Using list prices to collude or to compete?

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Abstract

It is often argued that collusion is not possible in wholesale markets where suppliers and buyers privately negotiate discounts off list prices and sales quotas are unfeasible. However, this would go against allegations in court of suppliers being able to collude by publicly announcing list prices. It would also appear to go against recent evidence from Chile's wholesale fresh-egg market: a sudden interruption in the publication of list prices in the local newspaper led to a significant drop in the prices effectively paid by different buyers, large and small. We develop a theory consistent with this evidence, whether suppliers collude or compete. Two effects are at work. When suppliers collude, public announcements of list prices enlarge collusion possibilities from small to large buyers (the multibuyer contact effect). When suppliers compete, these announcements provide them with commitment to unilaterally negotiate better terms with large buyers (the commitment effect).

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1 Introduction

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 and 2011; Bernheim and Madsen, 2017).

It appears that coordinating just on prices would not be possible in wholesale markets. However, as explained by Boshoff and Paha (2021) and Harrington and Ye (2019), this would go against recent allegations on both sides of the Atlantic of suppliers effectively coordinating on list prices. A problem courts face in deciding these cases is that defendants often claim that, due to pervasive secret discounts, any ostensible list price coordination cannot have any anticompetitive effect. Here is what a member of the thread cartel explained in court:[1]

> ...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.

According to this cartel member, list prices would not only constitute costless messages—cheap talk, using the language of Crawford and Sobel (1982)—but also be uninformative. Courts have expressed different views on this matter. In the fiberglass cartel, for example, the Seventh Circuit Court indicated that list prices[2]

> ....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.

In contrast, in the polyurethane cartel the Tenth Circuit Court commented that[3]

> ...product price lists and parallel price-increase announcements — 'presumably established an artificially inflated baseline' for negotiations.

Adding 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—on each Monday—in the country's main newspaper. For reasons unknown to us, this publication was suddenly interrupted in October of 2018.[4] After the cease of publication, suppliers continued communicating

[1] Commission of the European Communities, 14.09.2005, Case COMP/38337/E1/PO/Thread, 112, 159-60.

[2] *Reserve Supply v. Owens-Corning Fiberglas* 971 F. 2d 37 (7th Cir., 1992), para 62.

[3] *In Re: Urethane Antitrust Litigation,* No. 13-3215 (10th Cir., 2014), p. 7.

[4] Around the same time, this newspaper also interrupted the publication of (wholesale) list prices concerning many other products, including cattle, fruits, vegetables, fertilizers, etc. Our empirical analysis focuses on the egg market primarily because of data availability, but it would be useful to carry out similar analysis for these

their list prices but asynchronously and in a more decentralized and "opaque" way, using the internet, emails and phone calls. It was not uncommon for different buyers to get different quotes with list prices. Using detailed transaction-level data from two of its largest suppliers, in Section 2 we explore the effect that the cease of publication could have had on the wholesale market. We find strong effects on both list prices and prices effectively paid by large buyers (e.g., supermarkets): they fell by about 15% and 4%, respectively.

Motivated by this event and the cases, our goal in this paper is to contribute to our understanding of whether, how and to what extent simultaneous and public announcements of list prices—to which we will often refer as *public* list prices—can help suppliers to sustain supra-competitive prices. We start our analysis in Section 3 with an irrelevant result consistent with the above first and second quotes: public list prices play no role.

In formulating our theory we build on Horn and Wolinsky's (1988) model of bilateral negotiations and extend it to consider list-price announcements and negotiations over two-part tariffs that may suffer from contractual frictions *à la* Calzolari et al (2020). Contractual frictions help explain why sometimes we see parties bargaining just over linear prices, as in our motivating evidence but also elsewhere (e.g., Crawford and Yurukoglu, 2012; Noton and Elberg, 2018). In this setting, and regardless of the level of contractual frictions, list prices do not emerge in equilibrium; if they do, they are payoff irrelevant. For list prices to play some role, suppliers would need to set them low enough for buyers to prefer to buy at such prices than to bargain with suppliers. In equilibrium suppliers never want to announce list prices that low, whether they compete or attempt to collude.

This irrelevant result is in contrast to recent work by Harrington and Ye (2019) and Harrington (2022).[5] The reason is that these works rely on elements that are absent from our theory. In Harrington and Ye (2019) suppliers use list prices to coordinate on high-cost signals before buyers invite them to "negotiate," that is, to participate in their procurement auctions. In our setting suppliers and buyers negotiate bilaterally under complete information, so costless messages are never informative.[6]

In Harrington (2022), on the other hand, offering discounts carries a disutility to the sales agents offering them, so they keep them smaller than what discounts would otherwise be. In other words, list price announcements are no longer cheap talk, unlike in Harrington and Ye (2019). As a result, list prices serves to "inflate the baseline" for negotiations, much consistent with the third quote above. We abstract from such "organizational" costs, partly because we see discounts to vary widely—in absolute and percentage terms—across buyers and over time, including in our motivating evidence.[7]

other markets. Note also that no case has been opened by the Competition Authority on any of these markets as of this writing.

[5]There are also works looking at the effect of list-price announcements and discount offers directed at final consumers (e.g., Raskovich, 2007; Gill and Thanassoulis, 2016). We come back to their connection to our theory below.

[6]Lubensky (2017) is another setting of incomplete information and where final consumers must search for better prices. Announcements of list prices are again informative in that they affect the direction of this search.

[7]In fact, before the cease of publication large buyers (e.g., supermarkets) were able to negotiate discounts off

Collusion on prices can still emerge in our bargaining setting and in the absence of list prices but it does require two elements: transfers and communication to buyers about suppliers' intention to collude. Communication is needed because suppliers invite buyers to accept terms that may depart from the expected negotiation outcome, that is, from the Nash bargaining solution (Nash, 1950; Binmore et al., 1986; Collard-Wexler et al., 2019). Thus, in their attempt to collude suppliers must leave buyers with at least the Nash-bargaining-solution payoff (and more for lower discount factors). This incentive compatibility constraint (ICC) is also present in the hub-and-spoke cartels of Garrod et al (2021), where suppliers and buyers also engage in bilateral negotiations. Because of this ICC, when suppliers agree to increase wholesale prices they necessarily must compensate buyers with lower fixed fees.[8] But when contractual frictions are important—and parties bargain over linear prices only—there are no fixed fees suppliers can draw upon. In this case, collusion on prices is just not possible.[9]

This no-collusion result is an important piece of our theory because in none of the cases there is a mention to transfers nor they appear in our motivating evidence. There is however a key element present in the cases (see the first quote) and in our motivating evidence that we have omitted so far, which is the presence of "small" buyers that for most part pay list prices. Some of these small buyers may still get some discounts, but they rather respond to a price-discrimination motive than to bargaining. What ultimately distinguish small from large buyers in our theory is that the former are price takers and the latter are not. In addition, and this is particularly true in our motivating evidence, large and small buyers compete for final consumers in the downstream market, giving rise to a *multibuyer contact* effect.[10,11]

This multibuyer contact effect is similar in spirit to the multimarket contact effect of Bernheim and Whinston (1990) but is actually quite different. It is similar because market/buyer-group A allows to also monopolize market/buyer-group B. In Bernheim and Whinston (1990) suppliers can sustain collusion in market A with slack, some of which is used to sustain collusion in market B, that otherwise would not be possible. Here, suppliers can in principle agree to charge collusive list prices to small (group A) buyers—as in any retail market with price-taking consumers. And since this allows suppliers to negotiate better terms (i.e., higher wholesale prices) with large (group B) buyers, in an attempt to also monopolize group B buyers, suppliers agree on list prices above what they would have otherwise agreed if group B buyers did not

list prices of about 19%, whereas after the cease of publications these discounts dropped to about 11%.

[8]This resistance to price increases is well documented. See, for example, the discussions in Marshall and Marx (2012, chs. 2 and 6), Marshall et al (2008) 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.

[9]In Garrod et al (2021) the ICC does not pose a problem to the cartel. Suppliers and buyers negotiate linear terms but have an additional instrument to transfer rents, which is the level at which parties agree to maintain the retail price. As far as we know, this RPM option falls outside the above cases and our motivating evidence.

[10]That small and large retailers compete in downstream markets is well documented; see, for example, Thomassen et al (2017).

[11]Note that 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).

exist. This extra increase in list prices is the workings of the multibuyer contact effect.[12]

Note that because prices effectively paid by large buyers are determined in bilateral negotiations with suppliers, any additional increase in list prices is not passed through one-to-one to such prices, but only a fraction of it (it also adds to this incomplete pass-through the fact that large buyers are less aggressive than small buyers in the downstream market). As a result of this incomplete pass-through, any termination of collusion would predict not only a drop in both prices—list and negotiated prices—but also a drop in the gap between the two. In other words, we should also see an important reduction in discounts off list prices. Interestingly enough, our motivating evidence tells us exactly that: with the cease of publication of list prices in the local newspaper all prices fell, but list prices fell a lot more.

Does our theory support a collusive explanation for the role that simultaneous and public announcements of list prices may have played in the evolution of wholesale fresh-egg market, and possibly in the evolution of other markets? It certainly does. But at the same time, and on equal footing, it supports a non-collusive, competitive explanation, which is that public list prices would have allowed suppliers to unilaterally negotiate better terms with their large buyers. This is the workings of the *commitment* effect.

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. As a result, all prices are higher than when all prices are determined simultaneously. We often use the term *private* list prices to refer to prices posted simultaneously with negotiated prices (as in our motivating evidence after the cease of publication of list prices).[13]

Note that our theory is not prepared to distinguish the collusive explanation from the competitive one: both predict a fall in prices and in discounts as we move from public to private list prices.[14] The reason is that what distinguishes one from the other is a matter of magnitude since in both cases suppliers take advanatge of public list prices to obtain better terms from large buyers, only that in one case they do it coordinately and in the other independently. Whatever the explanation, our theory unambiguously predicts that public announcements of list prices would lead to supracompetitive prices.

A similar anticompetitive outcome is found in models of retail markets with discounts going to final consumers. Raskovich (2007), for example, assumes that a fraction of consumers are

[12]Interestingly, large buyers also benefit from suppliers' collusion. In the absence of transfers, suppliers have no choice but to share some of the profits coming from higher retail prices with large buyers.

[13]Unlike the multibuyer contact effect, the commitment effect may not exist when small buyers see suppliers as very close substitutes. In this case suppliers set list prices so low in (competitive) equilibrium that they stop negotiating discounts off list prices with large buyers altogether. It is as if suppliers were to compete by simultaneously setting a single price for small and large buyers, eliminating any difference between public and private list prices. Obviously, this possibility is little relevant when we do observe large and small buyers paying different prices, as in our motivating evidence.

[14]In the Extensions we also explore a third possibility: that collusion did not completely end with the cease of publication but rather turned into a less ambitious agreement. This possibility is also consistent with our motivating evidence.

given the opportunity to bargain with suppliers for discounts off the list prices. 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 so are more attractive to bargaining consumers. Closer to ours is Gill and Thanassoulis (2016) who assume that a fraction of consumers are offered discounts that they receive with some probability (these would be our large buyers; although ours all bargain with suppliers, so they are not "discount takers"). They find that the potential to offer discounts dampens competitive pressure in the market, thus raising all prices.

The rest of the paper is organized as follows. Our motivating evidence is presented in Section 2. The baseline model with the irrelevant result is in Section 3. We add small buyers who pay public list prices in Section 4. In Section 5 we consider the alternative timing of private list prices, when all prices are determined simultaneously. At the end of the section we contrast the collusive and competitive predictions of our theory to the motivating evidence of Section 2. The extension to the possibility of collusion with private list prices is in Section 6. We conclude in Section 7. Proofs and other auxiliary results are relegated to the Appendix.

2 Motivating evidence

Our theory is motivated, at least partly, by recent developments in Chile's wholesale fresh-egg market. Egg producers used to publish their list prices on a weekly basis—on each Monday—in the country's main newspaper. This publication was suddenly interrupted in October of 2018.[15] After the cease of publication, suppliers continued communicating their list prices but in a more decentralized and "opaque" way, using the internet, emails and phone calls. It was not uncommon for different buyers to get different quotes with list prices.

The event we exploit here is that before the cease of publication, list prices were publicly and readily available in a single place, where they were posted simultaneously, while afterward they became more dispersedly and asynchronously informed. For our purposes here, we will refer to *public* list prices as those posted before the interruption of publication in the local newspaper and to *private* list prices as those posted after the interruption.

We want to explore whether the cease of publication had any effect not only on list prices posted by suppliers but also on prices that resulted from bilateral negotiations between suppliers and buyers. If anything, one could argue that the cease of publication could have increased search costs of those small, price-taking buyers who pay list prices. If so, as the search literature suggests (e.g., Varian 1980),[16] the cease of publication could have resulted in higher list prices.

[15] Leaving aside explanations for this interruption, what is clear is that the interruption caught suppliers by surprise.

[16] Although less relevant for our motivating evidence, an increase in search costs may sometimes lead to lower prices. In a multiproduct setting, with firms carrying different set of products, an increase in search costs may also affect merger/product choice decisions toward more symmetric configurations, leading to fiercer competition in prices (see, e.g., Rhodes and Zhou 2019, Fabra and Montero 2021).

We find otherwise.

We identify two type of buyers in our sample. An important fraction of buyers comprises small grocery stores that for most part pay list prices, before and after the cease of publication. The remaining fraction corresponds to large buyers (e.g., supermarkets, retail chains) who engage in bilateral negotiations with suppliers. We want to compare wholesale prices paid by these different type of buyers before and after the cease of publication. We focus on the most popular fresh-egg category, white large eggs,[17] 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 of 2016 to August 2020. Identification of its effect over wholesale prices comes from the assumption that the cease of publication was an unexpected event for both suppliers and buyers. It seems a reasonable assumption based on a series of conversations with industry personnel.

We estimate the following "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,[18] $Post_t$ is an indicator that takes the value of one for days after the cease of publication, 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-year fixed effects, while in an 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 cease of publication, one and two-year windows before and after the event.

If the cease of publication 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 sum of the coefficients of $Post$ and $Large \times Post$, $\gamma + \phi$. In addition, any discount off list prices received by large buyers before the cease of publication should be captured by a negative coefficient of $Large$, β, and after the cease of publication by a negative sum of the coefficients of $Large$ and $Post \times Large$, $\beta + \phi$.

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 U.S. cents), we are talking

[17] 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.

[18] Prices that fall outside the 2nd and 98th percentiles are discarded.

of discounts in the range of 20% before the cease of publication. The table also shows that the coefficient of *Post* is always negative and statistically significant, meaning that list prices fell with the cease of publication, by about 15%. Meanwhile, the coefficient of $Post \times Large$ 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 cease of publication, but not as much as list prices. The F-tests at the bottom of the table indicate that these falls in prices 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 have reduced after the cease of publication.

Table 1: Impact of the Cease of Publication of List Prices on 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)
$Post \times Large$	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	200566	108723	200566	108723
F-tests, p-values				
$\gamma + \phi = 0$	0.000	0.000	0.000	0.000

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: Dependent variable is effective prices charged by two suppliers for 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 cease of publication (third week of October of 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. Standard errors, 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.

In preparation for our theory, several results in Table 1 deserve further discussion. It is clear that the weekly publication of list prices in the local newspaper had helped suppliers to charge higher prices to small buyers, those with no bargaining power that for most part pay list prices. One explanation is a collusive one: the "transparency" of posting list prices on a single place and at the same time would have facilitated the monitoring of compliance with a supposed collusive agreement.[19]

[19] Price transparency and its implications for competition has been studied in other industries; for example,

But even if this collusive explanation turns out to be correct, it does not automatically 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 $Post$ would suggest 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 $Post \times Large$, the discounts received by supermarkets before the cease of publications were 18.1 pesos on average, or 18.5% off list prices. With the cease of publication, these discounts dropped dramatically, to 9.4 pesos, or 10.9%. Despite prices paid by supermarkets also dropped with the cease of publication, from 79.7 to 76.8 pesos on average, it remains unclear how to explain such drop.

Two explanations come to mind. One can be found in the thesis advanced, for example, by the Tenth Circuit Court in the polyurethane price-fixing case that higher list prices serve to establish an "artificially inflated baseline for negotiations" with large buyers (see third quote in the Introduction). This thesis presumes that discounts are some "exogenously" given percentage of list prices, which our motivating evidence clearly fails to support. Discounts, when measured as a percentage of list prices, suffered a major drop with the cease of publication.[20]

Another explanation, in the spirit of Bernheim and Whinston (1990), could be a multimarket contact one. Even if prices paid by large buyers are set independently of list prices, the cease of publication could have not only terminated any collusion in the "small-buyer market" but also in the "large-buyer market" because the latter would no longer be sustainable in a stand-alone fashion. An important assumption in this multimarket contact thesis, however, is that collusion in the large-buyer market (as well as in the small-buyer market) is always sustainable in a stand-alone fashion for a sufficiently large discount factor. Since the latter is not supported by our theory,[21] this alternative thesis does not fit well our motivating evidence either. Besides, this thesis makes no prediction as to whether there should be a drop in prices paid by large buyers at all, let alone, whether that drop, if any, is expected to be larger or smaller than the drop in list prices.

Our theory advances a related but different multimarket contact effect than that of Bernheim and Whinston (1990), one that is based on the fact that small and large buyers compete in the retail market for final consumers.[22] We refer to it as a multibuyer contact effect. Because of this multibuyer competition in the retail market, any increase in prices paid by small buyers allows

retail gasoline (Luco, 2019), supermarkets (Atir and Ragid, 2022), and cement (Albæk et al, 1997; OFT 2011). Price transparency also play an important role in the (wholesale) collusive agreements in Piccolo and Miklós-Thal (2012).

[20]In the retail market of Gill and Thanassoulis (2009) higher list prices can serve firms to negotiate better transaction prices with the fraction of consumers that bargain (the *bargainers* as opposed to the price takers). The reason is that bargainers always have the list price as their outside option, which firms may want to distort in their favor. As we explain below, this mechanism does not operate in our wholesale market.

[21]The reason is that any collusion with regard to large buyers fails when suppliers have only linear prices at their disposal, which may happen in the presence of contractual frictions. For more see Proposition 2.

[22]This competition certainly extends beyond the market for fresh eggs. Thomassen et al (2017) offer a detail analysis of how supermarkets adjust their pricing strategies to the presence of smaller stores carrying a reduced number of products (e.g., butchers, bakers, greengrocers, etc).

suppliers to negotiate better terms (i.e., higher wholesale prices) with large buyers. Aware of this multibuyer contact, any attempt by suppliers to collude on list prices has collusive spillover effects over the prices paid by large buyers as well. Important for explaining our motivating evidence, this multibuyer contact thesis makes two clear predictions. If the cease of publication ended any collusion in list prices, we should observe (i) a drop in both list prices and prices paid by large buyers, and (ii) a drop in discounts (i.e., in the gap between the two prices).

As these predictions fit well our motivating evidence, one is tempted to embrace a collusive explanation for the evolution of prices in the wholesale egg-fresh market. Our theory, however, also advances an alternative, non-collusive explanation that is also consistent with the evolution of such prices, in particular, with predictions (i) and (ii). This alternative, competitive explanation is also based on the fact that small and large buyers compete in the retail market but exploits a different channel, a commitment channel *à la* Hart and Tirole (1990). The publication of list prices in the local newspaper could have provided suppliers with a vehicle to *unilaterally* commit to higher prices charged to small buyers, and thus to obtain better terms (i.e., higher wholesale price) from large buyers. A supplier has all the incentives to build and maintain a reputation of not secretly offering lower prices to small buyers after posting list prices and setting terms with large buyers.[23]

A final note is that our theory is not prepared to distinguish between these two explanations. The reason is that what distinguishes the collusive from the competitive explanation is a matter of magnitude since 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 coordinately and in the other independently. As suppliers become more patient, the multibuyer contact effect grows larger, allowing suppliers to sustain higher prices, for both small and large buyers. But predictions (i) and (ii) remain valid for any level of collusion, so the two effects remain qualitatively alike. In any case, our theory unambiguously predicts that public announcements of list prices would lead to supracompetitive prices.

3 A model of irrelevant list prices

We start our analysis with a model where list prices play no role, whether suppliers compete or collude. Throughout the paper we adopt simple functional forms to keep the model tractable. We think this is without much loss of generality because our goal is to simply document the presence of new forces that may help explain our motivating evidence, and possibly evidence from other similar cases. In that regard, our theory is not intended to provide a definitive explanation of the evidence just presented.

Following Horn and Wolinsky (1988) consider a set up with two upstream suppliers, U_1 and U_2, and two (large) downstream buyers or distributors, D_1 and D_2. Products are homogeneous and their production costs are normalized to zero. Distributors compete a la Cournot in the

[23]Some elements of a contract between a large buyer and a supplier (e.g., delivery and packing conditions) may not be subject to frequent changes as wholesale prices are, which in our sample change on a weekly basis.

downstream or retail market, but there is no direct upstream competition among suppliers, only indirectly through the retail market.[24] Each buyer negotiate with a single supplier under equal bargaining weights.[25]

Parties D_i and U_i negotiate two-part tariff contracts: a wholesale unit price w_i per each unit ordered and a transfer T_i from D_i to U_i upon contract acceptance. We let negotiations to be subject to contractual frictions that may preclude wholesale prices to drop all the way to marginal cost (or even below).[26] Following Calzolari et al (2020), we capture these contractual frictions in a reduced-form way. We assume that transferring rents from distributors to suppliers by means of fixed fees creates deadweight losses: the supplier only gets $(1-\kappa)T_i$, with $\kappa \in [0, 1]$. These losses extend in a similar way when transferring rents from suppliers to retailers by means of slotting allowances.

The timing of the game is as follows. In the first stage suppliers simultaneously post list prices l_i and l_j. In the second stage D_i has the option to skip negotiations and buy at the posted list price l_i or engage in negotiations with U_i. If D_i opts for the latter she forgoes the option to ever buy at the posted list price. Alternatively, one can view l_i as the initial offer made by U_i in his negotiation with D_i. We will see that in equilibrium D_i always rejects this offer and continues negotiating.[27] Finally, in the third stage, and after observing the terms of trade that governed the relationships between distributors and suppliers, distributors simultaneously set quantities q_1 and q_2. The downstream (inverse) demand is

$$p = a - q_1 - q_2$$

This three-stage game is repeated over an infinite number of periods. All parties, buyers and suppliers, exhibit a per-period discount factor equal to $\delta \in (0, 1)$.

3.1 Competitive equilibrium

To find the equilibrium of the one-shot game, let us proceed by backward induction. Consider first the case in which list prices are high enough (e.g., $l_1, l_2 \geq a$) that distributors decide to

[24]Cussen (2021) extends the Horn and Wolinsky's framework to allow buyers to buy from either supplier. He does it by letting a buyer's procurement costs to be decreasing in variety, so in (Nash-in-Nash) equilibrium buyers sign with both suppliers. Although the analysis gets cumbersome quite rapidly, he illustrates that results do not qualitatively change.

[25]Support for equal bargaining weights, i.e., $\beta_i = \beta_{-i} = 1/2$, can be found in Binmore et al's (1986) model of sequential bargaining with exogenous risk of breakdown. In that model, party i assigns a constant probability $1-\exp(-\lambda_i \Delta)$ that the bargaining process will breakdown between two bargaining periods, with Δ being the time elapsed between bargaining periods. In that model, party i's bargaining weight converges to $\beta_i = \lambda_i/(\lambda_i + \lambda_{-i})$ as $\Delta \to 0$, so when parties share a common belief about the probability of breakdown, $\beta_i = \beta_{-i}$. Cussen (2021) extends some of our results to the case of different bargaining weights, showing no qualitative implications.

[26]Departure from marginal-cost pricing is not only supported in practice (see, e.g., Crawford and Yurukoglu, 2012, and Noton and Elberg, 2018) but also in theory. It endogenously arises when bilateral negotiations are subject to moral hazard (Rey and Tirole, 1986; Bernheim and Whinston, 1998) or adverse selection (Calzolari and Denicolo, 2015).

[27]Below we discuss the implications of adopting an alternative outside option in case of a negotiation breakdown, which is for parties to trade at the list price.

negotiate with their respective suppliers at the second stage. If in that stage negotiating parties agreed to wholesale prices w_i and w_j, then the Cournot outcome in stage three is characterized by D_i's equilibrium output

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

and clearing price

$$p(w_i, w_j) = (a + w_i + w_j)/3 \tag{3}$$

In turn, D_i's profit gross of any fixed fees is given by

$$\pi_{D_i} = (p(w_i, w_j) - w_i)q_i(w_i, w_j) = q_i^2(w_i, w_j)$$

In the second stage, D_i and U_i bargain over the two-part tariff contract $\{w_i, T_i\}$ while forming some expectation about the contract $\{w_j, T_j\}$ that D_j and U_j will sign and anticipating the corresponding Cournot outcome (2) and (3) that would follow from such contracts. If D_i and U_i end up trading, their on-path payoffs are

$$\hat{\pi}_{D_i} = \pi_{D_i}(w_i, w_j) - T_i \tag{4}$$

and

$$\hat{\pi}_{U_i} = w_i q_i(w_i, w_j) + (1 - \kappa)T_i \tag{5}$$

respectively, whereas if they do not, their off-path payoffs are $\bar{\pi}_{D_i} = \bar{\pi}_{U_i} = 0$. Note that we are using an upper hat (resp. an upper bar) to denote on-path (resp. off-path) payoffs. Although we do not expect parties to fail to reach an agreement in equilibrium, 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 contracts $\{w_i^*, T_i^*\}$ and $\{w_j^*, T_j^*\}$ such that (w_i^*, T_i^*) is the Nash solution to the bargaining problem between D_i and U_i, given that both expect $\{w_j^*, T_j^*\}$ to be agreed upon between D_j and U_j. Thus, the Nash solution $\{w_i^*, T_i^*\}$ is found by solving

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

for $w_j = w_j^*$ and $T_j = T_j^*$.

Proposition 1 *If $\kappa \geq 1/2$, then the one-shot game exhibits an equilibrium with $w_1^* = w_2^* = a/7$ and $T_1^* = T_2^* = 0$; otherwise*

$$w_1^* = w_2^* = w^* = \frac{4\kappa - 1}{4\kappa + 5} a$$

and

$$T_1^* = T_2^* = T^* = \frac{3(1 - 2\kappa)}{(1 - \kappa)(4\kappa + 5)^2} a^2$$

Proof. See the Appendix. ■

Wholesale prices are increasing in contractual frictions κ while transfers are decreasing. At some point, when $\kappa = 1/2$, it becomes too costly for parties to use transfers to split the surplus generated by the vertical relationship. At that point, and consistent with what we observe in some wholesale markets (e.g., Noton and Elberg, 2018; Garrod et al., 2021, p. 30), parties rely exclusively on linear pricing. In contrast, when contractual frictions are very low suppliers are ready to sell even below cost and ask for a large transfer in return. Each pair agrees to this below-cost pricing in an effort to gain a Stackelberg position in the retail market against the other pair. As a result, they end up pricing too aggressively in the wholesale market.[28] In a way, contractual frictions allow parties to soften competition.

We finally move to the first stage of the game, when suppliers announce list prices. So far we have considered announcements that were payoff irrelevant, i.e., neglected by distributors. Do suppliers have incentives to announce list prices that may eventually be accepted by distributors before their negotiations? This possibility can be ruled out almost by definition in a world of high contractual frictions, where parties negotiate linear prices (the case for lower values of κ is covered in the Appendix). To formally see it, suppose that instead of announcing a high list price, U_1 announces l_1 with the hope that D_1 will take it at the beginning of their negotiation. Since this deviation will be observed by U_2 and D_2 before they initiate theirs, their negotiated response in anticipation to D_1 accepting l_1 is to agree on the wholesale price

$$w_2(l_1) = (a + l_1)/8 \tag{6}$$

Anticipating this response, U_1's best deviation would be to leave D_1 indifferent between accepting l_1 and continue negotiating with him. Given this acceptance restriction, the best deviation for U_1 would be to announce $l_1 = a/7$, to which U_2 and D_2 would respond with $w_2 = a/7$, as seen from (6).

According to Proposition 1, this deviation reports no benefit to U_i, showing that announcements of list prices at the first stage make no difference to the terms agreed on the bargaining stage, and hence, to retail prices. It is true, however, that if suppliers were to incur an arbitrarily small cost to bargaining, they would prefer to skip negotiations and announce list prices slightly less than $a/7$ for buyers to accept right away. But again, this possibility would have virtually no payoff implications (and none for lower values of κ), so it would not change the fact that list prices are irrelevant in this baseline setting.

A more fundamental observation is the assumption that list prices are completely absent from parties' outside options (i.e., off-path payoffs). In fact, in retail-market models it is often assumed that final consumers can always buy at the list price in case they fail to negotiate any discount with retailers (e.g., Gill and Thanassoulis, 2016). Adopting such assumption in our wholesale setting, however, would completely change the nature of negotiations, so much that suppliers would now enjoy full bargaining power. To explain, consider high contractual frictions. If suppliers anticipate that in case of a negotiation breakdown parties will trade at the

[28] Note that retail prices are nevertheless above cost, equal to $p = a/5$ when $\kappa = 0$.

list price—in which case $\bar{\pi}_{U_i} = l_i q_i(l_i, w_j)$ and $\bar{\pi}_{D_i} = q_i^2(l_i, w_j)$—then suppliers would announce $l_1 = l_2 = a/3$ at the first stage and then negotiate wholesale prices $w_1 = w_2 = a/3$ at the bargaining stage. It turns out that these are the exact same prices we would observe when suppliers have all the bargaining power and make take-it-or-leave-it offers to buyers (see the Appendix for details).

The reason is simple. Under this alternative outside option, a supplier secures a payoff of at least $l_i q_i(l_i, w_j)$ during negotiations when he anticipates that U_j and D_j will agree on w_j. As a result, U_i would set l_i above $w_i^* = a/7$—the equilibrium price in Proposition 1—to negotiate something higher than $a/7$. In turn, U_j would respond with a higher l_j, and so would U_i. This goes on until offers converge to the take-it-or-leave-it outcome. This alternative outside option not only leaves large buyers with no bargaining power, which makes little sense,[29] but also renders the negotiation useless as it adds no surplus over what parties would get if they do not bargain. In wholesale negotiations, outside options are supposed to determine the overall net surplus from trade over no trade and how is to be split. Our formulation does just that.

3.2 Collusive equilibrium

Since suppliers and buyers interact repeatedly in the market, less competitive outcomes may emerge in equilibrium. Our focus here is on less competitive outcomes in the wholesale market, while maintaining the assumption that retailers compete in the retail market.

As a benchmark, ask what would be the best collusive arrangement that suppliers could agree upon if they face no contractual frictions, have all the bargaining power and are sufficiently patient (i.e., have a discount factor sufficiently close to the unity). The retail price that maximizes the profit of the supply chain or the entire industry is $p^m = a/2$, so the best suppliers can do in such a case is to approach their respective retailers with take-it-or-leave-it offers that implement p^m and leave them with the industry profit, that is, with $w_1 = w_2 = w^m = a/4$ and $T_1 = T_2 = T^m = a^2/16$. A threat to return to the one-shot equilibrium of Proposition 1 should suffice to prevent suppliers from deviating of these collusive offers.

Even if suppliers were sufficiently patient, there are nevertheless two elements in our set up that may prevent suppliers from implementing the industry profit-maximizing outcome. One is that contract terms are not set unilaterally by suppliers but negotiated with buyers. This implies that any collusive agreement must not only satisfy suppliers' incentive compatibility constraint (ICC) but also buyers'. No buyer would ever accept an offer that leaves her worse off than in the one-shot equilibrium, even if she is infinitely patient. Buyers' ICC certainly reduces suppliers' gain from collusion but it does not, in itself, impede them from implementing the industry profit-maximizing outcome. Suppliers would just need to ask for a lower transfer in their offers, say, lower than T^m. Eventually this lower transfer may turn into a slotting allowance (i.e., a negative transfer).

What impedes the implementation of the industry profit-maximizing outcome is a second

[29] It does if buyers were price takers, as final consumers in retail markets.

element, the presence of contractual frictions. Since there is no other vehicle to transfer rents than direct transfers, suppliers would have to move away from the industry profit-maximizing outcome in an effort to reduce these transfers. The relevant question then is by how much. Could it be enough so as to eliminate any possible collusion? Does the announcement of list prices make any difference? The rest of the section is devoted to answering these questions.

We start with the case in which suppliers disregard the use of list prices, e.g., they agree to announce $l_i, l_j \geq a$ at the beginning of each period (below we will discuss whether list prices could play any role, for instance, help suppliers to manufacture a better agreement). Given the symmetry of the problem, and assuming that (on- and off-path) transfers always go from distributors to suppliers ($T \geq 0$),[30] suppliers' collusive problem is to maximize their collective payoff subject to buyers' ICC and their own, that is,

$$\max_{w,T} wq(w,w) + (1-\kappa)T$$

subject to (parties understand that any deviation from the collusive agreement is punished with a return to the one-shot equilibrium of Proposition 1 indefinitely)[31]

$$\pi_D(w,w) - T \geq (1-\delta)\left(\pi_D(w^d,w) - T^d\right) + \delta\left(\pi_D(w^*,w^*) - T^*\right) \quad (7)$$

and

$$wq(w,w) + (1-\kappa)T \geq (1-\delta)\left(w^d q(w^d,w) + (1-\kappa)T^d\right) + \delta\left(w^* q(w^*,w^*) + (1-\kappa)T^*\right) \quad (8)$$

where $\pi_D(w_i,w_j) = q^2(w_i,w_j)$, $q(w_i,w_j)$ is given by (2), and (w^d,T^d) is the "deviating" contract that U_i and D_i expect to negotiate if either one deviates from the agreement.

The way for D_i to deviate from the agreement is by rejecting the collusive offer $\{w,T\}$ that is presented to her at the begining of the bargaining stage while for U_i is by presenting an offer different from (w,T) that D_i would reject at the begining of that stage (which would be any offer that pays U_i strictly more than (w,T) in the current period). Either event would force parties to bargain over a new offer, which would be given by

$$\{w^d,T^d\} \in \arg\max_{w_i,T_i}(\hat{\pi}_{D_i}(w_i,w,T_i) - \bar{\pi}_{D_i})(\hat{\pi}_{U_i}(w_i,w,T_i) - \bar{\pi}_{U_i}) \quad (9)$$

where $\hat{\pi}_{D_i}(\cdot)$ and $\hat{\pi}_{U_i}(\cdot)$ are given by (4) and (5), respectively, and $\bar{\pi}_{D_i} = \bar{\pi}_{U_i} = 0$. Note that $\{w^d,T^d\}$ would also be the resulting offer if both parties agree to deviate from the agreement; bargaining is the only way for them to share the one-period deviation gains even when both agree to it. Let $\{w^c,T^c\}$ denotes the contract solution to suppliers' collusive problem.

Proposition 2 *Suppose that parties are highly patient, i.e., $\delta \to 1$. If $\kappa \geq 1/2$, then the*

[30] In principle one should be open to the possibility that suppliers may resort to slotting allowances (i.e., negative transfer), either on- or off-path. We show in the proposition below that this is never the case.

[31] Stronger punishments are available but they will not change anything fundamental in the analysis.

solution to suppliers' collusive problem is the one-shot equilibrium, $w^c = w^* = a/7$ *and* $T^c = T^* = 0$*; otherwise*

$$w^c = \left(1 - \frac{3}{5+4\kappa}\sqrt{\frac{1+2\kappa}{1-\kappa}}\right) a > w^*$$

and $T^c = 0$ *if* $\kappa \in [\kappa_0, 1/2)$*, where* $\kappa_0 \approx 1/5$ *solves the cubic* $3 - 11\kappa - 20\kappa^2 - 8\kappa^3 = 0$*, or*

$$w^c = \frac{1+2\kappa}{2(2+\kappa)} a > w^*$$

and

$$T^c = \frac{3\left(3 - 11\kappa - 20\kappa^2 - 8\kappa^3\right)}{4\left(1-\kappa\right)\left(10 + 13\kappa + 4\kappa^2\right)^2} a^2 < T^*$$

if $\kappa \in [0, \kappa_0)$.

Proof. See the Appendix, where we also cover the case of $\delta < 1$. ■

A key result in the proposition is that collusion can only emerge for low levels of contractual frictions, when $\kappa < 1/2$. To understand why, it helps to explain how suppliers accommodate their collusive agreement as contractual frictions raise. For low levels of frictions, when $\kappa \in [0, \kappa_0)$, suppliers elevate industry profits and simultaneously satisfy buyers' participation constraint by adjusting both terms in their offers, w and T. Increasing w^c above w^* yields industry profits in excess of those under competition. But this increase leaves buyers strictly worse off—their payoffs gross of fixed fees are decreasing in wholesale prices—which suppliers solve by lowering T^c below T^* accordingly. This adjustment proceeds until $\kappa = \kappa_0$, when $T^c = 0$.

Above κ_0 suppliers have a choice. One is to compensate buyers with slotting allowances, i.e., negative fixed fees. The other is to keep $T^c = 0$ and increase w^c above w^* just enough to keep buyers' ICC in balance (recall that $T^* > 0$ for all $\kappa < 1/2$, so there is still some collusive profits to be made in this range). It turns out that suppliers never resort to slotting allowances to compensate buyers; it is too costly in the presence of contractual frictions. As stated in the proposition, they simply exempt buyers from the payment of any fixed fee as compensation for any increase in wholesale prices. But at $\kappa = 1/2$, when $T^* = 0$, this exemption is no longer available to compensate buyers. At this point, suppliers find themselves with just one instrument to accomplish two conflicting goals, increasing industry profits and sharing enough of them with buyers. This is just not possible with one instrument.

It is not clear to us what other instruments suppliers could use in our context. More generally, one may think of retail price maintenance (RPM) contracts, like the ones studied by Garrod et al. (2021) in the context of hub-and-spoke cartels. In their setting, suppliers and buyers negotiate linear terms but have an additional instrument to transfer rents, which is the level at which parties agree to maintain the retail price. We have abstracted from this possibility here, partly because is absent in many of the markets we are interested in, let alone, in the market we have used as motivation for our theory.[32]

As we show in the proof of the proposition, what we learn from the case $\delta \to 1$ extends to lower values of δ but for minor adjustments. Most importanly, collusion ends for $\kappa \geq 1/2$ for any value of δ. When $\kappa < 1/2$, the agreement may eventually need to pay attention to suppliers' ICCs as well. In fact, there will be a critical value of δ, which is as a function of κ, below which the agreement $\{w^c, T^c\}$ solves buyers and suppliers' ICCs, (7) and (8), with equality. This form of the agreement remains until $\delta \to 0$, which is when it converges to the one-shot equilibrium outcome of Proposition 1.

We finally move to the first stage of the period game to see whether list prices play any role in suppliers' attempt to collude. They do not. When $\delta \to 1$, it is clear that list prices cannot do better than two-part tariff offers, by construction. Since when $\delta \to 1$ suppliers' ICC hold with slack, list prices have only the potential to replicate the agreement when $\kappa \geq \kappa_0$, but never improve upon it. Matters may change when $\delta < 1$, however. One can imagine that suppliers could be better off by colluding on list-price announcements at stage one because it would make it less attractive for a supplier, say U_i, to deviate from the agreement knowing that U_j and D_j would also disregard the agreement and bargain for new terms in response to U_i's deviation. This would clearly facilitate collusion and, hence, allow suppliers to aim for a better agreement. The problem with this is that if U_i were to deviate from the agreement the best for him is to do it at the bargaining stage, not before, in which case a supplier's relevant ICC continues to be (8).

Proposition 2 identifies two elements as part of a collusive agreement. One is suppliers' need to have buyers' consent to go ahead with the agreement, that is, they need to make sure that buyers' ICCs are satisfied. This condition points to some level of communication that needs to take place between buyers and suppliers, which the latter may want to avoid or that is simply not feasible.

The second element is the role of transfers as part of the agreement. Propositions 1 and 2 suggest that we should necesarily see these transfers emerge or go up in case of a collusion breakdown. We do not see any of these transfers, or changes in them for that matter, in the data of the fresh-egg market. The fact that we do not see them in our data does not mean they do not exist. Some of the terms agreed upon suppliers and (large) buyers are established on an annual basis. These terms, which may include transfers of some sort, would not be captured in our data, which only contains the result of weekly negotiations over wholesale prices. This way to organize wholesale transactions—where general terms are negotiated once a year while the rest, most importantly unit prices, are negotiated on a more frequent basis—is quite common in markets subject to frequent changes in production costs. The fresh-egg market is just one example.

These two elements make us wonder whether we can ever observe a collusive agreement in wholesale prices where suppliers disregard buyers' ICCs and transfers are unfeasible.[33] Absent

[32]Besides, in none of the cases listed in the Introduction there is mention to RPM contracts.

[33]One can imagine a "partial" collusive scheme in which suppliers only attempt to collude on wholesale prices

so far from our analysis is the presence of small, price-taking buyers who do pay list prices. As we show next, their presence not only alters suppliers' collusion possibilities but also their non-collusive ones. For the rest of the analysis we will focus on values of κ large enough that in equilibrium parties rely exclusively on linear contracts, whether they compete or collude. Likewise, we will focus on collusive agreements where suppliers pay no attention to large buyers' participation constraint, possibly because they do not want to communicate with them. We come back to the latter consideration in the Extensions.

4 Public list prices

We now extend our model to the presence of small buyers who pay list prices. The rest of the model remains the same, most importantly, that suppliers post their list prices at stage one, that is, before they negotiate with large buyers at stage two. This timing is intended to capture the situation of the fresh-egg market before the cease of publication of list prices in the local newspaper; more generally, a situation where list prices are readily available and posted simultaneously in a single place. We refer to these prices as *public* list prices. In terms of our model, what formally distinguish *public* from *private* list prices is that the former are posted before suppliers and larger buyers negotiate their terms and the latter are posted simultaneously as these terms are negotiated. According to this distinction, *public* list prices could have provided suppliers with some form of commitment to exploit a first-mover advantage over large buyers, something that could have been lost with the cease of publication.

In extending the model, we consider a fringe of small buyers following the structure of Horn and Wolinsky (1988) that we have used so far. In addition to the large buyer, each supplier $i = 1, 2$ faces his own fringe of price-taking buyers that pay the list price l_i. We adopt a linear supply function for each fringe. At stage three, fringe retailers buying from supplier i are ready to sell a total of

$$q_i^F = \gamma(p - l_i) \tag{10}$$

units in the retail market in anticipation of a retail price p and given their wholesale unit-cost l_i.[34] We assume that $\gamma > 0$ is a constant not too large so in equilibrium small and large buyers

but not on the rest of the terms agreed on their contracts (including transfers), which are revised much less frequently. There are many examples of these partial or semi-collusive arrangements. See, for example, Marshall and Marx (2012).

[34]In the Appendix we let fringe members to order from either U_i or U_j according to a Shubik and Levitan's (1980) specification of the form

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

where $\eta \in [0, 1)$ captures how close substitutes suppliers are, from none ($\eta = 0$) to perfect ($\eta \to 1$). We adopt $\eta = 0$ in the text mostly for expositional simplicity but also to be consistent with the fact that discounts off list prices are always observed in equilibrium. As we discuss below and show in the Appendix, there is a critical value of η above which discounts do not emerge in equilibrium. For instance, when $\gamma = 1$ that critical value is equal to 16/25.

always share the retail market (otherwise suppliers would only sell through the large buyers).[35]

Since the retail price now is given by

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

we can use (10) to derive what would be the large buyers' residual demand given the list prices announced by suppliers at stage one,

$$p(q_i, q_j) = \frac{1}{1+2\gamma}\left(\tilde{a} - q_i - q_j\right)$$

where

$$\tilde{a} = a + \gamma(l_i + l_j)$$

This residual demand is obviously increasing in list prices but ultimately decreasing in the fringe presence.[36] As a result, list prices will play a role now, whether suppliers compete or collude.

4.1 Competitive equilibrium with public list prices

Suppose that l_1 and l_2 are such that large buyers prefer to bargain with suppliers than to buy at those prices. Proceeding as in the previous section, given wholesale prices paid by small and large buyers, l_i and w_i, respectively, the Cournot outcome in stage three is characterized by D_i's equilibrium output

$$q_i(w_i, w_j) = (1+2\gamma)(\tilde{a}/(1+2\gamma) - 2w_i + w_j)/3 \tag{11}$$

and clearing price

$$p(w_i, w_j) = (\tilde{a}/(1+2\gamma) + w_i + w_j)/3. \tag{12}$$

Note that as $\gamma \to 0$, these expressions converge to (2) and (3), respectively. In turn, D_i's profit gross of any fixed fees is given by

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

The second stage, when D_i and U_i bargain, is also similar to what we saw in the previous

[35]We model small buyers as a continuum of agents mainly for simplicity. 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 of such ability; they accept or reject whatever offer is presented to them. These offers may include small discounts off the list price, but they should be interpreted as "tokens of appreciation" not as negotiated discounts. They could even respond to a price-discrimination motive tailor-made by suppliers. In fact, if we let fringe buyers to vary by size, suppliers could second-degree price discriminate them according to their sale orders and nothing would change in our analysis. The data in our motivating evidence confirms prices effectively paid by small buyers to be slightly dispersed around list prices.

[36]Given that in equilibrium $p > l_i$ for the fringe to sell a strictly positive amount, it is immediate that $\partial p/\partial\gamma < 0$.

section except for two aspects. One is that high contractual frictions have lead parties to bargain just over the wholesale price w_i. Given this and the fringe supply (10), we have that parties' on-path payoffs are now given by

$$\hat{\pi}_{D_i} = \pi_{D_i}(w_i, w_j) \tag{13}$$

and

$$\hat{\pi}_{U_i} = w_i q_i(w_i, w_j) + l_i \gamma(p - l_i) \tag{14}$$

respectively.

The second aspect is already evident from looking at (14). In case of a negotiation breakdown, D_i's off-path payoff continues to be zero, $\bar{\pi}_{D_i} = 0$, but U_i's is not. Now it is strictly positive, equal to

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

where

$$\bar{p} = a - q_i^F - q_j^F - q_j = (\tilde{a}/(1+2\gamma) + w_j)/2 \tag{15}$$

is the prevailing off-path price, which is obviously higher than the on-path price (12).

If D_i and U_i expect w_j be the wholesale price agreed upon between D_j and U_j, then their Nash bargaining solution as a function of w_j is

$$w_i^*(w_j) = \frac{a + (1+2\gamma)w_j + \gamma(4l_i + l_j)}{8(1+2\gamma)} \tag{16}$$

which together with $w_j^*(w_i)$ leads to

$$w_i^*(l_i, l_j) = \frac{3a + \gamma(11l_i + 4l_j)}{21(1+2\gamma)} \tag{17}$$

for $i = 1, 2$.

It turns out that higher list prices allow suppliers to negotiate better (i.e., higher) terms with large buyers. This is mainly explained by U_i's outside option to sell through the fringe in case of a negotiation breakdown. To see it, notice that an increase in l_i (and in l_j) augments both $\hat{\pi}_{U_i}$ and $\hat{\pi}_{D_i}$. As dictated by the maximization of the Nash product

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

while an increase in $\hat{\pi}_{U_i}$ calls for a decrease in w_i, as a way to share some of this extra profit with D_i, and increase in $\hat{\pi}_{D_i}$ calls for the exact opposite, an increase in w_i, and for the exact same reason. The latter effect dominates because the increase in $\hat{\pi}_{U_i}$ is partly muted by the outside option $\bar{\pi}_{U_i}$ being strictly positive.

As we move to the first stage of the game, suppliers simultaneously post list prices l_i and l_j while anticipating their consequences in the subsequent stages. Thus, if U_i expects U_j to post

l_j, then he anticipates a payoff of

$$\hat{\pi}_{U_i}(l_i, l_j) = w_i^*(\cdot)q_i(w_i^*(\cdot), w_j^*(\cdot)) + l_i\gamma(p(w_i^*(\cdot), w_j^*(\cdot)) - l_i) \tag{18}$$

from posting l_i, where $w_i^*(\cdot) \equiv w_i^*(l_i, l_j)$ is given by (17) and $p(w_i^*(\cdot), w_j^*(\cdot))$ is given by (12). 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 3 *Suppose that contractual frictions are sufficiently large, i.e., $\kappa \geq 1/2$. The one-shot game with public list prices exhibits an equilibrium in which suppliers post list prices*

$$l_1^* = l_2^* \equiv l^* = \frac{43}{147 + 149\gamma}a$$

at stage one, and then negotiate wholesale prices

$$w_1^* = w_2^* \equiv w^* = \frac{21 + 52\gamma}{(1 + 2\gamma)(147 + 149\gamma)}a < l^*$$

with large buyers at stage two.

Proof. See the Appendix, where we also cover the case in which fringe buyers have the option to buy from either supplier. ■

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 (18), these profits come from large and small buyers, respectively. An increase in list prices always help U_i to increase his profits from the large buyer, i.e., $\partial[w_i^*(\cdot)q_i(w_i^*(\cdot), w_j^*(\cdot))]/\partial l_i > 0$ for all l_i. There are two reasons for this. As shown in (17), one is that a higher list price allows U_i to commit to negotiate better terms with D_i. And as seen from

$$q_i(w_i^*(\cdot), w_j^*(\cdot)) = (6a + \gamma(l_i + 8l_j))/21,$$

the other is that higher list prices leave more residual demand to the large buyers, boosting their sales despite their higher wholesale costs. This boost in sales also benefits U_i.

An increase in list prices also helps U_i to increase his profit from small buyers when their levels are low, that is,

$$\frac{\partial}{\partial l_i}\left(l_i\gamma(p(l_i, l_j) - l_i)\right) = \frac{\gamma}{7(1 + 2\gamma)}\left(3a - 2(7 + 10\gamma)l_i + 4\gamma l_j\right) > 0 \tag{19}$$

when l_i is sufficiently small, and where $p(l_i, l_j) = p(w_i^*(\cdot), w_j^*(\cdot))$. Thus, for low levels of l_i, U_i faces no trade-off from increasing l_i. As l_i gets larger, above the level that takes the right-hand side of (19) to zero, U_i starts destroying profits from small buyers to increase those from the large buyer. The list price in the proposition is the solution to that trade-off.

Consistent with our motivating evidence, the solution to that trade-off confirms that large buyers do indeed negotiate discounts off list prices, which here amount to $w^*/l^* = (21 + 52\gamma)/43(1+2\gamma)$, i.e., to 50% or more. Note that nowhere in our formulation we have restricted large buyers to pay no more than list prices, although is a natural restriction to impose. Discounts emerge endogenously, as part of the equilibrium.

There are three reasons for that. One is that selling through small buyers introduces too much competition in the downstream market. In fact, if for the sake of the explanation we let small buyers be equally efficient than the large buyers, i.e., if $\gamma \to \infty$, then suppliers would restrain themselves from selling to the small buyers; otherwise, and according to the proposition, they would be selling at cost to both small and large buyers. Thus, in equilibrium suppliers maintain l_i above w_i in an effort to prevent small buyers from becoming too competitive. This "softening competition" effect arises even if suppliers had all the bargaining power when negotiating with large buyers.[37]

The second reason is the "commitment" effect already detected in (17), which arises when suppliers must bargain with large buyers the terms in their contracts. Increasing list prices—the prices paid by small buyers—allows suppliers to negotiate better terms with large buyers. This "commitment" effect introduces another consideration into the one-shot equilibrium of Proposition 3, which is a supplier's temptation to revise his list price once the negotiation with the large buyer is over or during the negotiation for that matter. Either way, the temptation is to revise the list price downward, which any small buyer would be happy to accept. A sufficiently patient supplier, however, has (unilateral) incentives to resist such temptation, regardless of what his rival supplier does. The equilibrium in Proposition 3 assumes that both suppliers commit to what they post at stage one.

A final reason why $l^* > w^*$ is our assumption that small buyers do not have the option to buy from either supplier.[38] In the proof of the proposition we relax this assumption and let fringe buyers to order from either supplier according to a Shubik and Levitan's (1980) specification of the form

$$q_i^F = \gamma \left(p - \frac{1}{1-\eta} l_i + \frac{\eta}{1-\eta} l_j \right) \geq 0 \tag{20}$$

where $\eta \in [0, 1)$ captures how close substitutes suppliers are, from none ($\eta = 0$) to perfect ($\eta \to 1$). So far we have assumed that $\eta = 0$. As η increases suppliers compete more aggresively to attract fringe buyers. At some point, when $\eta = \underline{\eta}^* \equiv 4(11 + 17\gamma)/5(13 + 22\gamma)$, $l^* = w^*$. From there onward, suppliers just announce list prices and all buyers, large and small, buy at that price, so discounts cease to exist and with that the commitment effect. Suppliers never stop serving fringe buyers, at least not in expectation. For values of η sufficiently close to 1, suppliers randomize 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).

[37] It is not difficult to show that when suppliers approach large buyers with take-it-or-leave-it (linear) offers we still have that $w^*/l^* = (15 + 29\gamma)/16(1 + 2\gamma) < 1$.

[38] As mentioned earlier, letting each large buyer to buy from both suppliers in equilibrium complicates the analysis but, as illustrated by Cussen (2021), does not qualitatively change the results.

4.2 Collusive equilibrium with public list prices

Imagine now an agreement among suppliers to collude on list prices, while staying away from any communication with buyers. Unlike the agreement in Proposition 2, this is an agreement in which suppliers do not need to pay attention to buyers' ICCs. If they seek to maximize their joint payoff

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

where $\hat{\pi}_{U_i}(l_i, l_j)$ is given by (18), their best course of action, provided they can sustain it, is the following.

Proposition 4 *Suppose small buyers have the option to buy from either supplier according to (20), i.e.,* $\eta \in [0, 1)$*, contractual frictions* κ *are sufficiently large, i.e.,* $\kappa \geq 1/2$*, and suppliers are sufficiently patient, i.e.,* $\delta \geq \underline{\delta} \in (1/2, 1)$*. The best collusive agreement on public list prices is for suppliers to post*

$$l_1 = l_2 \equiv l^c = \frac{17}{49 + 27\gamma} a > l^*$$

at stage one and then negotiate wholesale prices

$$w_1 = w_2 \equiv w^c = \frac{7 + 16\gamma}{(1 + 2\gamma)(49 + 27\gamma)} a > w^*$$

which large buyers at stage two. Relative to the one-shot competitive equilibrium characterized in Proposition 3, 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 the Appendix. ■

A few things are worth highlighting in the proposition. One is that discounts off list prices remain under the collusive agreement; if anything, they get larger, i.e., $w^*/l^* > w^c/l^c$, and this is regardless of the value of η. The other is that as $\gamma \to 0$, the collusive agreement reduces to the one-shot equilibrium of Proposition 1 (and 2), which is when list prices become irrelevant. It is the presence of the small buyers ($\gamma > 0$) what allows suppliers to coordinate on charging higher prices to both small and large buyers. This "multibuyer" contact effect is reminiscent of the multimarket contact effect of Bernheim and Whinston (1990), but is actually very different. It is not as if suppliers transfer collusive discipline from the "small-buyer market" to the "large-buyer market". Rather, colluding with respect to one group of buyers has spillover effects over a second group through the downstream market.

These spillovers explain the opposing implications of the agreement over small and large buyers. While the former see their sales reduced the latter see them enlarged, and with that, their profits. In their attempt to soften competition in the retail market, suppliers' only choice is to increase the wholesale price paid by small buyers. The resulting contraction of small buyers necessarily reports extra benefits to large buyers, part of which are shared with suppliers during their negotiations *via* higher wholesale prices.

Another aspect to highlight in the proposition is that the critical discount factor $\underline{\delta}$ above which suppliers can sustain l^c in equilibrium can be as low as 1/2—when $\gamma \to 0$ and $\eta = 0$—and is increasing in both γ and η. The role of η is easier to grasp. While collusive payoffs, $\hat{\pi}_{U_i}(l_i^c, l_j^c)$, are invariant to increases in η, deviation payoffs, $\hat{\pi}_{U_i}(l_i^d, l_j^c)$,[39] and punishment payoffs, $\hat{\pi}_{U_i}(l_i^*, l_j^*)$, move in opposite directions, up and down, repectively. As seen in many collusion models, the former effect dominates making collusion more difficult to sustain as η goes up. The role of gamma is less straight forward to explain not only because all payoffs react to changes in γ but also because they do so nonmonotonically. What is monotonic in γ, however, is that the difference $\hat{\pi}_{U_i}(l_i^d, l_j^c) - \hat{\pi}_{U_i}(l_i^c, l_j^c)$ increases faster than the difference $\hat{\pi}_{U_i}(l_i^d, l_j^c) - \hat{\pi}_{U_i}(l_i^*, l_j^*)$, which ultimately explains why $\underline{\delta}$ goes up with γ.

Propositions 3 and 4 have presented us with two potential explanations to describe the fresh-egg market before the cease of publication of list prices in the local newspaper, a competitive and a collusive one. Essentially, both equilibria are consistent with the fact that large buyers pay less than small buyers for each unit of product. Qualitatively speaking, not much else separate the two equilibria so far, unless of course, there was "outside-the-model" evidence that suppliers were sufficiently close substitutes for small buyers to erase any discount under competition.[40] What we want to explore next is whether the cease of the publication may shed further light on to which of these two equilibria is more plausible.

5 From public to private list prices

With the cease of publication in the local newspaper, suppliers had to resort to alternative means to communicate their list prices to potential buyers, particularly, small ones. To avoid confusion, we refer to them as *private* list prices to emphasize that are they no longer so readily available. In reality, we could dispense with any reference to list prices altogether, and simply refer to them as prices paid by small buyers. This is so because 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 only difference is that small buyers take whatever offer is presented to them (all small buyers receive the same offer since there is no means to discriminate across them; they all order one unit of the product at best) whereas large buyers engage in bilateral negotiations.

Approaching all buyers simultaneously brings another question, that of the feasibility of collusion. One of the potential explanations for the evidence presented in Section 2 is that public list prices would have helped suppliers to better monitor a possible collusive agreement. If so, the explanation goes, forcing suppliers to move to private list prices would have caused their agreement to end, or alternatively, to turn into a less ambitious one. Either post-publication path would be consistent with the evidence of the fall in prices paid by both large and small

[39] Recall that $l_i^d = l_i^*(l_j^c) = \arg\max_{l_i} \hat{\pi}_{U_i}(l_i, l_j^c)$

[40] In that regard there is a difference with the competitive and collusive equilibria in Propositions 1 and 2, respectively, in that the latter required transfers.

buyers. Here we take the first path—that collusion ended—and leave the alternative path for the next section (Extensions).

The rest of the section is organized as follows. We first characterize the competitive equilibrium with private list prices, again under the assumption that contractual frictions κ are sufficiently large so transfers do not emerge in equilibrium. We will continue denoting these list prices by l_i and l_j. Using this equilibrium as the post-publication benchmark, we then discuss which of the two explanations advanced by our motivating evidence gathers more support to explain the role of public list prices, the collusive explanation (Proposition 4) or the competitive one (Proposition 3).

5.1 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 of the the price l_i that U_i would charge small buyers. The equilibrium concept we adopt to find the outcome of this multibuyer bargaining problem is Nash-in-Nash (Horn and Wolinsky 1990, Collard-Wexler et al 2019).

The Nash-in-Nash solution is the set of price agreements w_i^s, l_i^s, w_j^s and l_j^s such that w_i^s 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^s, w_j^s and l_j^s (we use superscripts "s" to indicate that a supplier bargains simultaneously with several buyers). Similarly, l_i^s 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^s, w_j^s and l_j^s. The only difference with settings where the Nash-in-Nash concept has been used 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^s can be readily obtained from U_i's best response to the other prices, that is

$$l_i^s = \arg\max_{l_i}\{\hat{\pi}_{U_i}(w_i^s, l_i, w_j^s, l_j^s) = w_i^s q_i(w_i^s, l_i, w_j^s, l_j^s) + l_i\gamma(p(w_i^s, l_i, w_j^s, l_j^s) - l_i)\} \tag{21}$$

where $q_i(\cdot)$ and $p(\cdot)$ we are given by (11) and (12), respectively.

To obtain w_i^s, we maximize the Nash product (recall that $\bar{\pi}_{D_i} = 0$)

$$w_i^s = \arg\max_{w_i}(\hat{\pi}_{U_i}(w_i, l_i^s, w_j^s, l_j^s) - \bar{\pi}_{U_i}(l_i^s, w_j^s, l_j^s))\hat{\pi}_{D_i}(w_i, l_i^s, w_j^s, l_j^s) \tag{22}$$

where $\bar{\pi}_{U_i} = l_i^s\gamma(\bar{p}(l_i^s, w_j^s, l_j^s) - l_i^s)$ and $\bar{p}(\cdot)$ is given by (15). Expressions (21) and (22), for $i = 1, 2$, characterize the outcome of the one-shot game, which is summarized in the next proposition.

Proposition 5 *Suppose a small buyers has only the option to buy from a single supplier, i.e., $\eta = 0$, and contractual frictions κ are sufficiently large, i.e., $\kappa \geq 1/2$. The one-shot game with* *private list prices exhibits an equilibrium in which suppliers make take-it-or-leave-it (list price) offers*

$$l_1^s = l_2^s \equiv l^s = \frac{5}{3(7+8\gamma)}a$$

to small buyers and simultaneously negotiate wholesale prices

$$w_1^s = w_2^s \equiv w^s = \frac{3+7\gamma}{3\,(1+2\gamma)\,(7+8\gamma)}a < l^s$$

with large buyers.

Proof. See the Appendix, where we also cover the case where $\eta > 0$. ■

Note that as $\gamma \to 0$, $w^s \to a/7$, just as predicted by Proposition 1 for the case when there are no small buyers. Again the reason large buyers pay less than small buyers ($w^s < l^s$) is because it is not in U_i's best interest to make small buyers too competitive in the downstream market; something that is understood by both U_i and D_i during their negotiation. Similarly to the case of public list prices, if we let small buyers to have the option to buy from either supplier according to (20), then discounts may cease to exist when suppliers are too close substitutes for small buyers. In fact, and as shown in the proof of the proposition, when $\eta = \underline{\eta}^s \equiv 2(2+3\gamma)/(7+12\gamma) < \underline{\eta}^*$, $l^s = w^s$. From there onward, suppliers just announce list prices and all buyers, large and small, buy at that price.

5.2 Explaining our motivating evidence

Our motivating evidence, summarized in Table 1, showed that wholesale prices paid by small and large buyers not only fell with the cease of the publication of list prices in the local newspaper, but also their difference did. In other words, discounts became less prevalent with the cease of publication. As the next proposition indicates, this evolution of prices and discounts is consistent with a collusive explanation in which the publication of list prices had helped suppliers to coordinate on prices.

Proposition 6 *Relative to the collusive equilibrium characterized in Proposition 4, the competitive equilibrium with private list prices characterized in Proposition 5 leads to (i) lower prices paid by small buyers (i.e., $l^s < l^c$), (ii) lower prices paid by large buyers (i.e., $w^s < w^c$), (iii) smaller discounts received by large buyers (i.e., $l^s - w^s < l^c - w^c$ and $w^s/l^s < w^c/l^c$), (iv) larger sale of small buyers, (v) smaller sale of large buyers, (vi) larger total sales, and (vii) smaller profits of both suppliers and large buyers.*

However, as the next proposition indicates, the same evolution of prices is also consistent with a non-collusive explanation in which the publication of list prices had helped each supplier to negotiate independently better terms with large buyers.

Proposition 7 *Relative to the competitive equilibrium with public list prices characterized in Proposition 3, the competitive equilibrium with private list prices characterized in Proposition*

5 leads to (i) lower prices paid by small buyers (i.e., $l^s < l^*$), (ii) lower prices paid by large buyers (i.e., $w^s < w^*$), (iii) smaller discounts received by large buyers (i.e., $l^s - w^s < l^* - w^*$ and $w^s/l^s > w^c/l^c$), (iv) larger sale of small buyers, (v) smaller sale of large buyers, (vi) larger total sales, and (vii) smaller profits of both suppliers and large buyers.

Since prices paid by large buyers are increasing in public list prices, it is not surprising that prices paid by both large and small buyers fall as we move from public to private list prices, regardless of whether suppliers collude or compete. Less obvious is that discounts also reduce in either case. Because prices paid by large buyers are determined in bilateral negotiations, any additional increase in (public) list prices is not passed through one-to-one to such prices, but only a fraction of it (it also adds to this incomplete pass-through the fact that large buyers are less aggressive than small buyers in the downstream market). As a result of this incomplete pass-through, the elimination of public list prices would predict not only a drop in both prices—list and negotiated prices—but also a drop in the gap between the two.

As the two propositions are identical, it is clear that our theory is not prepared to distinguish, at least qualitatively, between the collusive and the non-collusive explanations when η is not too large, more precisely, when $\eta < \underline{\eta}^s$. This is the case when discounts emerge in all three propositions, that is, Propositions 3, 4 and 5. In this case what distinguishes one explanation from the other is only 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 coordinately and in the other independently.

When suppliers are highly impatient, i.e., $\delta \to 0$, the collusive equilibrium reduces to the competitive equilibrium. One may say that in this case the multibuyer contact effect reduces just to the commitment effect. As suppliers become more patient, the multibuyer contact effect grows larger, allowing suppliers to charge even higher prices to both type of buyers, with discounts growing larger as well.

That our theory cannot distinguish between the two explanations extends to higher values of η. Suppose for instance that our motivating showed discounts to disappear after the interruption of the publication, that is, the sum of the coefficients of *Large* and *Post* $\times$ *Large*, $\beta + \phi$, was not statistically different from zero. This would have been an indication that $\eta \geq \underline{\eta}^s$. Nevertheless, we could have still observed discounts before the interruption of the publication under competition, since $\underline{\eta}^s < \underline{\eta}^*$, as we would have observed discounts under collusion. One may argue that not observing discounts after the interruption of the publication makes the competitive explanation less plausible, as the commitment effect weakens and eventually disappears with higher values of η, but it does not rule it out. To rule it out requires evidence outside the model showing that η is also larger than $\underline{\eta}^*$.

6 Extension: Colluding with private list prices

Colluding with private list prices is not unthinkable but does require of some communication between suppliers and large buyers. This in itself could be problematic for collusion to be implemented, let alone, sustained. In the collusive agreement of Proposition 4 this communication was not necessary because large buyers were aware of the prices charged to the small buyers at the time of their negotiations. That is no longer the case here.

One can think of two types of communication, soft and hard. Under soft communication, suppliers communicate to large buyers only the list price they intend to charge small buyers. Whereas under hard communication suppliers not only communicate list prices but also make large buyers an offer that may depart from the Nash-bargaining solution that would ensue in anticipation to such list prices. In either case, suppliers need to make sure that (large) buyers' ICC is satisfied, as they did in Proposition 2. Note that in Proposition 4 we did not pay attention to this constraint. It turned out that larger buyers also benefited from the agreement; but had they not, this would have not invalidated the agreement.

6.1 Soft communication

Any agreement under soft communication would share the same properties of the agreement in Proposition 4 with the only difference being the level of list prices that suppliers would be able to sustain in equilibrium. Sufficiently patient suppliers would in principle be able to sustain the same level of list prices in Proposition 4, l^c, while less patient suppliers would have to content themselves with lower levels, anything between l^c and the competitive level in Proposition 5, l^s. Since in any of these intermediate levels of collusion large buyers' ICCs hold with slack,[41] one could in theory advance a third potential explanation for the evolution of prices in the wholesale fresh-egg market: the cease of publication of list prices did not end collusion altogether, it just forced suppliers to move to a less ambitious agreement that in addition had to be communicated to large buyers.

If one were to overlook the implications of communication with large buyers for the implementation and sustainability of a collusive agreement, support for this third explanation still requires that the agreement would be easier to sustain under public list prices than under private list prices. This is not entirely obvious. Suppose that punishment strategies involve reversion to the competitive equilibrium of either Proposition 3 or 5. It is clear from these propositions that moving from public to private list prices increases the severity of the punishments. However, moving from public to private list prices also increases the incentives to deviate from the agreement by postponing its detection from the second to the third stage. It can be shown that the latter effect dominates, although slightly, so collusion would indeed be

[41] Large buyers may feel uncomfortable with being aware of the suppliers' collusion agreement. They may seek to "sabotage" it by either refusing to deal with suppliers or approaching the competition authority. Either way, note that this sabotage motive is completely different from the buyer's deviation incentive detected in Proposition 2.

more difficult to sustain under private list prices.

6.2 Hard communication

With hard communication suppliers can in theory aim for an agreement that is more ambitious than that in Proposition 4. When $\delta \to 1$ (and $\eta = 0$), the most they can aim for is to post list prices

$$l_1^h = l_2^h \equiv l^h = \frac{a}{2}$$

and simultaneously approach large buyers with offers

$$w_1^h = w_2^h \equiv w^h = \frac{1+4\gamma}{7+8\gamma} a < l^h$$

where superscripts "h" indicate hard communication.

Since large buyers' ICC holds with slack in the agreement of Proposition 4, the way suppliers improve upon such agreement here is by increasing the price paid by large buyers ($w^h > w^c$) until the ICC binds, that is, until $\hat{\pi}_{D_i}(l^h, l^h) \to \hat{\pi}_{D_i}(l^s, l^s)$ given that $\delta \to 1$. And while doing that, suppliers also increase the price paid by small buyers ($l^h > l^c$). When $\delta < 1$, the way suppliers would adjust the agreement is by lowering both prices and closing their gap, much in line with the predictions of Propositions 6 and 7. Furthermore, the pattern of adjustment is no different whether suppliers remain in the hard-communication mode or, as part of the adjustment, must switch to a soft-communication mode.

This adjustment of prices presents us with another, yet closely related, explanation of the evolution of prices in our motivating evidence, which is that the cease of publication of list prices could have prompted suppliers to water down their "hard-communication" agreement. Whether the publication of list prices could have indeed played such a role is something our theory cannot tell.

7 Conclusions

Our goal has been to contribute to a better understanding of whether, how and to what extent simultaneous and public announcements of list prices could help suppliers to sustain supra-competitive wholesale prices. Our interest in the topic has been motivated by antitrust cases and also by recent developments in Chile's wholesale fresh-egg market, where we have seen a significant drop in list and transaction (i.e., effectively paid) prices after its main suppliers had to stop publishing their list prices in the local newspaper.

Our theory provides two explanations for this drop in prices, a collusive and a non-collusive, competitive one. Whether one turns out to be more plausible than the other is less relevant for consumer welfare, as our theory unambiguously predicts that public announcements of list prices lead to supracompetitive prices. This suggests that terminating with the publication of list prices was a sensible decision to make.[42]

A totally different matter is the legal implications of finding more support for one explanation over the other. Unfortunately, our theory sheds little light on that regard. Both explanations are equally plausible, i.e., they share the same qualitative predictions in terms of changes in quantities, prices and profits. Distinguishing between the two explanations may need of further empirical (and structural) analysis, possibly using additional data from the retail market. Clearly, this is something beyond the scope of this paper.

Appendix

The Appendix contains proofs of propositions and results mentioned in the text.

Proof of Proposition 1

Consider first the case of $\kappa < 1/2$. From the first-order conditions of the Nash problem we arrive at the equilibrium terms stated in the propositions, so by construction U_i and D_i cannot do better by locally deviating in the neighboord of such terms. It remains to rule out nonlocal deviations, which in this case would be for U_i and D_i to restrict their bargaining space to just w_i. Reducing the number of instruments cannot be profitable either. In fact, the deviation profits of doing so are $(1+2\kappa)^2 a^2/2\left(5+4\kappa\right)^2$ and $(1+2\kappa)^2 a^2/\left(5+4\kappa\right)^2$, respectively, which are strictly lower than the equilibrium profits, $(1+2\kappa)a^2/\left(5+4\kappa\right)^2$ and $(1+2\kappa)a^2/(1-\kappa)\left(5+4\kappa\right)^2$, for all $\kappa < 1/2$. Consider now $\kappa \geq 1/2$. The only relevant (nonlocal) deviation to study in this case is the use of slotting allowances (i.e., $T_i \leq 0$), in which case on-path (deviation) payoffs change to $\hat{\pi}_{U_i} = w_i q_i(w_i, w_j) + T_i$ and $\hat{\pi}_{D_i} = \pi_{D_i}(w_i, w_j) - (1-\kappa)T_i$. It is easy to see that the optimal deviation is to agree on the corner $T = 0$ (and $w = a/7$) for any $\kappa \geq 1/2$.

List prices as deviations

Consider the case of $\kappa < 1/2$ and suppose that U_i deviates to announce a list price l_i^d that D_i will accept at the beginning of their negotiation. Since this deviation will be observed by U_j and D_j before they initiate theirs, their negotiated response in anticipation to D_i accepting l_i^d is to agree on the terms

$$w_j(l_i^d) = \frac{4\kappa - 1}{4(1+2\kappa)}\left(a + l_i^d\right)$$

and

$$T_j(l_i^d) = \frac{3(1-2\kappa)}{16\left(1-\kappa\right)\left(1+2\kappa\right)^2}\left(a + l_i^d\right)^2$$

[42] Some industry observers might argue that in the past the publication of list prices helped reduce search costs, particularly, of small buyers. Whether that is true today is hard to tell. The evidence presented in Section 2 tells us that if anything this procompetitive factor carries much less weight than the anticompetitive ones highlighted by our theory.

Note that $T_j(l_i^d) \to 0$ as $\kappa \to 1/2$. Anticipating this response, U_i's best deviation is to leave D_i indifferent between accepting l_i^d and bargaining with him. In other words, l_i^d should be such that $q_i^2(l_i^d, w_j(l_i^d)) = q_i^2(w^*, w^*) - T^* + \epsilon$ (with $\epsilon \to 0$), that is,

$$l_i^d = \frac{1+2\kappa}{3+4\kappa}\left(\frac{1+4\kappa}{1+2\kappa} - \frac{4}{4\kappa+5}\sqrt{\frac{1+2\kappa}{1-\kappa}}\right)a$$

But

$$\pi_{U_i}^d = l_i^d q_i(l_i^d, w_j(l_i^d)) < \hat{\pi}_{U_i}(w_i^*, w_j^*, T_i^*) = (1+2\kappa)a^2/(1-\kappa)\,(4\kappa+5)^2$$

for all $\kappa < 1/2$, so it is never profitable for U_i to deviate to a list price that D_i would accept.

List prices as outside options

Consider this alternative outside option: in case of a negotiation breakdown parties have the option to trade at list prices. For simplicity we focus on the case $\kappa \geq 1/2$ (the other case is left to the reader). If U_i and D_i conjecture that U_j and D_j will agree on w_j when all parties have the option to trade at list prices in case of a negotiation breakdown, then their bargaining outcome would be to trade at $w_i^*(w_j, l_i) = (a+w_j)/8$ when $l_i \geq (a+w_j)/2$, i.e., when $q_i(l_i, w_j) \leq 0$, and

$$w_i^*(w_j, l_i) = \frac{1}{16}\left(9a - 8l_i + 9w_j - \sqrt{17(a+w_j)^2 + 16l_i\,(4l_i - 3w_j - 3a)}\right) \geq l_i \qquad (23)$$

when $l_i \leq (a+w_j)/2$, i.e., when $q_i(l_i, w_j) \geq 0$.

In the region where these responses do depend on l_i we can use $w_i^*(w_j, l_i)$ and $w_j^*(w_i, l_j)$ to obtain $w_i^*(l_i, l_j)$ for $i = 1, 2$. After some manipulation (which we omit here to save on space) it is possible to establish that

$$\partial w_i^*(l_i, l_j)/\partial l_i < 0 \text{ and } \partial w_j^*(l_i, l_j)/\partial l_i < 0 \qquad (24)$$

in the relevant region, that is, where $q_i(l_i, w_j^*(l_i, l_j)) \geq 0$ and $w_i^*(l_i, l_j) \leq l_i$. The reason for (24) is twofold. On the one hand, a drop in l_i in the relevant region improves U_i's payoff from trading at l_i more than D_i's, which explains the negative sign on the left. On the other hand, an increase in the value of w_i invites U_j and D_j to negotiate a higher value of w_j, which explains the negative sign on the right.

Anticipating $w_i^*(w_j, l_i)$ and $w_j^*(w_i, l_j)$, U_i's problem of choosing l_i under the conjecture that U_j will announce l_j can be written as

$$\max_{l_i} w_i^*(l_i, l_j) q_i(w_i^*(l_i, l_j), w_j^*(l_j, l_i)) \qquad (25)$$

It is evident that the equilibrium in Proposition 1—where $w_i = w_j = a/7 \approx 0.143a$ and l_i and l_j are large enough (i.e., $l_i \geq l^0 \equiv 4a/7 \approx 0.571a$)—is not longer an equilibrium under this alternative outside option. For instance, if U_i expect U_j to announce $l_j = l^0$, so $q_j(l^0, w_i =$

$a/7) = 0$, U_i's optimal announcement at stage one is not $l_i \geq l^0$ but lower; the one given by the first-order condition of problem (25), that is,

$$\Big(a - 4w_i^*(l_i, l_j) + w_j^*(l_j, l_i)\Big) \frac{\partial w_i^*(\cdot)}{\partial l_i} + w_i^*(l_i, l_j) \frac{\partial w_j^*(\cdot)}{\partial l_i} \leq 0 \tag{26}$$

which yields the corner $l_i^d = w_i^*(l_i^d, l^0) = 91a/300 \approx 0.303a$. Having observed l_i^d, U_j and D_j would, in response, negotiate $w_j^*(l^0, l_i^d) = 16a/75 \approx 0.213a$. Both $w_i^*(l_i^d, l^0)$ and $w_j^*(l^0, l_i^d,)$ are higher than the negotiated prices in Proposition 1.

This deviation incentive toward lower list prices implies that in equilibrium list prices coverge to negotiated prices. Imposing this covergence result ($w_i = l_i$) and symmetry ($w_i = w_j$) into (23) yields the corner

$$l_i^* = l_j^* = w_i^*(l_i^*, l_j^*) = w_j^*(l_i^*, l_j^*) = a/3 \tag{27}$$

Note from (26) that in principle suppliers would like to announce even lower list prices (lower than $a/3$) that would fall below negotiated prices. But that cannot happen in equilibrium since buyers would rather skip negotiations and buy at list prices. Thus, prices (27) are exactly the ones that U_i and U_j would have announced had they had the opportunity to make take-it-or-leave-it offers to D_i and D_j, respectively. This can be easily seen from solving (25) for the case where $w_i = l_i$ and $w_j = l_j$, i.e., from solving $\max_{l_i} l_i q_i(l_i, l_j)$ for $i = 1, 2$.

Proof of Proposition 2

We first cover the case when $\delta \to 1$ and then the case when parties are less patient, $\delta < 1$. Suppose then that $\delta \to 1$, in which case buyers' ICC reduces to $T \leq \pi_D(w, w) - \pi_D(w^*, w^*) + T^*$. Since the latter must hold with equality when $T > 0$, the solution to the suppliers' problem when κ is sufficiently small is given by

$$w^c = \arg\max_{w} \{wq(w, w) + (1 - \kappa)\pi_D(w, w)\} = \frac{1 + 2\kappa}{2(2 + \kappa)} a$$

and

$$T^c = \pi_D(w^c, w^c) - \pi_D(w^*, w^*) + T^* = \frac{3\left(3 - 11\kappa - 20\kappa^2 - 8\kappa^3\right)}{4\left(1 - \kappa\right)\left(10 + 13\kappa + 4\kappa^2\right)^2} a^2$$

This solution is valid as long as $T^c > 0$, that is, as long as $\kappa < \kappa_0$, where $\kappa_0 \approx 1/5$ solves the cubic $3 - 11\kappa - 20\kappa^2 - 8\kappa^3 = 0$. When $\kappa \geq \kappa_0$, suppliers have the option to resort to slotting allowances (i.e., negative transfers) in which case their problem changes to

$$\max_{w,T} wq(w, w) + T$$

subject to (recall that $\delta \to 1$) $\pi_D(w, w) - (1 - \kappa)T \geq \pi_D(w^*, w^*) - T^*$. Again, if $T < 0$, buyers' ICC must hold with equality, in which case the solution $w^\# = \arg\max_w \{wq(w, w) + \pi_D(w, w)/(1 - \kappa)\}$ results in a contradiction: suppliers are strictly worse off than setting $T^c = 0$

and

$$w^c = \left(1 - \frac{3}{5+4\kappa}\sqrt{\frac{1+2\kappa}{1-\kappa}}\right)a$$

which solves $\pi_D(w^c, w^c) = \pi_D(w^*, w^*) - T^*$. Therefore, these terms must constitute suppliers' collusive solution for $\kappa \geq \kappa_0$, which necesarily converges to the competitive solution when $T^* = 0$, that is, when $\kappa = 1/2$.

Consider now the case $\delta < 1$. To facilitate the exposition suppose that κ is small enough such that the collusive agreement always include transfers. We know that such threshold is equal to κ_0 for $\delta \to 1$ but it will change as we vary δ. Thus, consider a collusive agreement given by w and $T > 0$. If U_i and/or D_i decide to deviate from such an agreement, they anticipate deviation terms (9) equal to

$$w^d = -\frac{1-4\kappa}{4(1+2\kappa)}(a+w) \tag{28}$$

and

$$T^d = \frac{3(1-2\kappa)}{16(1-\kappa)(1+2\kappa)^2}(a+w)^2 \tag{29}$$

We also know from the analysis for $\delta \to 1$ that when δ is sufficiently close to 1, the only ICC to be binding is that of buyers, in which case the suppliers' problem reduces to

$$\max_{w,T} wq(w,w) + (1-\kappa)T$$

subject to (7), or which is the same, subject to

$$T \geq \Upsilon(w) \equiv \frac{(a-w)^2}{9} - (1-\delta)\frac{(a+w)^2}{16(1-\kappa)(1+2\kappa)} - \delta\frac{1+2\kappa}{(1-\kappa)(5+4\kappa)^2}a^2$$

Plugging $\Upsilon(w)$ into the suppliers' problem yields

$$w^c = -\frac{1-9\delta-32\kappa(1+\kappa)}{41-9\delta+16\kappa(5+2\kappa)}a$$

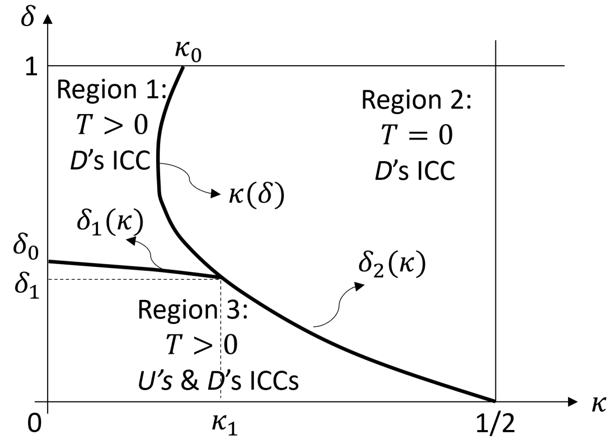
and $T^c = \Upsilon(w^c)$.

This solution requires both that $T^c > 0$ and that the suppliers' ICC holds with slack. The former requires that $\kappa < \kappa(\delta)$, where function $\kappa(\delta)$ is obtained from plugging w^c into $\Upsilon(w)$ and solving $\Upsilon(w^c) = 0$ (recall that $\kappa_0 = \kappa(\delta \to 1)$). The latter, on the other hand, requires that $\delta > \delta_1(\kappa)$, where function $\delta_1(\kappa)$ is obtained from plugging w^c and T^c into the supplier's ICC (8) and imposing that it holds with equality. Doing so yields

$$\delta_1(\kappa) = \left(11 + 20\kappa + 8\kappa^2 - 4\sqrt{(1+\kappa)(2+\kappa)(1+2\kappa)(3+2\kappa)}\right)/3$$

Figure 1 depicts the κ-δ region (Region 1) where the solution to the suppliers' collusive problem

Figure 1: Sustainability of collusion as a function of δ and κ



we just described applies. Note that $\delta_0 = \delta_1(\kappa = 0) \approx 0.401$, $\kappa_1 = \kappa(\delta_1(\kappa_1)) \approx 0.238$ and $\delta_1 = \delta_1(\kappa(\delta_1)) \approx 0.377$.

We now describe how the collusive agreement changes as we move to the other regions in the figure. Let us start with Region 2. When $\kappa > \kappa(\delta)$, the collusive agreement does not include transfers, which does not necesarily mean that a deviation from the agreement does not include them either. In fact, since the terms agreed after a deviation only depend on w, they happen to be the same as those above: (28) and (29). Assuming that δ is large enough for the suppliers' ICC to hold with slack, the suppliers' problem then reduces to find the wholesale price that exactly satisfies the buyers' ICC, that is, the wholesale price w^c that solves $\Upsilon(w^c) = 0$. This solution requires that the suppliers' ICC holds with slack, that is, it requires that $\delta > \delta_2(\kappa)$, which is obtained from plugging w^c into the suppliers' ICC (8) and imposing that it holds with equality. Doing so yields

$$\delta_2(\kappa) = (1 - 2\kappa)(4\kappa + 5)^2 / (41 + 38\kappa - 16\kappa^2)$$

(Note that $\delta_2(\kappa_1) = \delta_1$). It is easy to see that the collusive solution in Region 2 converges to $w^c = w^*$ for any $\delta < 1$ when $\kappa = 1/2$.

Let us now consider Region 3. When either $\delta < \delta_1(\kappa)$ if $\kappa \leq \kappa_1$ or $\delta < \delta_2(\kappa)$ if $\kappa_1 < \kappa \leq 1/2$, the collusive agreement includes transfers again but this time both ICCs are binding. Therefore, the solution to the suppliers' collusive problem reduces to solving the system of ICCs with equality, which yields

$$w^c = \frac{60\kappa + 81\delta + 144\kappa^2 + 64\kappa^3 + 108\kappa\delta - 25}{(5 + 4\kappa)(25 + 40\kappa - 9\delta + 16\kappa^2)} a$$

and $T^c = \Upsilon(w^c)$. This solution converges to $w^c = w^*$ and $T^c = T^*$ as $\delta \to 0$.

Proof of Proposition 3

The proof is divided in three parts. In Part I we show that under the fringe presence transfers do not emerge in equilibrium when $\kappa \geq 1/2$. In Part II we demonstrate that suppliers have no incentives to skip negotiations with large buyers and let them also to buy at list prices. Finally, in Part III, we extend our baseline model to the case where small buyers have the option to buy from either supplier.

Part I. Let us first demonstrate that under the fringe presence transfers do not emerge in equilibrium when $\kappa \geq 1/2$. We know from (16) that if U_i and D_i agree on $T_i = 0$, then they must also agree on

$$w_i^*(w_j) = (a + (1+2\gamma)w_j + 4\gamma l_i + \gamma l_j)\,/8(1+2\gamma) \tag{30}$$

given announcements l_i and l_j and the conjecture that U_j and U_j will agree on w_j. Plugging the above on the Nash-bargaining first-order condition for T_i yields

$$T_i^*(w_j) = \frac{1-2\kappa}{64\,(1-\kappa)\,(1+2\gamma)}\,(a + (1+2\gamma)w_j + \gamma l_j)^2$$

which shows that $T_i^*(w_j) = 0$ when $\kappa = 1/2$ (or above).

Part II. Let us now demonstrate that suppliers have no incentives to let large large buyers to 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. Making $w_j = l_j = l_j^d$ in (30), we know that U_i and D_i would respond to such deviation with the terms

$$w_i^d(l_i^*, l_j^d) = \left(a + (1+3\gamma)l_j^d + 4\gamma l_i^*\right)/8(1+2\gamma)$$

where l_i^* 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

$$q_j^2(l_j^d, w_i^d(\cdot)) = q_j^2(w_j^*(w_i^d(\cdot)), w_i^d(\cdot)) + \epsilon \tag{31}$$

with $\epsilon \to 0$ and where, following (16), $w_j^*(w_i^d(\cdot))$ 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)

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

Using (11) and solving (31) we obtain

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

But

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

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

Part III. Let us finally consider a fringe of small buyers that can buy from either supplier according to a Shubik and Levitan's (1980) specification. Given list prices l_i and l_j and retail price p, each fringe member's choices of $q_i^F \geq 0$ and $q_j^F \geq 0$ are the solution to the maximization of

$$p(q_i^F + q_j^F) - l_i q_i^F - l_j q_j^F - \frac{1}{2\gamma(1+\eta)}\left(\left(q_i^F\right)^2 + \left(q_j^F\right)^2 + 2\eta q_i^F q_j^F\right)$$

where $\eta \in [0,1)$ captures how close substitutes suppliers are, from none ($\eta = 0$) to perfect ($\eta \to 1$). Thus,

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

for $i = 1, 2$.

Our goal in this part of the proof is to show (i) that the existence of discounts off list prices (i.e., $w_i^* > l_i^*$) characterized in the proposition is only valid when suppliers are not too close substitute for fringe members, more especifically, when $\eta < \underline{\eta} < 1$, which is when $w_i^* = l_i^*$; (ii) that the equilibrium solution without discounts (i.e., $w_i^* = l_i^*$) remains valid for $\eta \in [\underline{\eta}, \bar{\eta}]$, with $\underline{\eta} < \bar{\eta} < 1$; and (iii) that when $\eta > \bar{\eta}$ suppliers must randomize over whether to sell to the fringe by setting list prices accordingly. We omit the characterization of the mixed strategy equilibrium; we simply show that there are deviation incentives in either case, when both sell to the fringe and when none does.

To show (i) note that given list prices l_i and l_j, the negotiated prices are given by (17) in the text, that is,

$$w_i^*(l_i, l_j) = \frac{3a + \gamma(11l_i + 4l_j)}{21(1+2\gamma)} \tag{32}$$

Anticipating the latter, U_i's best response to l_j is given by

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

where w_i is given by (32), and q_i and p are given by (11) and (12), respectively. Applying symmetry, $l_i^*(l_j^*) = l_j^*$, we arrive at

$$l_i^* = l_j^* = l^*(\eta) = \frac{86(1-\eta)}{147(2-\eta) + 2\gamma(149-2\eta)}a \tag{33}$$

(note that (33) reduces to the expression in the proposition when $\eta = 0$). Plugging l_i^* and l_j^* into (32) to obtain $w_i^* = w_j^* = w^*(\eta)$ and making $w^*(\underline{\eta}) = l^*(\underline{\eta})$ yields

$$\underline{\eta} \equiv \frac{4(11+17\gamma)}{5(13+22\gamma)}$$

The proof to (i) finishes by showing that deviating to sell nothing to small buyers results in a strict loss, i.e.,

$$\pi_{U_i}(l_i^0, l^*(\eta)) < \pi_{U_i}(l^*(\eta), l^*(\eta)) \tag{34}$$

for all $\eta \leq \underline{\eta}$ and where l_i^0 is such that

$$q_i^F(l_i^0, l^*(\eta)) = p(l_i^0, l^*(\eta)) - \frac{1}{1-\eta} l_i^0 + \frac{\eta}{1-\eta} l^*(\eta) = 0$$

so (32) applies.

To show (ii) note first that for $\eta > \underline{\eta}$ an equilibrium candidate would be for list prices l_i and l_j be given by (33) and negotiated prices w_i and w_j by (32). The problem with this is that $w_i > l_i$ for $i = 1, 2$, to which larger buyers would deviate at the beginning of the bargaining stage by adopting the list prices. Therefore, it must hold in equilibrium that $w_i^* = l_i^*$ for $\eta > \underline{\eta}$. Thus, if U_i anticipates that U_j will sell all his units at l_j, U_i would in principle like to sell his at

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

where q_i and p are given by (11) and (12) for $w_i = l_i$ for $i = 1, 2$, respectively. Again, applying symmetry, $l_i^*(l_j^*) = l_j^*$, we arrive at the equilibrium candidate

$$\tilde{l}_i^* = \tilde{l}_j^* = \tilde{l}^*(\eta) = \frac{(1-\eta)(1+3\gamma)}{3(1-\eta)(1+\gamma)(1+3\gamma) + 3\eta\gamma(1+2\gamma)} a \tag{35}$$

for $\eta > \underline{\eta}$ (the "upper tilde" indicates equilibrium candidate).

Two observations regarding (35) are in order. The first is that according to (33), $\tilde{l}^*(\underline{\eta}) > l^*(\underline{\eta})$. This implies that having all buyers buying at $\tilde{l}^*(\eta)$ cannot be an equilibrium in the neighborhood of $\underline{\eta}$ since D_i would have incentives to disregard $\tilde{l}^*(\eta)$ and bargain with U_i to obtain a lower offer, i.e., $w_i^*(\tilde{l}^*(\underline{\eta}), w_j = l_j = \tilde{l}^*(\underline{\eta})) < \tilde{l}^*(\underline{\eta})$. This deviation incentive disappears when $\eta = \tilde{\eta} > \underline{\eta}$, where $\tilde{\eta}$ solves

$$\tilde{l}^*(\tilde{\eta}) = l^*(\underline{\eta}),$$

that is, when

$$\eta = \tilde{\eta} \equiv 2(2+3\gamma)(1+3\gamma)/(4+21\gamma+24\gamma^2) > \underline{\eta}$$

Therefore, the equilibrium for $\eta \in [\underline{\eta}, \tilde{\eta}]$ is for suppliers to announce list prices $l_i^* = l_j^* = l^*(\underline{\eta})$. Large buyers are ready to trade at those list prices and suppliers do not want to deviate from them since condition (34) continues to hold strictly even beyond $\tilde{\eta}$. Above $\tilde{\eta}$, the equilibrium is for suppliers to announce list prices according to (35) up to $\eta = \bar{\eta} > \tilde{\eta}$, which is when (34) holds with equality ($\bar{\eta}$ solves a cuartic equation, so its closed-form solution is ommited). For example, for $\gamma = 1$ we have that $\underline{\eta} = 0.64$, $\tilde{\eta} \approx 0.82$ and $\bar{\eta} \approx 0.88$. Again, for $\eta \in [\tilde{\eta}, \bar{\eta}]$ large buyers are ready to trade at list prices and suppliers have no incentives to stop selling through the fringe.

The second observation regarding (35) is that $\tilde{l}^*(\eta) \to 0$ as $\eta \to 1$, which takes us to point (iii) of this part of the proof. It is clear that (35) cannot be an equilibrium as $\eta \to 1$: U_i would deviate to stop selling through the fringe and bargain with D_i for an offer above cost. More generally, it cannot be an equilibrium for both suppliers to sell through the fringe when $\eta > \bar{\eta}$ since (34) not longer holds. Neither can be an equilibrium for both suppliers to completely disregard the fringe. If they do so, suppliers obtain $2a^2/49$ each (see Proposition 1). But the payoff from deviating to also sell through the fringe is strictly greater than that. Consequently, for $\eta > \bar{\eta}$ suppliers must randomize over whether to sell through the fringe in equilibrium.

Proof of Proposition 4

Since collusion is in list-price announcements and large buyers observe them before their negotiations, we only need to pay attention to suppliers' ICC. Assuming that η is not too large so discounts emerge on- and off-path, the critical discount factor $\underline{\delta}$ is the solution to

$$\hat{\pi}_{U_i}(l^c, l^c, w_i^*(l^c, l^c), w_j^*(l^c, l^c)) = (1 - \underline{\delta})\hat{\pi}_{U_i}(l_i^d, l^c, w_i^*(\cdot), w_j^*(\cdot)) + \underline{\delta}\hat{\pi}_{U_i}(l^*, l^*, w_i^*(\cdot), w_j^*(\cdot)) \quad (36)$$

where $w_i^*(l_i, l_j)$ is given by (17) and

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

Note that only $\hat{\pi}_{U_i}(l_i^d, l^c, w_i^*(\cdot), w_j^*(\cdot))$ and $\hat{\pi}_{U_i}(l^*, l^*, w_i^*(\cdot), w_j^*(\cdot))$ depend on η. Plugging l_i^d into (36) and solving we obtain an expression for $\underline{\delta}(\gamma, \eta)$ which for $\eta = 0$ reduces to $\underline{\delta}(\gamma, 0) = (147 + 149\gamma)^2 / 2(21\,609 + 43\,022\gamma + 19\,457\gamma^2)$. To show that $\underline{\delta}(\gamma, \eta)$ is increasing in both γ and δ is tedious but not difficult.

Proof of Proposition 5

We know from (16) 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 (12) and (11), respectively. To obtain the equilibrium prices l^s and w^s, we apply symmetry, i.e., $l_i = l_j = l^s$ and $w_i = w_j = w^s$, and solve the system (i)

$w_i^*(l^s, w^s, l^s) = w^s$ and (ii) $l_i^*(w^s, w^s, l^s) = l^s$, which yields

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

and

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

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 anticipate that $w_i^*(l^s, w^s, l^s) = w^s < l^s$, which requires

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

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