprofitable for U_i to deviate to stop serving the small buyers and only bargain with the large buyer (for example, by setting $l_i \geq a$), and (*iii*) that it is unprofitable for U_i to deviate to a list price at which the large buyer is ready to buy along with the small buyers. □

To get some intuition as to how list prices are determined in equilibrium, note that a supplier has two sources of profits. As captured by the first and second terms in (8), these profits come from large and small buyers, respectively. An increase in list prices always helps U_i to increase his profits from the large buyer. There are two reasons for this. One is that a higher list prices increase D_i's residual demand, so U_i sells more through the large buyer. The second reason, as shown in (6) and (7), is that a higher list price allows U_i to obtain better terms from D_i.

Supplier U_i's second source of profits comes from the small buyers, the second term in (8). Increasing l_i has two effects: a price and a quantity effect. Supplier U_i benefits from the price effect (higher l_i), but suffers from the quantity effect (lower $\gamma(p - l_i)$). For low levels of l_i, the price effect dominates, so an increase in l_i also helps U_i to obtain higher profits from the small buyers. As l_i gets larger, so does the quantity effect relative to the price effect. There is a value of l_i at which the two effects cancel out. Above this level U_i faces a trade-off: destroying profits from small buyers against increasing profits from the large buyer. The list price in the proposition is the solution to that trade-off.

2.2. *What Drives Discounts?*

As seen from Proposition 1, the solution to U_i's trade-off results in large buyers obtaining discounts off list prices, that is, $l_i^{pb}/w_i^{pb} = 43(1 + 2\gamma)/(21 + 52\gamma) > 1$. Note that these discounts are not exogenously imposed; they emerge endogenously, as part of the equilibrium. There are two reasons for that. One is that selling through small buyers introduces too much competition in the downstream market. In fact, if small buyers were equally efficient as large buyers, i.e., if $\gamma \to \infty$, suppliers would be selling at cost to both small and large buyers. Small buyers present suppliers with a prisoner's dilemma: they introduce too much competition, but in a static framework suppliers have no means to commit not to serve them.

In equilibrium, suppliers maintain l_i above w_i in an effort to prevent small buyers from becoming too competitive. As we elaborate below, this 'softening competition' effect arises even if suppliers had all the bargaining power when negotiating with large buyers.[21]

The second reason is implicit in (6) and (7), which say, not only that higher list prices allow suppliers to negotiate better terms with large buyers, but also that any increase in list prices is not passed through one to one to negotiated prices, only a fraction of it (i.e., $\partial w_i^N(\cdot)/\partial l_i, \partial w_i^{NB}(\cdot)/\partial l_i < 1$). The reason for this incomplete pass-through follows from our

[21] In this case, we still have $l^{pb}/w^{pb} = 16(1 + 2\gamma)/(15 + 29\gamma) > 1$.

previous discussion and goes beyond our linear-Cournot setup. If the increase in list prices were to be passed through completely into w_i then D_i would be strictly worse off, for both fewer final consumers and a weaker competitive advantage relative to small buyers.

This would lead to a contradiction. We know from our previous discussion that any increase in list prices (while keeping w_i fixed), reports an extra net benefit to D_i, part of which is to be shared with U_i during negotiations in the form of a higher w_i. But, by the very definition of bargaining, no matter the bargaining weights, this sharing can never be such that D_i ends up worse off, so the pass-through must necessarily be less than one.

The exact level of this pass-through and, hence, of the discounts is in the end an empirical matter. Yet, our model serves to illuminate what to expect from the different factors that might explain the level of discounts.

One factor, which can be readily seen in Proposition 1, is the cost-effectiveness of small buyers relative to large buyers, here captured by the value of γ. Discounts, measured by the ratio l_i^{pb}/w_i^{pb}, are shown to be decreasing in γ. This is a direct consequence of the pass-through rate being increasing in γ (see either (6) or (7)). The latter is quite intuitive. As small buyers become more competitive, D_i sees a greater benefit from an increase in list prices. This, in turn, calls for a larger redistribution of surplus during negotiations from D_i to U_i in the form of an even larger w_i.

A second factor, which we have mentioned before, is parties' relative bargaining powers (or weights, to be more precise). Our model can be easily extended to the case of asymmetric bargaining weights. If we let $\beta \in (0, 1)$ and $1 - \beta$ be U_i and D_i's bargaining weights, respectively, then (7) becomes

$$w_i^{NB}(l_i, l_j) = \frac{(4+\beta)\beta a + \gamma((8+\beta^2)l_i + 6\beta l_j)}{(16-\beta^2)(1+2\gamma)}.$$

Not surprisingly, the pass-through is increasing in β. When $\beta \to 0$, the pass-through is just enough to leave U_i indifferent between increasing the list price and not (above the level where the price and quantity effects cancel out). This explains why discounts are decreasing in U_i's bargaining weight, as U_i can bargain a larger share of D_i's extra surplus from any increase in list prices (equilibrium list prices as a function of β can be found in Section V of the Online Appendix).

Can discounts ever disappear in our setting, in that suppliers serve both large and small buyers at exactly the same price in equilibrium? This requires suppliers to become relatively more aggressive in announcing their list prices.

A tractable way to explore this possibility is by giving each small buyer the option to order from either supplier according to a specification of Shubik and Levitan (1980) of the form (see Section II of the Online Appendix for details)

$$q_i^F = \gamma\left(p - \frac{1}{1-\eta}l_i + \frac{\eta}{1-\eta}l_j\right) \geq 0,$$

where $\eta \in [0, 1)$ captures how each small buyer sees the two suppliers, from infinitely distant ($\eta = 0$) to perfect substitutes ($\eta \to 1$). Our baseline setting assumes that $\eta = 0$.

As shown in Section II of the Online Appendix, negotiated prices, $w_i^{pb}(\eta)$, are still given by (7), but equilibrium list prices are now decreasing in η:

$$l_i^{pb}(\eta) = \frac{86(1-\eta)}{147(2-\eta) + 2\gamma(149-2\eta)}a.$$

Since list prices decrease with η at a faster rate than negotiated prices (another consequence of the incomplete pass-through from list to negotiated prices), there is a point, when $\eta = \underline{\eta}^{pb} \equiv 4(11 + 17\gamma)/5(13 + 22\gamma) < 1$,[22] at which discounts end in equilibrium: $l_i^{pb}(\underline{\eta}^{pb}) = w_i^{pb}(\underline{\eta}^{pb})$. For larger values of η, suppliers just announce list prices and all buyers, large and small, buy at that price. Suppliers never stop serving small buyers, at least not in expectation. For values of η sufficiently close to 1, suppliers randomise over whether to serve small buyers or not (i.e., to announce sufficiently high list prices that small buyers cannot afford and large buyers are invited to bargain).

2.3. *Colluding with Public List Prices*

Consider now the case in which suppliers are trying to collude. One can imagine two cases. One is when suppliers just coordinate on list prices and let negotiated prices follow accordingly, that is, according to $w_i^{NB}(l_i, l_j)$ in (7). Another case is, when in addition to agreeing on list prices, suppliers agree on approaching their large buyers with an initial offer that departs from $w_i^{NB}(l_i, l_j)$, but that nevertheless buyers may be willing to accept, and skip bargaining in order to prevent the collusive agreement from falling apart.

This second case is clearly more complicated to implement and sustain than the first. It requires suppliers, not only to communicate their collusive intentions to large buyers, but also to pay explicit attention to the buyers' incentive compatibility (i.e., no deviation) constraint.[23] For these two reasons, in what follows we concentrate on the more likely first case. We return to the second case at the end of Section 3.2 below and in Appendix B.

Thus, the suppliers' collusive problem is to announce list prices that maximise their joint payoff

$$\hat{\pi}_{U_1}(l_1, l_2) + \hat{\pi}_{U_2}(l_2, l_1),$$

subject to their incentive compatibility constraint (ICC)[24]

$$\hat{\pi}_{U_i}(l_i, l_j) \geq (1 - \delta)\hat{\pi}_{U_i}(l_i^d, l_j) + \delta\hat{\pi}_{U_i}(l_i^{pb}, l_j^{pb}),$$

and where $\hat{\pi}_{U_i}(x, y)$ is given by (8).

When U_i deviates from the agreement (l_i, l_j) by announcing $l_i^d < l_i$, all buyers and suppliers observe this deviation before they engage in negotiations. As a result, the expected negotiated prices that follow such deviation are $w_i^{NB}(l_i^d, l_j)$ and $w_j^{NB}(l_j, l_i^d)$, respectively, so U_i's deviation payoff, $\hat{\pi}_{U_i}(l_i^d, l_j)$, is the (expected) payoff as a function of this new set of negotiated prices and of l_i^d and l_j. Supplier U_i's punishment payoff, on the other hand, is the payoff of returning to the one-shot equilibrium of Proposition 1 indefinitely.[25]

[22] This cutoff level depends on the parties' bargaining weights; here we are presenting the cutoff for symmetric weights, i.e., $\beta = 1/2$.

[23] In our complete-information setting, buyers may infer that suppliers are trying to collude after observing list prices higher than those in Proposition 1. But a completely different matter is for buyers to be explicitly informed of suppliers' collusive intentions. There are obvious reasons why suppliers would not like to leave such footprints.

[24] The only deviation available to a large buyer is to refuse to negotiate or take the list price; neither one is profitable. Note also that negotiation breakdown, which is observable, cannot be interpreted as a deviation, as both parties end up strictly worse off.

[25] Stronger punishments (e.g., Abreu, 1988) are available, but they will not change anything fundamental in the analysis.

PROPOSITION 2. *If $\delta \geq \underline{\delta}^{pb} \in (1/2, 1)$ and $\gamma \leq \bar{\gamma} \approx 0.7$, the best collusive agreement on public (cpb) list prices is for suppliers $i = 1, 2$ to announce*

$$l_i^{cpb} = \frac{17}{49 + 27\gamma} a > l_i^{pb},$$

at stage one and then negotiate wholesale prices

$$w_i^{NB}(l_i^{cpb}, l_j^{cpb}) \equiv w_i^{cpb} = \frac{7 + 16\gamma}{(1 + 2\gamma)(49 + 27\gamma)} a > w_i^{pb},$$

with large buyers at stage two; otherwise, if $\gamma > \bar{\gamma}$, the best collusive agreement is for suppliers not to serve the small buyers on path, but to use them off path, as outside options, and announce

$$l_i^{cpb} = \frac{9 + 14\gamma}{21 + 32\gamma} a > l_i^{pb},$$

at stage one and then negotiate wholesale prices

$$w_i^{NB}(l_i^{cpb}, l_j^{cpb}) \equiv w_i^{cpb} = \frac{3 + 5\gamma}{21 + 32\gamma} a > w_i^{pb},$$

with large buyers at stage two. Relative to the one-shot competitive equilibrium characterised in Proposition 1, this collusive agreement (i) reduces the sales of small buyers, (ii) increases the sales of large buyers, (iii) reduces total sales and (iv) increases the profits of both suppliers and large buyers.

PROOF. See Appendix A. □

Agreeing on list prices allows suppliers to obtain better terms, not only from small buyers, but also, indirectly, from large buyers. When small buyers are too efficient (i.e., when $\gamma > \bar{\gamma}$), suppliers prefer not to serve them in equilibrium as they would introduce too much competition in the downstream market. However, suppliers still use them to obtain better terms from large buyers, but only as outside options in the case of a negotiation breakdown.[26] In fact, in the limit when the small buyers are equally efficient as the large buyers (i.e, $\gamma \to \infty$), suppliers can secure terms with large buyers ($5a/32$) that are strictly better than those had the small buyers not existed ($a/7$).

The incomplete pass-through from list to negotiated prices is also present in the collusive agreement. It explains why discounts are larger under collusion than under competition, i.e., $l_i^{cpb}/w_i^{cpb} > l_i^{pb}/w_i^{pb}$.

It is evident that the agreement has opposing implications for small and large buyers. While the former see their sales reduced, the latter see them expanded, and with that, their profits. In their attempt to soften competition in the retail market, a supplier's only choice is to increase the price paid by small buyers. As explained earlier, the resulting contraction of small buyers necessarily reports extra benefits to large buyers, part of which are distributed back to suppliers during their negotiations *via* higher wholesale prices.

Proposition 2 also shows that, when small buyers play a minor role in the market (i.e., $\gamma \to 0$), the collusive agreement reduces to the one-shot equilibrium of Proposition 1 (i.e., $w_i^{cpb} \to w_i^{pb}$), and list prices become irrelevant. It is the presence of small buyers ($\gamma > 0$) that allows suppliers

[26] As δ drops below the critical level $\underline{\delta}^{pb}$, suppliers must adjust the ambition of their agreement, which completely vanishes only as $\delta \to 0$. In Appendix A we also explain how $\underline{\delta}^{pb}$ depends on γ and η.

to use public announcements of list prices to coordinate on higher prices to both small and large buyers. This 'multi-buyer' contact effect is reminiscent of the multi-market contact effect of Bernheim and Whinston (1990), but is actually different. It is not as if suppliers transfer collusive discipline from one group to the other. Instead, collusion over one group has spillover effects over a second group through the downstream market.

Does this mean that suppliers cannot sustain collusion on prices in the absence of small buyers? As shown in Section III of the Online Appendix, suppliers can in principle sustain collusion in the absence of small buyers, but that would require access to lump-sum transfers, e.g., bargaining over two-part tariffs. The reason they cannot sustain collusion when they bargain only over linear prices is that they have only one instrument to accomplish two goals: to soften competition downstream and to share part of the resulting rents with buyers.

The possibility of bargaining over two-part tariffs adds a new element to suppliers' collusive agreements, which is the need to pay attention, not only to their ICCs, but also to the (large) buyers', and compensate them accordingly.[27] More interesting for the purpose of our paper is that the role of public list prices in helping suppliers to obtain better terms from both small and large buyers extends to the case where suppliers and large buyers negotiate over two-part tariffs. But, to grasp why this is the case, we need to understand first the difference it makes to move from public to private list prices in our baseline setting, where suppliers and large buyers negotiate over linear prices. We turn to that next.

3. From Public to Private List Prices

Consider now a situation in which suppliers do not have the opportunity to publicly announce the list prices to be charged to small buyers before they bargain with large buyers. Large buyers and rival suppliers are now forced to form expectations about the price offers small buyers will privately get while negotiations take place. In terms of our model, we are merging stages one and two into a single stage: suppliers now approach all buyers, large and small, simultaneously.

The rest of this section is organised as follows. We first discuss the implications for competition of moving from public to private list prices. We continue denoting private list prices by l_i and l_j. We then discuss the implications of such a move for collusion.

3.1. *Competitive Equilibrium with Private List Prices*

Since U_i now approaches D_i at the same time as he approaches the small buyers, during their negotiation, not only U_i and D_i must form (correct) expectations of the prices l_j and w_j at which U_j would sell his products, but also D_i must form correct expectations about the price l_i that U_i would offer each of the small buyers. In this game of complete information one could imagine that U_i might like to offer different prices to different small buyers. He has no incentives to do so; he cares only about demand (2), i.e., the small buyers' aggregate demand.[28]

[27] The need to compensate buyers is not new. See, for example, the discussions in Marshall and Marx (2012, chs.2 and 6), Marshall *et al.* (2008), Garrod *et al.* (2021) and the European Commission's decision on the *Vitamins* case: Case COMP/E-1/37.512 - Vitamins, Comm'n Decision (Nov 21, 2001), para 325.

[28] To see this, let $q_{ik}^F = \gamma_k(p - l_{ik})$ be fringe buyer ik's demand as a function of its list price l_{ik} and retail price p, where $\int_0^1 \gamma_k dk = \gamma$. Supplier U_i's problem is to choose the vector $\{l_{ik}\}_{k=0}^{k=1}$ of list prices that maximises his payoff $\int_0^1 l_{ik} q_{ik}^F dk$ for a given target $\bar{q}_i^F$ (the actual chosen target, which will depend on expectations about the outcome in the remaining negotiations, is not relevant). Thus, the solution to U_i's problem is given by the first-order condition (note that

Since U_i has no incentives to discriminate across (heterogeneous) small buyers,[29] there is no loss in assuming that U_i will charge the same price l_i to each of them (in other words, it makes no difference in our setting whether small buyers assume that each of them get the same price offer because U_i is constrained not to discriminate or small buyers must form expectations about the price offers other small buyers get in equilibrium).

The equilibrium concept we adopt to find the outcome of this multi-buyer bargaining problem is the Nash-in-Nash concept (Horn and Wolinsky, 1988; Collard-Wexler *et al.*, 2019). The Nash-in-Nash solution is the set of price agreements w_i^{pr}, l_i^{pr}, w_j^{pr} and l_j^{pr} such that w_i^{pr} is the Nash solution to the bargaining problem between U_i and D_i given that both anticipate correctly that the other prices will be l_i^{pr}, w_j^{pr} and l_j^{pr} (we use superscript '*pr*' to indicate competitive equilibrium under private list prices). Similarly, l_i^{pr} is the Nash solution to the bargaining problem between U_i and each of his small buyers given that both anticipate correctly that the other prices will be w_i^{pr}, w_j^{pr} and l_j^{pr}.

The only difference with settings where the Nash-in-Nash concept has been used in the past is that here many negotiations, those of U_i and each of the many small buyers, have one of the parties, here U_i, with all the bargaining power. This implies that l_i^{pr} can be readily obtained from U_i's best response to the other prices, that is,

$$l_i^{pr} = \arg\max_{l_i} \{\hat{\pi}_{U_i}(w_i^{pr}, l_i, w_j^{pr}, l_j^{pr}) = w_i^{pr} q_i(w_i^{pr}, l_i, w_j^{pr}, l_j^{pr}) \\ + l_i \gamma (p(w_i^{pr}, l_i, w_j^{pr}, l_j^{pr}) - l_i)\}, \tag{9}$$

where $q_i(\cdot)$ and $p(\cdot)$ are given by (3) and (4), respectively.

To obtain w_i^{pr}, assume that U_i's initial offer is large enough for D_i to engage in negotiations, that is, to maximise the Nash product (recall that $\bar{\pi}_{D_i} = 0$)

$$w_i^{pr} = \arg\max_{w_i} \{\hat{\pi}_{U_i}(w_i, l_i^{pr}, w_j^{pr}, l_j^{pr}) - \bar{\pi}_{U_i}(l_i^{pr}, w_j^{pr}, l_j^{pr})\}\hat{\pi}_{D_i}(w_i, l_i^{pr}, w_j^{pr}, l_j^{pr}), \tag{10}$$

where $\bar{\pi}_{U_i} = l_i^{pr} \gamma (\bar{p}(l_i^{pr}, w_j^{pr}, l_j^{pr}) - l_i^{pr})$ and $\bar{p}(\cdot)$ is given by (5). Expressions (9) and (10), for $i = 1, 2$, characterise the outcome of the one-shot game, which is summarised in the next proposition.

PROPOSITION 3. *The one-shot game with private (pr) list prices has a unique equilibrium in which suppliers $i = 1, 2$ make take-it-or-leave-it (list-price) offers*

$$l_i^{pr} = \frac{5}{3(7+8\gamma)} a,$$

to small buyers and simultaneously negotiate wholesale prices

$$w_i^{NB}(l_i^{pr}, l_j^{pr}) \equiv w_i^{pr} = \frac{3+7\gamma}{3(1+2\gamma)(7+8\gamma)} a < l_i^{pr},$$

with large buyers.

the retail price p depends on $\bar{q}_i^F$ along with the remaining quantities)

$$\gamma_k p(\bar{q}_i^F, \cdot) - 2\gamma_k l_{ik} - \lambda \gamma_k l_{ik} = 0,$$

for all k, and where λ is the Lagrange multiplier of the quantity constraint $\bar{q}_i^F = \int_0^1 q_{ik}^F dk$. It is clear that it is optimal for U_i to set the same list price to all fringe buyers, l_i. Note that this result extends to more general demand functions, e.g., $q_{ik}^F = \gamma_k f(p - l_{ik})$ with $f'(\cdot) > 0$ and $f''(\cdot) \leq 0$.

[29] Incentives would surely change if suppliers could use two-part tariffs, which we are ruling out here and with regard to large buyers.

PROOF. The only global deviation we need to rule out is that U_i's initial offer to D_i is never such that D_i skips bargaining. The latter would require this offer to be lower than w_i^{pr}, leaving U_i strictly worse off, a contradiction. The proof of uniqueness of equilibrium follows the proof of Proposition 1, so it is omitted. In Appendix A we extend the game to $\eta > 0$ and show that the equilibrium outcome characterised above extends to $\eta \leq \underline{\eta}^{pr} \equiv (4 + 6\gamma)/(7 + 12\gamma) < 1$. □

As with public list prices (Proposition 1), the competitive equilibrium with private list prices exhibits discounts off list prices. The intuition for these discounts is the same. The main difference between Propositions 1 and 3 is that, under public list prices, suppliers can commit to higher list prices and, hence, to better terms from large buyers.

By publicly communicating in advance—before bargaining with large buyers—the price to be charged to small buyers, suppliers solve a commitment problem, akin to that in Hart and Tirole (1990), which is the temptation to offer better deals to small buyers after setting terms with large buyers. We refer to this as the *commitment* effect of public list prices.[30]

The incomplete pass-through from list to negotiated prices that we documented for the case of public list prices extends to the case of private list prices. Any increase in list prices, whether observed or conjectured, is not passed through one to one to negotiated prices, only a fraction of it. This leads to the following proposition.

PROPOSITION 4. *In a world where suppliers compete, moving from public to private list prices results in (i) lower prices for small and large buyers, (ii) smaller discounts for large buyers, (iii) an increase in the sales of small buyers and a decrease in the sales of large buyers, (iv) lower retail prices and (v) a decrease in the profits of suppliers and large buyers.*

PROOF. The proof follows from Propositions 1, 2 and 3. □

An important condition for the commitment effect in Proposition 4 to operate is the presence of discounts. If suppliers compete too aggressively for small buyers—for instance, when η is sufficiently large—then the commitment effect vanishes, making no difference for competition whether list prices are public or private. This happens in our model when $\eta \geq \underline{\eta}^{pb} > \underline{\eta}^{pr}$.

3.2. *Colluding with Private List Prices*

Collusion may also be affected as we move from public to private list prices. In the one-shot game leading to Proposition 3, it was more or less straightforward for large buyers to conjecture about the prices suppliers would offer small buyers. In a repeated interaction, where multiple equilibria may coexist, this conjecture is far less obvious, not least because buyers may form different conjectures. This in itself renders communication between suppliers and large buyers almost a necessary condition for any collusive agreement to be successful.

To get supra-competitive profits, suppliers must convince large buyers that the list prices small buyers will pay in equilibrium will be higher than those they would otherwise pay in the non-collusive (i.e., static) equilibrium. Suppliers may be reluctant to share their collusive intentions with large buyers for obvious reasons (not to leave a footprint), even if the latter benefit from such intentions. Buyers, in turn, may want to avoid being caught in a conspiracy to increase prices to

[30] While the timing in the public-list-price case does not explicitly consider the possibility for a supplier to revise his list-price offer to any small buyer, it is a natural thing to consider, particularly if it is a more convenient (i.e., lower) offer. In this case, the repeated interaction is what would allow the supplier to credibly (and unilaterally) commit to his public offers.

final consumers. Either way, moving from public to private list prices would make collusion less likely.

Collusion is less likely under private list prices even if one dispenses from this communication requirement. Suppose that in their repeated interaction buyers conjecture that suppliers will agree on the pair of list prices that result in the best possible collusive equilibrium, for instance, the one in Proposition 2, if suppliers were sufficiently patient. The relevant question then is whether such a collusive agreement is easier to sustain (i.e., demands a lower discount factor) under public or private list prices.

The answer is not obvious because, like in many collusion analyses (see, e.g., Marshall and Marx, 2012), deviation and punishment forces act in different directions. On the one hand, deviations are less attractive under public list prices because they are detected before suppliers bargain with large buyers, as opposed to when all prices are determined simultaneously. On the other hand, and as seen from Proposition 4, private list prices result in harsher punishments (i.e., stronger one-shot competition) than public list prices, unless $\eta \geq \underline{\eta}^{pb}$, in which case there is no difference. It is clear then that, for higher values of η, collusion is easier to sustain under public than private list prices.

As η drops below $\underline{\eta}^{pb}$, the punishment force becomes relatively more important (there is more competition under private than under public list prices). It can be shown, however, that the punishment force is never strong enough to completely offset the deviation force, except in a vanishingly small and irrelevant range of parameter values, when collusion and competition are indistinguishable.[31] We can summarise this discussion in the following proposition.

PROPOSITION 5. *Suppose that* $\gamma > \gamma^c(\eta) \in [0, 1/25]$. *Moving from public to private list prices makes the collusive agreement of Proposition 2 more difficult to sustain: it increases the critical discount factor required to sustain collusion from* $\underline{\delta}^{pb}$ *to* $\underline{\delta}^{pr} > \underline{\delta}^{pb}$. *Whether this move results in less collusion or no collusion, the outcome is qualitatively the same: both small and large buyers see their prices drop, although large buyers see a smaller drop.*

PROOF. Whether collusion is terminated altogether or diminished, the incomplete pass-through from list to negotiated prices explains why large buyers see a smaller drop in their prices as we move from public to private list prices. The proof that collusion is more difficult to sustain under private list prices when $\gamma > \gamma^c(\eta) \in [0, 1/25]$ is given in Appendix A. □

Collusion with private list prices would likely require some communication between suppliers and large buyers, at least for the latter to correctly anticipate the list prices suppliers intend to charge small buyers. But, if suppliers are ready to share their intentions to collude with large buyers, why not go a step further, from 'soft' to 'hard' communication? In addition to communicating list prices, why not make large buyers an offer that departs from the Nash-bargaining solution that would ensue such list prices?

This hard form of communication raises two issues. One is that suppliers must now pay explicit attention to (large) buyers' ICCs, that is, suppliers need to make sure that buyers will accept their initial offers and skip bargaining. The way suppliers secure these better terms (better than under soft communication) is by exploiting the fact that a rejection of either supplier's initial offer (and

[31] When $\eta \geq 1/29$, there is no value of γ below which the critical discount factor with private list prices ($\underline{\delta}^{pr}$) is smaller than with public list prices ($\underline{\delta}^{pb}$). When $\eta = 0$, $\underline{\delta^{pr} > \underline{\delta}^{pb}}$ for $\gamma < 1/25$, which is where collusion and competition are indistinguishable (e.g., $w_i^{cpb}/w_i^{pb} = 1.005$ when $\gamma = 1/50$). Adding an arbitrarily small probability of being investigated by the competition authority rules out any possibility of collusion for low values of γ.

subsequent invitation to bargain) would be interpreted as a deviation from the agreement by his rival supplier, shattering the agreement and leaving both suppliers and large buyers worse off.

The second issue is that this opportunity to secure better terms is also available under public list prices. Nothing prevents suppliers from approaching buyers with offers that depart from the Nash-bargaining solution following the list price announcements made at the previous stage. We formally address these issues in Appendix B and show that the message of Proposition 5, that collusion is easier to sustain with public list prices, extends to the case of hard communication.

4. Can Our Theory Inform Conduct?

The main lesson that emerges from Propositions 4 and 5 is that price transparency—here, making list prices publicly available to everyone—unambiguously leads to higher prices, whether facilitating collusion (Proposition 5) or softening competition (Proposition 4). Another lesson that emerges from these propositions is that it may prove difficult for an antitrust authority to separate collusive from competitive conduct by simply looking at how prices (and eventually quantities) respond to a move from public to private list prices (and vice versa). For the most part, what distinguishes one conduct from the other in our theory is a matter of magnitude: in both cases suppliers take advantage of public list prices to obtain better terms from large buyers, only that in one case they do it in a coordinated fashion and in the other independently.

In general, it is difficult for authorities to separate collusive from competitive conduct by simply looking at the evolution of economic variables. One exception, for example, is the theory of Rotemberg and Saloner (1986). According to this theory, collusion is more difficult to sustain when demand is expected to decline or cost to increase, so if at two different times we observe different prices despite their demands and costs being equal, then this can only be consistent with collusive behaviour (under competition, prices would have been the same).[32] We want to explore here whether our theory can provide similar qualitative insights.

So far, we have considered the cases in which either both suppliers use public list prices or both use private list prices. The asymmetric case when only one of them uses public list prices is interesting for the following reason: does the public announcement of list prices by all suppliers require coordination? If it does, it makes it more likely that suppliers are also coordinating prices. Either way, our theory would suggest some coordination, enough to initiate a deeper investigation.

It is clear that no supplier would like to switch from public to private list prices when rivals are using public list prices, as public list prices can always replicate the work of private list prices. But would a supplier like to switch from private to public list prices—provided the technology exists (whether that is a newspaper or trade association)—when his rivals continue using private list prices? The answer is not obvious because, as shown in Section VI of the Online Appendix, the payoff of the supplier switching to public list prices is lower than the payoff of the supplier staying on private list prices.[33]

It turns out, however, that this lower payoff does not prevent a supplier from making the switch to public list prices, whenever available, regardless of what rivals do. Furthermore, if the opportunity to switch to public list prices becomes available to the second supplier, he will proceed with the switch. In other words, switching to (or staying on) public list prices is the equilibrium of the one-shot game.

[32] Borenstein and Shepard (1996) exploited this insight to test for tacit collusion in the retail gasoline market.

[33] Depending on γ, the public list price announced by the switching supplier can be higher or lower than l^{pb}, the equilibrium price when both suppliers use public list prices.

There are other instances in which our theory can be more informative about conduct, at least to better screen cases for further investigation. One is when small buyers are sufficiently efficient (i.e., when $\gamma > \bar{\gamma}$) enough for suppliers not to serve them under collusion (Proposition 2), while they are always served under competition (Propositions 1 and 3). Thus, a move from public to private list prices that results in a strong expansion of small buyers can only be consistent with collusive conduct when list prices were public.[34]

A second instance in which our theory could inform conduct is when suppliers compete relatively intensely for small buyers (i.e., when $\eta \geq \underline{\eta}^{pb}$), enough for the commitment effect to disappear. In this case suppliers set list prices low enough that in (competitive) equilibrium they stop negotiating discounts off list prices with large buyers. This eliminates any difference between public and private list prices, as long as suppliers compete. Therefore, observing the elimination of discounts as we move from public to private list prices makes it very likely that suppliers were colluding when list prices were public.[35]

The commitment effect could also disappear in a setting with $\eta = 0$ and where large suppliers U_1 and U_2 share the upstream market with small suppliers who can serve both small and large buyers. Small suppliers would force large suppliers to match their prices for small buyers. In turn, large buyers would make reference to these prices as outside options in their negotiations with large buyers. But, unless small suppliers form a perfectly elastic supply, this outside option poses a limit. A large buyer exercising this outside option would necessarily face an upward sloping supply curve. As a result, the off-path price paid to small suppliers would be higher than that observed on path. When small suppliers are sufficiently efficient, this price difference should extinguish any discount in competitive equilibrium, both under public and private list prices.[36]

Based on these two empirically testable observations, can our theory say more about the fresh-egg market, as to whether the evolution of prices shown in Table 1 is more consistent with competition or collusion before the newspaper interrupted the publication of list prices?

Unfortunately, our empirical analysis and data do not allow us to say much more. On the one hand, Table 1 shows that discounts continued to exist after the newspaper interruption, despite their big reduction from 19% to 11%. On the other hand, our data are too limited to test for a possible strong expansion of small buyers after the newspaper interruption. Such expansion should be reflected, not only in a significantly larger market share, but also in a more diversified purchasing pattern, leaning more toward the (large) suppliers taking part of the newspaper

[34] The market share expansion of small buyers would jump from zero to $2\gamma/(3+8\gamma)$; for example, to 18% if $\gamma = 1$.

[35] Strictly speaking, competition with public list prices could accept some very small discounts, since $\underline{\eta}^{pr}$ is slightly smaller than $\underline{\eta}^{pb}$.

[36] We have formally modelled the case of a perfectly elastic supply of small suppliers, which delivers some interesting results, but is quite unrealistic (small suppliers never sell on path). For instance, we find that, when large suppliers compete with public list prices, the introduction of small suppliers has a non-monotonic impact on downstream buyers. When small suppliers are little competitive, buyers are affected in different directions: large buyers benefit (negotiate lower prices), while small buyers suffer (pay higher list prices). The reason large buyers benefit is because small suppliers are now a suitable outside option for them in the case of a negotiation breakdown. Anticipating this, large suppliers set even higher (public) list prices to countervail this outside-option effect. As small suppliers become more competitive, all buyers benefit. This non-monotonic impact on buyers does not extend to private list prices. As soon as small suppliers become a suitable outside option to large buyers, small buyers also benefit from the better terms that large buyers negotiate (and more so, given the incomplete pass-through from list to negotiated prices). The upward-sloping-supply case, while far more realistic, is much more difficult to tackle. Among other things, it introduces Cournot players procuring units from different suppliers, some with increasing costs (e.g., capacity constraints), which would lead to some rationing.

publication. None of this can be properly tested with our data since we only have information from two large suppliers that together account for no more than 16% of the market.

5. Conclusions

The goal of this paper has been to contribute to a better understanding of whether, how and to what extent price transparency could help suppliers to sustain supra-competitive prices. Our focus has been on markets where suppliers sell to wholesale buyers (i.e., distributors) of different sizes, large and small, who in turn compete for final consumers in the retail market. Small buyers lack any bargaining power, so, for the most part, they pay list prices, while large buyers bilaterally negotiate discounts off list prices. One example is Chile's fresh-egg market, which partly motivated this study, but there are many others.

In this wholesale-retail context, we find that price transparency—here, having suppliers making simultaneous public announcements of list prices—unambiguously leads to higher prices, whether facilitating collusion or softening competition. Our theory predicts that these public announcements lead, not only to higher list and negotiated prices, but also to larger discounts off list prices. The latter is due to the incomplete pass-through from list to negotiated prices. There are cases in which our theory can help separate collusive from competitive conduct by looking at changes in economic variables; for instance, an end of discounts and/or a strong market expansion of small buyers.

Our theory fits well the evolution of wholesale prices in the fresh-egg market, which saw a sudden interruption in the publication of their list prices in the local newspaper. What our theory cannot tell in this particular case (but could in others) is whether the drop in prices and discounts that followed the interruption is more consistent with competition or collusion during the time when list prices were public. Distinguishing between the two may require further empirical (and structural) analysis, possibly using additional data from the retail market. Clearly, this is something beyond the scope of this paper.[37]

Appendix A. Omitted Proofs

Proof of Proposition 1.

We use this section to (*i*) show uniqueness of equilibrium, and to rule out two 'global' deviations, namely, (*ii*) that it is unprofitable for U_i to deviate to stop serving the small buyers (for example, by setting $l_i \geq a$) and only bargain with the large buyer, and (*iii*) that it is unprofitable for U_i to deviate to a list price at which the large buyer is ready to buy along with the small buyers.

Part (i). To show uniqueness, we proceed by showing uniqueness in each stage of the game. In the last stage, distributors play a standard Cournot game that has a unique equilibrium. In the bargaining stage, given l_1, l_2 and w_j, U_i and D_i bargain over a compact, convex set. In addition, both $\hat{\pi}_{U_i}(w_i) - \bar{\pi}_{U_i}$ and $\hat{\pi}_{D_i}(w_i) - \bar{\pi}_{D_i}$ are strictly log-concave, so the Nash product is strictly quasi-concave and the bargaining solution unique. This leads to a 2×2 system of linear equations with a unique, symmetric solution, (7) in the main text. It remains to prove that there is

[37] In a settlement presentation to Chile's Competition Tribunal in October 2023, we learned that the National Economic Prosecutor had initiated an investigation of egg producers in October 2018 following its instruction to the local newspaper to end the publication of their list prices (as well as list prices of other products). The National Prosecutor decided to close the investigation and settle with the egg producers in exchange for a series of obligations, including a payment of one million dollars.

a unique pair (l_1, l_2) that solves the suppliers' problem in the first stage. Both objective functions are strictly concave in their respective list prices, meaning that their solutions yield a unique 2×2 system of equations with a unique, symmetric solution.

Part (ii). Suppose that U_1 deviates and sets $l_1 \to \infty$. To find the wholesale prices w_1 and w_2 that parties negotiate following such a deviation, solve the system of first-order conditions

$$\frac{1}{\hat{\pi}_{U_i} - \bar{\pi}_{U_i}} \frac{\partial \hat{\pi}_{U_i}}{\partial w_i} + \frac{1}{\hat{\pi}_{D_i} - \bar{\pi}_{D_i}} \frac{\partial \hat{\pi}_{D_i}}{\partial w_i} = 0, \tag{A1}$$

for $i = 1, 2$, where $\bar{\pi}_{U_1} = \bar{\pi}_{D_1} = \bar{\pi}_{D_2} = 0$, $\bar{\pi}_{U_2} = l_2\gamma(\bar{p} - l_2)$, $\hat{\pi}_{U_1} = w_1 q_1$, $\hat{\pi}_{U_2} = w_2 q_2 + l_2\gamma(p - l_2)$ and $\bar{p}$ is the price that would prevail in the case U_2 and D_2 fail to reach an agreement, i.e., $\bar{p} = ((a + \gamma l_2)/(1 + \gamma) + w_1)/2$. Substituting the latter, $p = ((a + \gamma l_2)/(1 + \gamma) + w_1 + w_2)/2$ and $q_i = (a + \gamma l_2 - (1 + \gamma)(2w_i - w_j))/3$ into (A1) and solving yields

$$w_1 = w_1^{NB}(\infty, l_2) = \frac{3a + 4\gamma l_2}{21(1 + \gamma)},$$

and

$$w_2 = w_2^{NB}(l_2, \infty) = \frac{3a + 11\gamma l_2}{21(1 + \gamma)}.$$

From here, it is easy to establish for $l_2 = l_2^{pb}$ that $\hat{\pi}_{U_1}(\infty, l_2^{pb}) < \hat{\pi}_{U_1}(l_1^{pb}, l_1^{pb})$ for all γ.

Part (iii). Let us now demonstrate that suppliers have no incentives to let large buyers also buy at list prices. Suppose that U_j were to deviate to a list price l_j^d that D_j is ready to buy from. Setting $w_j = l_j = l_j^d$ in (6), we know that U_i and D_i would respond to such a deviation by agreeing on

$$w_i^N(l_i^{pb}, l_j^d) = [a + (1 + 3\gamma)l_j^d + 4\gamma l_i^{pb}]/8(1 + 2\gamma),$$

where l_i^{pb} is the equilibrium list price stated in the proposition. Anticipating this response, U_j's optimal deviation would be to leave D_j indifferent between accepting l_j^d and bargaining with him. In other words, l_j^d should be such that

$$q_j^2(l_j^d, w_i^N(\cdot)) = q_j^2(w_j^N(w_i^N(\cdot)), w_i^N(\cdot)) + \epsilon, \tag{A2}$$

with $\epsilon \to 0$ and where, following (6), $w_j^N(w_i^N(\cdot))$ is given by (recall that after observing l_j^d, U_i and D_i expect D_j to skip negotiations and buy at l_j^d)

$$w_j^N(w_i^N(\cdot)) = \frac{a + (1 + 2\gamma)w_i^N(l_i^{pb}, l_j^d) + \gamma(4l_j^d + l_i^{pb})}{8(1 + 2\gamma)}.$$

Using (3) and solving (A2) we obtain

$$l_j^d = \frac{441 + 619\gamma}{(147 + 149\gamma)(21 + 31\gamma)} a.$$

But,

$$\hat{\pi}_{U_j}(l_j^d, l_i^{pb}) - \hat{\pi}_{U_j}(l_j^{pb}, l_i^{pb}) = -\frac{4\gamma(441 + 619\gamma)(11 + 17\gamma)^2}{(1 + 2\gamma)(147 + 149\gamma)^2(21 + 31\gamma)^2} < 0,$$

so it is strictly unprofitable for U_j to deviate to a list price that D_j would accept for all $\gamma > 0$. □

Proof of Proposition 2.
In part (i) we show the existence of $\bar{\gamma}$, and in part (ii) we show that $\underline{\delta}^{pb} \in (1/2, 1)$.

Part (i). To simplify the exposition, suppose that $\eta = 0$ and γ is small enough so small buyers are served under the collusive scheme. If so, their supply is given by

$$q_i^F = \gamma(p - l_i^{cpb}) = \frac{\gamma(4 - 3\gamma)}{(49 + 27\gamma)(1 + 2\gamma)}a.$$

This implies that there exists a value of $\gamma \leq 4/3$ when it is optimal for the suppliers to stop serving the small buyers along the collusive path. This can be done following two distinct strategies. One is to agree on list prices high enough (e.g., $l_i > a$) that small buyers never supply to the downstream market, neither on path nor off path (i.e., in the case of a negotiation breakdown). The other strategy is to agree on list prices not so high that small buyers do not supply on path, but they do off path. By improving their outside options, suppliers can negotiate better terms under the latter strategy.

Let l_i and l_j be the list prices that suppliers agree on under the latter strategy. These prices must be such that the negotiated prices $w_i^{NB}(l_i, l_j)$ and $w_j^{NB}(l_i, l_j)$ that follow such announcements lead to an equilibrium price in the retail market, $p(w_i^{NB}(\cdot), w_j^{NB}(\cdot))$, that, for incentive-compatibility-constraint (ICC) reasons, just reduces the supply of small buyers to zero, that is,

$$\gamma(p(w_i^{NB}(l_i, l_j), w_j^{NB}(l_j, l_i)) - l_i) = 0, \tag{A3}$$

for $i = 1, 2$.

Substituting (7) into (A3) and solving for $l_i = l_j$ we arrive at the list prices stated in the proposition for $\gamma > \bar{\gamma}$. Finally, to find $\bar{\gamma}$, we equalise the suppliers' profits for the list prices stated in the proposition when $\gamma \leq \bar{\gamma}$ with those for the list prices when $\gamma > \bar{\gamma}$, leading to the equation

$$3(3 + 5\gamma)(2 + 3\gamma)(49 + 27\gamma)(1 + 2\gamma) - (2 + 7\gamma)(21 + 32\gamma)^2 = 0,$$

which has two real solutions, a trivial one (zero) and the one we are interested in, $\bar{\gamma} = 0.6898$.

Part (ii). For simplicity, here we focus on $\gamma \leq \bar{\gamma}$ and the values of η that are not too large so discounts emerge on and off path (the other cases follow similar steps, so they are omitted). Since collusion is in list-price announcements and large buyers observe them before their negotiations, we only need to pay attention to suppliers' ICCs. The critical discount factor $\underline{\delta}^{pb}$ is the solution to

$$\hat{\pi}_{U_i}(l^{cpb}, l^{cpb}, w_i^{NB}(\cdot), w_j^{NB}(\cdot)) = (1 - \underline{\delta})\hat{\pi}_{U_i}(l_i^d, l^{cpb}, w_i^{NB}(\cdot), w_j^{NB}(\cdot)) + \underline{\delta}\hat{\pi}_{U_i}(l^{pb}, l^{pb}, w_i^{NB}(\cdot), w_j^{NB}(\cdot)), \tag{A4}$$

where $w_i^{NB}(l_i, l_j)$ is given by (7) and

$$l_i^d = \frac{86(147 + 149\gamma) - 5\eta(1029 - 436\gamma)}{2(49 + 27\gamma)(441 + 619\gamma + 263\gamma\eta)}a = \arg\max_{l_i} \hat{\pi}_{U_i}(l_i, l_j^{cpb}, w_i^{NB}(\cdot), w_j^{NB}(\cdot)).$$

Note that only $\hat{\pi}_{U_i}(l_i^d, l^{cpb}, w_i^{NB}(\cdot), w_j^{NB}(\cdot))$ and $\hat{\pi}_{U_i}(l_i^{pb}, l_j^{pb}, w_i^{NB}(\cdot), w_j^{NB}(\cdot))$ depend on η. Substituting l_i^d into (A4) and solving we obtain an expression for $\underline{\delta}^{pb}(\gamma, \eta)$ that, for $\eta = 0$, reduces to $\underline{\delta}^{pb}(\gamma, 0) = (147 + 149\gamma)^2/2(21\,609 + 43\,022\gamma + 19\,457\gamma^2) \in (1/2, 1)$. To show that $\underline{\delta}(\gamma, \eta)$ is increasing in both γ and η is tedious but not difficult. □

Proof of Proposition 3.

Here we extend the proposition to the case of $\eta > 0$. We know from (6) that if U_i and D_i conjecture that the terms agreed on the remaining negotiations are l_i, w_j and l_j, then they will agree on

$$w_i^*(l_i, w_j, l_j) = (a + (1 + 2\gamma)w_j + \gamma(4l_i + l_j))/8(1 + 2\gamma).$$

Similarly, U_i will set l_i as the best response to his conjectures on w_i, w_j and l_j, that is,

$$l_i^*(w_i, w_j, l_j) = \arg\max_{l_i} w_i q_i + l_i \gamma \left(p - \frac{1}{1-\eta} l_i + \frac{\eta}{1-\eta} l_j \right),$$

where p and q_i are given by (4) and (3), respectively.

To obtain the equilibrium prices l^{pr} and w^{pr}, we apply symmetry, i.e., $l_i = l_j = l^{pr}$ and $w_i = w_j = w^{pr}$, and solve the systems (i) $w_i^*(l^{pr}, w^{pr}, l^{pr}) = w^{pr}$ and (ii) $l_i^*(w^{pr}, w^{pr}, l^{pr}) = l^{pr}$, which yields

$$l^{pr} = \frac{10(1-\eta)}{6(7+8\gamma) - 3\eta(7+2\gamma)} a,$$

and

$$w^{pr} = \frac{2(3+7\gamma) - \eta(3+8\gamma)}{6(1+2\gamma)(7+8\gamma) - 3\eta(1+2\gamma)(7+2\gamma)} a.$$

These equilibrium prices are valid as long as D_i is ready to bargain with U_i instead of asking U_i for the same list-price offer made to small buyers, that is, as long as D_i anticipates that $w_i^*(l^{pr}, w^{pr}, l^{pr}) = w^{pr} < l^{pr}$, which requires

$$\eta < \frac{2(2+3\gamma)}{7+12\gamma} \equiv \underline{\eta}^{pr}.$$

□

Proof of Proposition 5.

Let us denote by $\hat{\pi}_{U_i}^c = \hat{\pi}_{U_i}^{cpb} = \hat{\pi}_{U_i}^{cpr}$ a supplier's per-period profit along the collusive path, whether under private or public list prices; by $\hat{\pi}_{U_i}^{dpr}$ and $\hat{\pi}_{U_i}^{dpb}$ the one-period deviation profits under private and public list prices, respectively; and by $\hat{\pi}_{U_i}^{pr}$ and $\hat{\pi}_{U_i}^{pb}$ the per-period competition profits under private and public list prices, respectively. We want to demonstrate that

$$\underline{\delta}^{pr}(\gamma, \eta) = \frac{\hat{\pi}_{U_i}^{dpr} - \hat{\pi}_{U_i}^c}{\hat{\pi}_{U_i}^{dpr} - \hat{\pi}_{U_i}^{pr}} > \frac{\hat{\pi}_{U_i}^{dpb} - \hat{\pi}_{U_i}^c}{\hat{\pi}_{U_i}^{dpb} - \hat{\pi}_{U_i}^{pb}} = \underline{\delta}^{pb}(\gamma, \eta), \tag{A5}$$

for all η and $\gamma > \gamma^c(\eta) \in [0, 1/25]$.

We know that, for high values of η, where $\hat{\pi}_{U_i}^{pr} = \hat{\pi}_{U_i}^{pb}$, (A5) holds immediately since $\hat{\pi}_{U_i}^{dpr} > \hat{\pi}_{U_i}^{dpb}$ for all γ and η. So, we focus on low values of η, where $\hat{\pi}_{U_i}^{pr} < \hat{\pi}_{U_i}^{pb}$. We initiate our analysis for low values of γ (below $\bar{\gamma}$), when small buyers are served along the collusive path (the same analysis extends with minor adjustments to higher values of γ, so it is omitted).

Expressions for $\hat{\pi}_{U_i}^{pb}$, $\hat{\pi}_{U_i}^c$ and $\hat{\pi}_{U_i}^{pr}$ are easily obtained using the list and negotiated prices stated in Propositions 1, 2 and 3, respectively. Expressions for $\hat{\pi}_{U_i}^{dpb}$ and $\hat{\pi}_{U_i}^{dpr}$ are a bit more involved. The former is given by

$$\hat{\pi}_{U_i}^{dpb} = \hat{\pi}_{U_i}(l_i^{dpb}, l_j^c, w_i^{NB}(l_i^{dpb}, l_j^c), w_j^{NB}(l_j^c, l_i^{dpb})),$$

where $l_j^c = l_j^{cpb} = l_j^{cpr}$ (see Proposition 2) and

$$\begin{aligned} l_i^{dpb} &= \arg\max_{l_i} w_i^{NB}(l_i, l_j^c) q_i(l_i, l_j^c) + l_i \gamma \left(p(l_i, l_j^c) - \frac{1}{1-\eta} l_i + \frac{\eta}{1-\eta} l_j^c \right) \\ &= \frac{86(147 + 149\gamma) - 5\eta(1029 - 436\gamma)}{2(49 + 27\gamma)(441 + 619\gamma + 263\gamma\eta)} a. \end{aligned}$$

A deviation from the collusive agreement under private list prices is easier to compute because there is no need to recompute negotiated prices

$$\hat{\pi}_{U_i}^{dpr} = \hat{\pi}_{U_i}(l_i^{dpr}, l_j^c, w_i^c, w_j^c),$$

where $w_i^c = w_i^{cpb} = w_i^{cpr}$ (see Proposition 2) and

$$\begin{aligned} l_i^{dpr} &= \arg\max_{l_i} w_i^c q_i(l_i^{dpr}, l_j^c, w_i^c, w_j^c) + l_i \gamma \left(p(l_i, l_j^c, w_i^c, w_j^c) - \frac{1}{1-\eta} l_i + \frac{\eta}{1-\eta} l_j^c \right) \\ &= \frac{92\gamma - 19\eta + 10\gamma\eta + 70}{2(27\gamma + 49)(5\gamma + \gamma\eta + 3)} a. \end{aligned}$$

Substituting all these expressions into (A5) and rearranging terms we arrive at (A5) holding as long as

$$\begin{aligned} \Psi(\gamma, \eta) &= 7{,}023\gamma + 7{,}843\gamma^2 - 294 + \eta(14{,}670\gamma + 9{,}406\gamma^2 + 8{,}673) \\ &\quad - \eta^2(5{,}229\gamma + 785\gamma^2 + 4{,}263) \\ &> 0, \end{aligned}$$

or as long as $\gamma > \gamma^c(\eta)$, where $\gamma^c(\eta)$ is the solution to $\Psi(\gamma, \eta) = 0$. When $\eta = 1/29$, $\gamma^c(\eta) = 0$, so (A5) holds for any γ and $\eta \geq 1/29$. When $\eta = 0$, $\gamma^c(\eta) \approx 1/25$, so (A5) holds for any η and $\gamma \geq 1/25$. □

Appendix B. Collusion with Hard Communication

To facilitate the exposition, consider first the case of collusion with hard communication under private list prices. The suppliers' collusive problem is now to agree on a pair of offers $\{l_i, w_i\}_{i=1,2}$ to be made to small and large buyers that maximises their collective payoff

$$\hat{\pi}_{U_1}(l_1, l_2, w_1, w_2) + \hat{\pi}_{U_2}(l_2, l_1, w_2, w_1),$$

subject to their ICCs

$$\hat{\pi}_{U_i}(l_i, l_j, w_i, w_j) \geq (1-\delta)\,\hat{\pi}_{U_i}(l_i^d, l_j, w_i^d, w_j) + \delta \hat{\pi}_{U_i}(l_i^{pr}, l_j^{pr}, w_i^{pr}, w_j^{pr}),$$

and those of the large buyers

$$\hat{\pi}_{D_i}(l_i, l_j, w_i, w_j) \geq (1-\delta)\,\hat{\pi}_{D_i}(l_i^d, l_j, w_i^d, w_j) + \delta \hat{\pi}_{D_i}(l_i^{pr}, l_j^{pr}, w_i^{pr}, w_j^{pr}),$$

for $i = 1, 2$.

The tuple $\{l_i^d, w_i^d\}$ corresponds to the offers that follow a deviation by either U_i or D_i. In the case that D_i deviates from the agreement, which is done by simply rejecting U_i's initial offer w_i, this will trigger parties to bargain over a new wholesale price, w_i^d. In our Nash-in-Nash context,

U_i's collusive offer to the small buyers and U_j's offers remain unchanged, so $l_i^d = l_i$ and

$$w_i^d \in \arg\max_w (\hat{\pi}_{U_i}(l_i, l_j, w, w_j) - \bar{\pi}_{U_i})\hat{\pi}_{D_i}(l_i, l_j, w, w_j).$$

In contrast, U_i has more than one way to deviate from the agreement (depending on how U_i informs his 'Nash-in-Nash negotiating agents' about the deviation).[38] One option is to continue approaching large buyers with the collusive offer while adjusting the offer to small buyers, in which case $w_i^d = w_i$ and

$$l_i^d \in \arg\max_l \hat{\pi}_{U_i}(l, l_j, w_i, w_j).$$

Another option is for U_i to approach D_i with an offer that D_i is sure to reject and trigger bargaining. Given this deviation, the question now is what would D_i conjecture about U_i's offer to small buyers. It can no longer be the collusive offer l_i, because this would result in a sub-optimal deviation by U_i. Distributor D_i would correctly anticipate that if U_i reneges from the collusive offer w_i, he must also be adjusting his offer to the small buyers. In this case l_i^d and w_i^d are the solution to the system

$$l_i^d \in \arg\max_l \hat{\pi}_{U_i}(l, l_j, w_i^d, w_j),$$
$$w_i^d \in \arg\max_w (\hat{\pi}_{U_i}(l_i^d, l_j, w, w_j) - \bar{\pi}_{U_i})\hat{\pi}_{D_i}(l_i^d, l_j, w, w_j).$$

Since in the second option U_i must share with D_i part of the deviation profits, it is not immediately obvious which of the two options is to be preferred by U_i if he decides to deviate. When suppliers are highly patient (i.e., $\delta \to 1$), this question is less relevant because their ICCs hold with slack, unlike the buyers'. In this case, we arrive at the following result.

LEMMA 1. *Suppose that $\delta \to 1$. The best collusive agreement that suppliers $i = 1, 2$ can sustain with private list prices and hard communication is to simultaneously approach small and large buyers with offers*

$$l_i^h = \frac{a}{2},$$

and

$$w_i^h = \frac{1+4\gamma}{7+8\gamma}a < l_i^h,$$

respectively.

PROOF. When $\delta \to 1$, $\hat{\pi}_{D_i}(l_i, l_j, w_i, w_j) \to \hat{\pi}_{D_i}(l_i^{pr}, l_j^{pr}, w_i^{pr}, w_j^{pr})$, so w_i^h can be found by simply solving $\hat{\pi}_{D_i}(l_i^h, l_j^h, w_i, w_j) = \hat{\pi}_{D_i}(l_i^{pr}, l_j^{pr}, w_i^{pr}, w_j^{pr})$. □

Suppliers agree on monopoly prices for small buyers, which are invariant to γ given our linear setup, and on prices for large buyers high enough that their ICCs are satisfied without slack. The reason suppliers increase the list price up to its monopoly level is intuitive. It helps suppliers two-fold: to increase their profits and to more easily satisfy buyers' ICCs. Suppliers only begin

[38] Consistent with the Nash-in-Nash protocol, in a collusive agreement U_i still sends a different agent to negotiate with the different downstream buyers each period. The only difference with the competitive equilibrium is that if U_i decides to deviate from the collusive agreement at a given period, she informs all or a subset of agents—depending on whether she wants to deviate using all or only some of them—to negotiate knowing the agents who have been informed to deviate from the agreement.

adjusting the list price downwards when their own ICCs start binding, which happens when δ falls below a critical level strictly lower than one. And, as $\gamma \to 0$, the collusive outcome in the lemma converges to the one-shot equilibrium outcome in either Proposition 1 or 3.

The agreement in Lemma 1 differs from that in Proposition 2 in the important aspect that small buyers are always served along the collusive path. Under hard communication, suppliers have control over list and 'negotiated' prices, explaining why they keep both distribution channels open for any level of γ.

More important for our theory is that the collusive outcome in the lemma remains unchanged as we move from private to public list prices. This is because, when $\delta \to 1$, only the buyers' ICCs are binding. As soon as the suppliers' ICCs start binding, the two collusive agreements begin to differ. It becomes easier for suppliers to sustain collusion under public list prices given their weaker incentives to deviate.

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Additional Supplementary material may be found in the online version of this article:

Online Appendix
Replication Package

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