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COLLUSION THROUGH COORDINATION OF ANNOUNCEMENTS*

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A theory is developed to explain how sellers can effectively collude by coordinating on list prices (or surcharges), while leaving sellers to set their final prices. List prices are interpreted to be cheap talk announcements about cost information unknown to buyers. Buyers use those announcements to decide whom to invite to their procurement auction and the reserve price to set. By coordinating on a high list price to signal high cost, sellers produce supracompetitive prices by inducing buyers to be less aggressive, as reflected in a higher reserve price. We show that collusion can raise social welfare.

I. INTRODUCTION

Collusion involves firms' coordinating their conduct so that, as long as all firms comply with how they agreed to behave, supracompetitive prices and profits will result. In posted price markets (such as most retail markets), coordinated conduct typically takes the form of agreeing to charge prices above competitive levels and then monitoring prices for compliance. Examples include collusion among retail gasoline stations (Clark and Houde [2013]), retail pharmacies (Chilet [2016]), and fine arts auction houses (Mason [2004]). For many cartels in intermediate goods markets, coordination is again on price but compliance is more problematic because, given prices can be privately negotiated, monitoring of prices is difficult. For this reason, cartels also commonly coordinate on a market allocation scheme, and then monitor compliance with respect to that scheme. For example, cartels in citric acid, lysine, and vitamins agreed to sales quotas, and

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monitoring involved comparing actual sales with agreed-upon sales.[1] With all of these schemes, success occurs as long as all firms comply with the agreed-upon conduct because coordination directly constrains competition. The challenge is whether firms will act as agreed. As a result, the theory of collusion has focused on the characterization of effective monitoring and severe punishments.

In contrast to those canonical forms of collusion, there are some recent collusive practices for which coordinated conduct does not directly constrain competition, in which case it is not apparent that compliance is sufficient to produce supracompetitive outcomes. First, some cartels coordinated on list prices but not on discounts, which meant firms did not coordinate on transaction prices. While it is easy to monitor and ensure that all firms set the agreed-upon list price, collusion could prove ineffective due to firms' competing in discounts off of list prices. In fact, discounts were common in some of the cases involving coordination on list prices. That coordination on list prices presents a puzzle is evident from this observation by a member of the thread cartel which took the more common path of coordinating on transaction prices:

> *[A cartel member] explained that 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.*[2]

A second set of collusive practices has firms coordinate on a surcharge for an input, such as fuel in markets for transportation services. Cartel members were essentially agreeing on how they wrote up the invoice – there would be a line assigning a part of the transaction price to this surcharge – and not coordinating on the transaction price itself. Collusion could prove ineffective due to firms' competing in the non-surcharge components of the transaction price, while complying by charging the agreed-upon surcharge. In Section II, some of the cases involving coordination on list prices and surcharges are reviewed.

The contribution of this paper is providing an explanation for how these collusive practices could be effective. Contrary to the usual perspective of collusion – which focuses on how a collusive practice affects sellers'

[1] Harrington [2006], Connor [2008], and Marshall and Marx [2012] provide details on these and other relevant cartels. For an analysis of this collusive practice and related ones, see Harrington and Skrzypacz [2011], Chan and Zhang [2015], Spector [2015], Awaya and Krishna [2016, 2019], and Sugaya and Wolitzky [2018].

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

conduct – our approach takes account of how it affects *buyers' conduct*. The theory developed here is that these collusive practices work, not because they influence what prices sellers propose to buyers, but rather because they influence *what prices buyers propose to sellers*. As reviewed in Section II, all of these cases have occurred in intermediate goods markets for which buyer-seller negotiation is the norm. Coordination on list prices and surcharges is effective because it influences buyers' beliefs in the negotiation process, and it is the manipulation of those beliefs that results in supracompetitive prices. In fact, our theory will have sellers offering the *same* prices as under competition, in which case the impact of collusion is entirely on the prices that buyers offer and are willing to accept.[3]

The theory focuses on the information about a seller's cost that is conveyed by its list price or surcharge. While recognizing that list prices and surcharges can be more than information, the model parsimoniously isolates attention on the informational component by assuming that firms make cheap talk announcements about their costs. There are two sellers and each seller receives some private information about its cost. Sellers then make announcements – such as in the form of list prices – about whether it is a low-cost or a high-cost type. Buyers decide with whom to negotiate based on the announcements. When a buyer shows up at a seller to negotiate, a seller learns its cost which is a draw from its distribution. Buyers are heterogeneous in their values and in how many sellers they approach to negotiate. As a tractable representation of buyer-seller negotiations, a buyer is modelled as conducting a second-price auction with a reserve price in which case the sellers that are invited to a buyer's auction represent the sellers with which a buyer negotiates.

When sellers are competing, sufficient conditions are provided for a separating equilibrium to exist whereby a seller's announcement reveals its cost type to buyers. Collusion has sellers coordinate on announcements that signal they are high-cost types. These coordinated announcements induce buyers to set a high reserve price (or, in other words, negotiate less aggressively). Buyers recognize the possibility that sellers may be colluding and thus that a high-cost announcement may not signal that a seller is a high-cost type.

In viewing list prices and surcharges as cheap talk messages, the model is stylized but has the benefit of generality in that it encompasses many variables that can convey cost information. Though the theory does not address why firms would choose list prices or surcharges as the vehicle to manipulate buyers' beliefs about cost, they are natural candidates because

[3] That sellers' prices are exactly the same under competition is likely due to the particular modelling of the negotiation process. With other models of negotiation, sellers' prices could also be influenced, but that does not affect the main takeaway of the paper which is that collusion is profitable because of how it affects buyers' conduct.

they are a feature of the competitive process and are most likely perceived by buyers to be influenced by cost (indeed, surcharges are expressed to be associated with some input).[4] Furthermore, for the markets we have in mind, treating list prices and surcharges as cheap talk is probably a reasonable approximation. If buyers can always anticipate a discount off of the list price then list prices as an upper bound on a seller's negotiated price are not a binding constraint.[5] The argument for surcharges being cheap talk is perhaps even more compelling. At most, it provides a lower bound on the total price (equal to the surcharge) but that is surely a non-binding constraint. In any case, our analysis shows that the information in list prices and surcharges is sufficient for coordination on them to produce supracompetitive prices.

This paper offers the first theory of collusion for which efficacy is based on influencing buyers' conduct and, in doing so, offers an explanation for why some recent collusive practices are effective even if they do not constrain the prices that sellers offer. Section II reviews some legal cases in which firms coordinated their list prices or surcharges. Section III describes the model and relates it to past work, and Section IV presents the candidate strategy profile. There are two steps to developing the theoretical argument. The first step is establishing an endogenous connection between announcements and final transaction prices; that is performed in Section VI. The second step is showing that firms can jointly raise profits by coordinating their announcements; that is done in Sections VI and VII.

II. CASES

Reserve Supply v. Owens-Corning Fiberglas (1992) is a private litigation case involving collusion in the market for fiberglass insulation. Two of the top three suppliers were accused of coordinating their list prices over 1979-83. The plaintiffs and defendants disagreed whether the alleged coordination could have resulted in supracompetitive transaction prices:

> *Reserve points to Owens-Corning and CertainTeed's practices of maintaining price lists for products and … asserts that these lists have no independent value because no buyer in the industry pays list price for insulation. Instead, it claims that the price lists are an easy means for producers to communicate and monitor the price activity of rivals by providing a common starting point for the application of percentage*

[4] Note that it is illegal for firms explicitly to coordinate their conduct in any manner that raises transaction prices. Hence, sellers are no less open to prosecution by coordinating on literal announcements about cost than they are by coordinating on list prices or surcharges. Thus, concerns about prosecution will not determine the vehicle used to influence buyers' beliefs.

[5] The previous quotation from the thread cartel highlights the 'fictitious' nature of list prices.

discounts. … Owens-Corning and CertainTeed counter by arguing that the use of list prices to monitor pricing would not be possible because the widespread use of discounts in the industry ensures that list prices do not reflect the actual price that a purchaser pays.[6]

The Seventh Circuit Court expressed skepticism with regards to the plaintiffs' argument:

We agree that the industry practice of maintaining price lists and announcing price increases in advance does not necessarily lead to an inference of price fixing. … [T]his pricing system 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.[7]

In a case involving the market for urethane, plaintiffs claimed:

[T]hroughout the alleged conspiracy period, the alleged conspirators announced identical price increases simultaneously or within a very short time period. … [P]urchasers could negotiate down from the increased price. But the increase formed the baseline for negotiations. … [T]he announced increases caused prices to rise or prevented prices from falling as fast as they otherwise would have.[8]

Supporting the alleged effect of list prices on transaction prices were internal memos from defendant Dow Chemical, such as:

In March 2002, Dow touted 'Recent Successes,' emphasizing a class-wide price increase: 'We announced 10 cts on Polyols March 1. We announced 15 cts on TDI March 1, 2002. It's Working!!!!!!!,[9]

The Tenth Circuit Court quoted the District Court in supporting the plaintiffs:

The court reasoned that the industry's standardized pricing structure – reflected in product price lists and parallel price-increase announcements – 'presumably established an artificially inflated baseline' for negotiations. Consequently, any impact resulting from a price-fixing conspiracy would have permeated all polyurethane transactions, causing market-wide impact despite individualized negotiations.[10]

[6] *Reserve Supply v. Owens-Corning Fiberglas* 971 F. 2d 37 (7th Cir. 1992), para 61.
[7] Ibid, para. 62.
[8] Class Plaintiffs' Response Brief (February 14, 2014), *In Re: Urethane Antitrust Litigation*, No. 13-3215, 10th Cir.; pp. 8-9.
[9] Ibid, p. 15.
[10] *In Re: Urethane Antitrust Litigation*, No. 13-3215 (10th Cir. Sep. 29, 2014); p. 7.

Turning to surcharges, over 40 air cargo companies participated in an agreement to coordinate fuel surcharges from late 1999 to early 2006. The surcharge was initially as low as four cents per kilogram and ultimately reached 72 cents per kilogram (LeClair [2012]). Guilty pleas led to fines of around $3 billion and customer damages exceeding $1.2 billion.[11] The collection of damages means there was an estimated overcharge and, therefore, coordination on fuel surcharges affected transaction prices.

In on-going private litigation, four Class I railroads have been accused of coordinating their fuel surcharges starting in 2003.

> *The barrier to this plan [to coordinate fuel surcharges], according to plaintiffs, was that the great majority of rail freight transportation contracts already included rate escalation provisions that weighted a variety of cost factors, including fuel, based on an index called the All Inclusive Index (the 'AII'). The railroad trade organization known as the Association of American Railroads ('AAR'), which is dominated by the four defendants, publishes this index. … Plaintiffs allege that the defendants conspired to remove fuel from the AII so that they could apply a separate 'fuel surcharge' as a percentage of the total cost of freight transportation.*[12]

The plaintiffs alleged that railroads' conduct became coordinated after the AAR moved to this All Inclusive Index Less Fuel (AIILF):

> *[A]lthough the railroads' surcharges had varied in the past, from July, 2003, onward the western railroads imposed identical surcharges. And from March, 2004, three months after the December announcement of the AIILF, the eastern railroads imposed identical fuel surcharges. Plaintiffs further assert that it is unlikely that the eastern and western defendants would independently impose identical fuel surcharges, because fuel cost as a percentage of operating cost and fuel efficiency differed widely among the defendant railroads.*[13]

The fuel surcharge was 0.4 per cent of the base rate for each dollar that the price of oil on the West Texas Intermediate index exceeded $23 per barrel.[14] The Surface Transportation Board ruled that

[11] 'Hausfeld Announces Final Settlement in Decade-Long Air Cargo Price Fixing Litigation,' Hausfeld, May 19, 2016; downloaded from <*www.hausfeld.com/news/us/hausfeld-announces-final-settlement-in-air-cargo-price-fixing-litigation*> on September 16, 2017.

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

[13] *In re Rail Freight Surcharge Antitrust Litig.*, 587 F.Supp.2d 27, 34 (2008), United States District Court, District of Columbia. November 7, 2008.

[14] *In re Rail Freight Surcharge Antitrust Litig.*, U.S. District Court for the District of Columbia, Opinion, June 21, 2012, p. 11.

> *[b]ecause railroads rely on differential pricing, under which rates are dependent on factors other than costs, a surcharge that is tied to the level of the base rate … stands virtually no prospect of reflecting the actual increase in fuel costs.*[15]

Over 2001-07, fuel surcharges exceeded the rise in fuel costs by 55 per cent.[16]

Fuel is not only the only input for which there has been illegal coordination on surcharges. Six manufacturers of motive power batteries in Belgium were found guilty of coordinating on a common surcharge for lead.[17] The cartel lasted from 2004 to 2011, and ended with an application for leniency.

A final example of coordinated announcements is a cement cartel in the United Kingdom.[18] Annually, cement suppliers sent letters to their customers announcing price increases. However, prices were then individually negotiated with customers and the full price increase was rarely implemented. The Competition and Markets Authority concluded that firms coordinated their price announcement letters and noted 'that firms generally fail to achieve the prices set out in the price letters, in part because of the rebates offered to large customers.'[19] In commenting on the U.K. cement case, the head of Compass Lexecon's London office posed the question: 'How do price announcements help firms coordinate on prices if prices are ultimately individually negotiated?'[20] It is to that question that we now turn.

III. MODEL

Consider a market with two sellers offering identical products. A seller may be one of two types, L or H, and type L occurs with probability q. Sellers' types are independent. A type t seller's unit cost is assumed to be a random draw from the cdf F_t: $\left[\underline{c}_t, \overline{c}_t\right] \rightarrow [0, 1]$, $t \in \{L, H\}$. F_t is continuously differentiable with positive density everywhere on $\left(\underline{c}_t, \overline{c}_t\right)$. The inverse hazard rate function, $h_t(c) \equiv F_t(c)/F_t'(c)$, is assumed to be non-decreasing, $h_t'(c) \geq 0$, which holds for most of the common distributions such as uniform, normal, exponential, logistic, chi-squared, and Laplace. The two cost distributions are ranked in terms of their inverse hazard rates: $h_L(c) > h_H(c)$ for all $c \in (\underline{c}_t, \overline{c}_t]$. Note that the latter condition implies F_H first-order

[15] Surface Transportation Board Decision, STB Ex Parte No. 661 Rail Fuel Surcharges, Decided: January 25, 2007, p. 6.
[16] USDA: Study of Rural Transportation Issues, June 3, 2010.
[17] Belgian Competition Authority, Press Release, N∘ 4/2016, 23, February, 2016.
[18] 'Aggregates: Report on the Market Study and Proposed Decision to Make a Market Investigation Reference,' Office of Fair Trading, OFT1358, August, 2011.
[19] Ibid, p. 53.
[20] 'Exchange of Information: Current Issues,' 30 April, 2014, Allen & Overy, Brussels.

stochastically dominates F_L and, consequently, we will refer to a type L seller as a low-cost type and a type H seller as a high-cost type.

There is a continuum of buyers. Each buyer is endowed with a per unit valuation $v \in [\overline{v}, v]$ and volume $z \in [\overline{z}, z]$ (that is, the number of units demanded). In addition, buyers differ according to whether they solicit offers from either one or two sellers.[21] What exactly it means to 'solicit' an offer is described below. A fraction $\gamma \in [0, 1]$ of buyers solicit an offer from a single seller and a fraction $1-\gamma$ from two sellers. A buyer's per unit valuation is assumed to be independent of its volume and how many offers are solicited. Valuations are distributed according to the cdf G:$[\overline{v}, v] \rightarrow [0, 1]$, where G is continuously differentiable with positive density everywhere on $(\overline{v}, v)$. A buyer's volume is allowed to be correlated with how many offers are solicited, and let μ^w be the expected volume of a buyer who solicits w offers. Normalizing total market volume to one, define

$$b \equiv \frac{\gamma \mu^1}{\gamma \mu^1 + (1-\gamma)\mu^2}$$

as the fraction of market volume that is from buyers who solicit an offer from one seller, and $1-b$ as the fraction of market volume that is from buyers who solicit an offer from two sellers. The ensuing analysis depends on γ, μ^1, and μ^2 only through b.[22]

The modelling of the interaction between buyers and sellers is intended to capture many intermediate goods markets for which buyers are industrial customers. Sellers first make some announcement informative of their costs which could be a list price, surcharge, or some other variable. After observing those announcements, each buyer approaches either one or two sellers to negotiate. A buyer who approaches two sellers is presumed to engage in an iterative bargaining process whereby she uses an offer from one seller to obtain a better offer from the other seller. Rather than explicitly model that process, we will use the second-price auction with a publicly observed reserve price as a metaphor for it. More specifically, a buyer 'invites' w sellers to the auction, where $w \in \{1, 2\}$. The buyer sets a reserve price and the w sellers submit bids which, in equilibrium, equal their cost. We have buyers choose a reserve price so they are not passive, which better mimics negotiation. A transaction occurs if the lowest bid is below the buyer's reserve price. In the case of having chosen just one seller, the mechanism is equivalent to the buyer's making a take it or leave it offer.

[21] It is for reasons of tractability that the number of sellers solicited by a buyer is exogenous. This specification could be rationalized by assuming that buyers incur a cost to negotiating with each seller. Some buyers have very low cost and thus negotiate with both sellers, while other buyers have a high enough cost that it is optimal to only negotiate with one seller.

[22] The critical heterogeneity in the model is the number of sellers approached by a buyer. Heterogeneity in value and volume is allowed for purposes of generality (and eliminating it would not simplify the analysis).

Announcements, such as list prices, are presumed to be chosen less frequently than negotiated prices and this has the implication that a seller knows its cost type when it makes its announcement but does not know its actual cost until the time of negotiation. In practice, this uncertainty about future cost may be due to volatility in input prices or not knowing the opportunity cost of supply because future inventories or capacity constraints are uncertain.[23]

The extensive form is as follows. In stage 1, sellers draw types from $\{L, H\}$ (which is private information to each seller) and choose announcements from $\{l, h\}$. In stage 2, buyers learn their valuations and volumes and observe sellers' announcements. If a buyer is specified as approaching only one seller then it chooses a seller.[24] In stage 3, each seller realizes its cost. If a seller is type t then its cost is a draw from $\left[\underline{c}_t, \overline{c}_t\right]$ according to F_t. In stage 4, each buyer conducts a second-price auction with a reserve price, with the outcome determined as follows. If there are two sellers in the auction and: i) both bids are below the reserve price then the buyer buys from the seller with the lowest bid at a price equal to the second lowest bid; ii) one bid is below the reserve price and the other bid is above the reserve price then the buyer buys from the seller with the lowest bid at a price equal to the reserve price; iii) both bids are above the reserve price then there is no transaction. If there is one seller in the auction and: i) the bid is below the reserve price then the buyer buys from the seller at the reserve price; ii) the bid is above the reserve price then there is no transaction.

A strategy for a seller is a pair of functions: an announcement function and a bid function. The announcement function maps from $\{L,H\}$ to $\{l,h\}$ and thus has a seller select an announcement based on its cost type. When a seller and a buyer meet, a bid function assigns a bid depending on the seller's cost type, seller's cost, other seller's announcement, buyer's reserve price, and whether the buyer matches with one or two sellers. The weakly dominant bidding strategy for a seller is to bid its cost. From here on, we will think of a strategy for a seller as an announcement function and a bid function that has its bid equal to its cost. For a buyer who only meets

[23] We realize that this is not an optimal procurement mechanism when a buyer has two sellers at its auction and holds different beliefs over the two sellers (e.g., a buyer believes seller 1 is type L and seller 2 is type H). In that situation, a buyer could do better by choosing seller-specific (Myersonian) reserve prices. However, our objective is not to characterize an optimal mechanism but rather to have a plausible and tractable model of buyer-seller interaction, and we feel that a standard procurement auction achieves that modelling goal. It is worth noting that our main results hold when all buyers deal with only one seller ($\gamma = 1$ and thus $b = 1$) in which case this issue does not. Once our main results are presented and explained, it should be apparent that the delivered insight is not tied to a seller's only offering one reserve price.

[24] While a buyer's valuation is private information, results are robust to assuming that a buyer's volume is private or public information. If volume distinguishes small and large buyers then assuming it is observed by sellers is more natural.

with one seller, a strategy selects a seller and a reserve price conditional on the announcements and the buyer's valuation and volume (though the latter variable will not matter). If the buyer meets with two sellers then a strategy selects a reserve price conditional on the announcements and the buyer's valuation and volume. The solution concept is perfect Bayes-Nash equilibrium.

III(i). *Related Literature*

Our model is related to models of directed search in a market setting, as announcements may induce buyers to negotiate with certain sellers. The paper closest to ours is Menzio [2007], who considers cheap talk in a search model of a competitive labor market. Employers have private information about the quality of their vacancies and can costlessly communicate with unemployed workers before they engage in an alternating offer bargaining game to determine the wage. Under certain conditions, there exists an equilibrium in which cheap-talk messages about compensation are correlated with actual wages and, therefore, serve to direct the search of workers. Our theory encompasses similar forces to those present in Menzio [2007] though in the context of an imperfectly competitive product market setting.

Our paper is also related to indicative bidding, which serves as the basis for shortlisting bidders in a two-stage auction procedure. Ye [2007] shows there does not exist a symmetric separating equilibrium bid function in indicative bidding; hence, the most 'qualified' bidders may not be selected for the final stage. By restricting indicative bids to a finite domain, Quint and Hendricks [2015] explicitly models indicative bidding as cheap talk with commitment, and show that a symmetric equilibrium exists in weakly-monotone strategies. But again, the highest-value bidders are not always selected, as bidder types pool over a finite number of bids. Announcements in our setting are like indicative bids in those settings. However, unlike in their analysis, in our setting the trading mechanism depends on the announcement in that it affects a buyer's reserve price as well as the seller that the buyer selects. As a result, a separating equilibrium in the cheap-talk stage becomes possible.

Independently, Lubensky [2017] interprets a manufacturer-suggested retail price (MSRP) as a cheap talk signal about cost. The model assumes a single manufacturer with private cost information that chooses an MSRP and a wholesale price for its retailers. After observing the MSRP, buyers sequentially search among retailers and a stochastic outside option, with their beliefs on retail prices influenced by any cost information conveyed by the MSRP. In contrast, our model has two competing manufacturers (each with private information on their costs), no retail sector, and buyers negotiate with sellers. After presenting our result on the informativeness of cost announcements, we will discuss how the underlying forces at play differ from those in Lubensky [2017].

IV. STRATEGIES UNDER COMPETITION AND COLLUSION

Our specification of candidate equilibrium strategies for sellers is motivated by two facts: 1) list prices positively affected transaction prices; and 2) sellers coordinated by charging higher list prices. In the context of our model, a necessary condition for consistency with the first fact is that announcements (i.e., list prices) are informative, so that they are potentially impactful on transaction prices. For that reason, we consider a seller using a separating strategy under competition so that its announcement is informative of its cost type:

$$\phi(t)=\begin{cases} l & \text{if } t=L \\ h & \text{if } t=H \end{cases} \tag{1}$$

To capture the second fact, it is specified that sellers coordinate on a high cost announcement (i.e., high list price) regardless of their cost type. Thus, sellers use a pooling strategy under collusion:

$$\psi(t)=\begin{cases} h & \text{if } t=L \\ h & \text{if } t=H \end{cases} \tag{2}$$

At this point, it is helpful to think about the industry state – competition or collusion – as being exogenous to sellers. Sellers either are competing or colluding, and act accordingly. We will derive conditions whereby it is optimal for a seller to use a separating strategy when it believes the other seller will use a separating strategy (competition state) and it is optimal for a seller to use a pooling strategy when it believes the other seller will use a pooling strategy (collusion state).

As is the case in reality, buyers do not know whether the state is competition or collusion.[25] Buyers assign probability κ (for the German 'kartell') that firms are colluding and thus using (1), and probability $1-\kappa$ that firms are competing and thus using (2). Hence, buyers recognize that collusion is

[25] That other agents – whether buyers, the competition authority, or potential entrants – are uncertain about whether market outcomes are the product of competition or collusion is assumed, for example, in Harrington [1984], Besanko and Spulber [1989, 1990], LaCasse [1995], Souam [2001], and Schinkel and Tuinstra [2006].

possible and know how collusion operates.[26] Buyers are assumed to live for only one period and do not observe the history.[27]

Given these beliefs on collusion, a buyer's beliefs as to sellers' types given their announcements can be derived. When buyers observe either or both sellers choosing a low-cost announcement, they infer that firms are competing. Letting m_i denote the message and t_i denote the type of firm i, respectively, posterior beliefs (conditional on announcements) are:

1. If $(m_1, m_2) = (l, l)$ then firms are competing and $\Pr(t_i = L | (m_1, m_2) = (l,l)) = 1, i = 1,2$.
2. If $(m_i, m_j) = (l, h)$ then firms are competing and $\Pr(t_i = L | (m_i, m_j) = (l, h)) = 1$, $\Pr(t_j = L | (m_i, m_j) = (l, h)) = 0$, $i \neq j$, $i, j = 1, 2$.

However, when buyers observe both sellers choosing a high-cost announcement, they do not know whether sellers are competing (and are high-cost types) or are colluding. Bayesian updating implies:

$$\Pr(t_i = L \,\big|\, (m_1, m_2) = (h, h)) = \frac{\kappa q}{\kappa + (1-\kappa)(1-q)^2}, i = 1,2. \tag{3}$$

With these beliefs on sellers' types, the next step is to derive a buyer's reserve price. Let $R^w_{m_1 m_2}(v)$ denote the optimal reserve price when a buyer's valuation is v, announcements are (m_1, m_2), and the buyer approaches w sellers. (As a buyer's payoff is linear in its volume z, the optimal reserve price does not depend on z, so that term is suppressed.) If $(m_1, m_2) \in \{(l, l), (l, h), (h, l)\}$ then sellers are inferred to be competing in which case a seller's announcement

[26] To provide a more formal game of incomplete information approach, assume a seller's type includes the manager's willingness to engage in an unlawful practice such as collusion. If a seller's manager is *ethical*, s/he would not be willing to collude; if a seller's manager is *unethical*, s/he would be willing to collude. Assume managers' 'moral' types are known to managers but not to buyers, a manager's moral type is independent of their firm's cost type, and collusion occurs if and only if both managers are an unethical type. With that structure, κ is interpreted to be the joint probability that both managers are an unethical type. Thus, with probability $1-\kappa$, sellers compete (because one or both managers are ethical) and, with probability κ, sellers collude (because both managers are unethical). With either realized state, buyers are assigning probability κ to sellers' colluding because they do not observe the managers' moral types.

[27] Though this assumption is inconsistent with their being industrial buyers, it allows us to avoid a difficult dynamic problem. If buyers were long-lived or observed the history then they would update their beliefs over time regarding the hypothesis that there is collusion. While characterizing buyers' beliefs over time is tractable, colluding sellers would take into account how their current actions (both with regards to announcements and bids) impact buyers' beliefs and the future value of collusion. Thus, it now becomes a dynamic game between buyers and sellers. That is clearly a setting worth examining but is one we leave to future research.

fully reveals its type. When a buyer approaches only one seller, she will randomly choose a seller when $(m_1, m_2) = (l, l)$ and choose the seller with the low-cost announcement when $(m_1, m_2) \in \{(l, h), (h, l)\}$. Hence, in all cases, a buyer's beliefs on the seller's cost (and bid) is F_L. It follows that the optimal reserve price is:

$$R^1_{m_1 m_2}(v) \equiv \arg\max z\,(v-R)\,F_L(R)\,,\forall\,(m_1, m_2) \in \{(l,l),(l,h),(h,l)\}. \tag{4}$$

If a buyer instead solicits bids from two sellers, she infers the sellers' types are $(\phi^{-1}(m_1), \phi^{-1}(m_2))$ where recall ϕ is a seller's strategy under competition (see (1)). It follows that

$$\begin{aligned} R^2_{m_1 m_2}(v) \equiv\ & \arg\max_R z \int_{\underline{c}_{\phi^{-1}(m_1)}}^{R} \int_{c_1}^{R} (v-c_2)\, dF_{\phi^{-1}(m_2)}(c_2)\, dF_{\phi^{-1}(m_1)}(c_1) \\ & + z \int_{\underline{c}_{\phi^{-1}(m_2)}}^{R} \int_{c_2}^{R} (v-c_1)\, dF_{\phi^{-1}(m_1)}(c_1)\, dF_{\phi^{-1}(m_2)}(c_2) \\ & + z\,(v-R)\left[\left(1-F_{\phi^{-1}(m_2)}(R)\right) F_{\phi^{-1}(m_1)}(R) + \left(1-F_{\phi^{-1}(m_1)}(R)\right) F_{\phi^{-1}(m_2)}(R)\right]. \end{aligned} \tag{5}$$

Now suppose $(m_1, m_2) = (h, h)$ so buyers remain uncertain regarding whether firms are competing or colluding. Given posterior beliefs (3) as to a seller's type, a buyer believes a seller chooses its cost according to the mixture cdf F_κ:

$$F_\kappa \equiv \left(\frac{\kappa q}{\kappa + (1-\kappa)(1-q)^2}\right) \circ F_L + \left(\frac{\kappa(1-q) + (1-\kappa)(1-q)^2}{\kappa + (1-\kappa)(1-q)^2}\right) \circ F_H.$$

It follows that:

$$R^1_{hh}(v) \equiv \arg\max_R z\,(v-R)\,F_\kappa(R)\,, \tag{6}$$

and

$$\begin{aligned} R^2_{hh}(v) \equiv\ & \arg\max_R z \int_{\underline{c}_L}^{R} \int_{c_1}^{R} (v-c_2)\, dF_\kappa(c_2)\, dF_\kappa(c_1) \\ & + z \int_{\underline{c}_L}^{R} \int_{c_2}^{R} (v-c_1)\, dF_\kappa(c_1)\, dF_\kappa(c_2) \\ & + z\,(v-R)\, 2\left(1-F_\kappa(R)\right) F_\kappa(R). \end{aligned} \tag{7}$$

where this expression uses the assumption $\underline{c}_L \leq \underline{c}_H$.[28]

[28] The optimal (Myersonian) procurement mechanism differs from what we have characterized only when a seller meets with two buyers and the buyers are of different types. For all other cases, the optimal procurement mechanism has a single reserve price, as we have assumed. Also note that our procurement auction is optimal when all buyers meet with one seller ($b = 1$) and, as we show later, all key findings hold for that case.

When a buyer approaches one seller, Lemma 1 shows that the optimal reserve price is higher when both sellers post high-cost announcements (and thus buyers recognize they may either be competing or colluding) than when one or both sellers posts a low-cost announcement (in which case buyers infer sellers are competing).[29]

Lemma 1. $R^1_{hh}(v) > R^1_{ll}(v)\,(=R^1_{lh}(v)), \forall v$

For when a buyer approaches both sellers, Lemma 2 provides sufficient conditions for the optimal reserve price to be increasing in the number of sellers posting high-cost announcements.

Lemma 2. If κ is sufficiently small then $R^2_{hh}(v) > R^2_{lh}(v) > R^2_{ll}(v), \forall v$

As stated, the monotonicity in the optimal reserve price is proven when the probability of colluding κ is not too high. Otherwise, it is possible that $R^2_{hh}(v) < R^2_{lh}(v)$, though $R^2_{hh}(v), R^2_{lh}(v) > R^2_{ll}(v)$ regardless of κ.[30] The main results in the paper are proven for when the optimal reserve price is monotonic and, for that reason, results will be stated assuming collusion is sufficiently unlikely.

Having solved for buyers' beliefs and strategies that satisfy the conditions of a perfect Bayes-Nash equilibrium, Section V derives sufficient conditions for (1) to be an equilibrium strategy when firms are competing, and Section VI derives sufficient conditions for (2) to be an equilibrium strategy when firms are colluding.

V. COMPETITION

The objective of this section is to show that announcements can be informative under competition. Coordinating on announcements cannot be profitable unless announcements are impactful with regards to transaction prices, which requires that announcements be perceived by buyers as containing information. In determining when a separating equilibrium (under competition) exists, the analysis will examine when $b = 1$ (so the entire market volume is from buyers who negotiate with one seller), $b = 0$ (all buyers negotiate with both sellers), and finally the general case of $b \in [0, 1]$.

[29] Proofs are in the Appendix.

[30] For example, when $\kappa = 1$, $R^2_{hh}(v)$ is based on each seller's having a low-cost distribution with probability q. In comparison, $R^2_{lh}(v)$ is based on one seller's having a low-cost distribution for sure and the other seller's having a high-cost distribution for sure. The relationship between those reserve prices is ambiguous.

V(i). *All Buyers Negotiate with One Seller*

Suppose $b = 1$ so that all buyers approach only one seller. Let us derive the conditions for sellers' competitive strategy (1) to be part of a perfect Bayes-Nash equilibrium. We have already dealt with a buyer's beliefs and strategy and just need to derive conditions for a seller's strategy to be optimal.

A low-cost type seller prefers to choose message l (as prescribed by the competitive strategy) and signal it is a low-cost type if and only if

$$\begin{aligned} &\left(\frac{q}{2}+1-q\right)\int_{\underline{v}}^{\overline{v}}\int_{\underline{c}_L}^{R_{ll}^1(v)}\left(R_{ll}^1(v)-c\right)dF_L(c)\,dG(v) \\ &\geq\left(\frac{1-q}{2}\right)\int_{\underline{v}}^{\overline{v}}\int_{\underline{c}_L}^{R_{hh}^1(v)}\left(R_{hh}^1(v)-c\right)dF_L(c)\,dG(v). \end{aligned} \tag{8}$$

On the LHS of the inequality is the payoff from choosing l (which uses the property, $R_{ll}^1(v) = R_{lh}^1(v)$). A seller posting l is chosen for sure by the buyer when the other seller posted h , which occurs when the other seller is type H (and that occurs with probability $1-q$); and is chosen with probability 1/2 when the other seller posted l, which occurs when the other seller is type L (and that occurs with probability q). Thus, a seller who chooses a low-cost announcement is approached by a buyer with probability $\frac{q}{2} + 1 - q$. In that case, the buyer offers a price of $R_{ll}^1(v)$ and the seller accepts the offer if its realized cost is less than $R_{ll}^1(v)$. If the seller selects a high-cost announcement then it is approached by the buyer with probability 1/2 in the event that the other seller also posted a high-cost announcement, and is not approached when the other seller posted a low-cost announcement. Hence, a seller with announcement h assigns probability $(1-q)/2$ to being approached by a buyer and, in that situation, is offered $R_{hh}^1(v)$.

If instead a seller is a high-cost type then it prefers to choose h if and only if

$$\begin{aligned} &\left(\frac{1-q}{2}\right)\int_{\underline{v}}^{\overline{v}}\int_{\underline{c}_H}^{R_{hh}^1(v)}\left(R_{hh}^1(v)-c\right)dF_H(c)\,dG(v) \\ &\geq\left(\frac{q}{2}+1-q\right)\int_{\underline{v}}^{\overline{v}}\int_{\underline{c}_H}^{R_{ll}^1(v)}\left(R_{ll}^1(v)-c\right)dF_H(c)\,dG(v). \end{aligned} \tag{9}$$

The expressions are the same as in (8) except that the inequality is reversed and the cost distribution is F_H instead of F_L.

When a buyer selects one seller with which to negotiate, a seller's announcement plays two roles. First, it affects the likelihood that a seller is selected by a buyer. By conveying it is low cost with announcement l, a seller is selected with probability $1-(q/2)$, while the probability is only $(1-q)/2$ if it conveys that it is high cost with announcement h. This effect is referred to as the *inclusion effect* in that a low-cost announcement makes it more likely that a buyer includes a seller in the negotiation process. A low-cost announcement signals a seller has a low-cost distribution in which case it is more likely to accept the buyer's offer. The inclusion effect makes a low-cost announcement attractive because it induces more buyers to approach a seller and thereby results in more sales. However, there is a countervailing effect from a seller's posting conveying that message, which is that a buyer negotiates more aggressively knowing it is more likely the seller's cost is low given it conveyed it as a low-cost type. Referred to as the *bargaining effect*, it manifests itself by a buyer's making a lower offer (in the form of a lower reserve price) in response to a low-cost announcement.[31]

In sum, a low-cost announcement makes it more likely that a buyer will negotiate with a seller but then the buyer will demand a lower price in those negotiations. Announcements can be informative because only a low-cost seller is willing to accept more aggressive buyers in exchange for attracting more buyers.[32]

Theorem 3. If $b = 1$ then there exists $\underline{q}$ and $\overline{q}$ such that a separating equilibrium exists if and only if $q \in [\underline{q}, \overline{q}]$.

The probability that the other seller is a low-cost type cannot be too low ($\underline{q} > \overline{q}$), so that a low-cost seller prefers a low-cost announcement in order to compete with a possible low-cost rival, nor too high ($\underline{q} < \overline{q}$), so that a high-cost seller does *not* prefer a low-cost announcement in order to compete with a possible low-cost rival. In Section VII, we offer a parametric model for which $0 < \underline{q} < \overline{q} < 1$ and, therefore, a separating equilibrium exists.[33]

V(ii). *All Buyers Negotiate with Both Sellers*

When all buyers approach both sellers ($b = 0$), separating equilibria do not exist. The expected profit per unit to a seller of type t_1 whose announcement

[31] The inclusion and bargaining effects are present in Menzio [2007] and there is a similar tradeoff, though in the context of a competitive labor market with search.

[32] For reasons of economizing on the analysis, the proofs of Theorems 3 and 4 are combined.

[33] In Lubensky [2017], a low MSRP reveals a manufacturer with low cost and that causes buyers to expect low retail prices because retailers will face a low wholesale price. With a higher reservation utility, buyers search more. A low-cost manufacturer prefers more search (and thus has an incentive to reveal its type) because it is more likely a buyer will not buy from the outside option and will instead search for a really good deal from one of the manufacturer's retailers. As a result, an MSRP can be informative of cost. That mechanism is very different from the one operating in the model of this paper. Here, a low list price serves to attract buyers to negotiate with a seller but also makes buyers negotiate more aggressively. In brief, MSRPs' are informative in Lubensky [2017] because they affect the *intensity* of search, while list prices are informative here because they affect the *direction* of search and a *buyer's price* during negotiation.

is m_1 (and thus inferred to be $\phi^{-1}(m_1)$) when the other seller's type and announcement are t_2 and m_2, respectively, is

$$\begin{aligned} &B(m_1, t_1; m_2, t_2) \\ (10) \quad &\equiv \int_{\underline{v}}^{\overline{v}} \int_{\underline{c}_{t_2}}^{\overline{c}_{t_2}} \int_{\underline{c}_{t_1}}^{\min\left\{R^2_{m_1 m_2}(v),\, c_2\right\}} \left(\min\left\{R^2_{m_1 m_2}(v), c_2\right\} - c_1\right) dF_{t_1}(c_1)\, dF_{t_2}(c_2)\, dG(v), \end{aligned}$$

and the function is referred to as B because a buyer approaches *both* sellers. Recall that a buyer's optimal reserve price is $R^2_{m_1 m_2}(v)$ given announcements m_1 and m_2. If seller 1's bid (= cost) is less than $\min\left\{R^2_{m_1 m_2}(v), c_2\right\}$ then a buyer with valuation v buys from seller 1 and pays a price equal to $\min\left\{R^2_{m_1 m_2}(v), c_2\right\}$. Hence, the probability that seller 1 makes a sale is weakly increasing in the reserve price $R^2_{m_1 m_2}(v)$, as is the profit conditional on making a sale which equals $\min\left\{R^2_{m_1 m_2}(v), c_2\right\} - c_1$. For realizations of c_2 and v such that $R^2_{m_1 m_2}(v) < c_2$, both are strictly increasing in the reserve price. $B(m_1, t_1; m_2, t_2)$ is then increasing in the reserve price.

If seller 2 uses (1) then seller 1's expected payoff from announcement m_1 is

$$qB(m_1, t_1; l, L) + (1-q)\, B(m_1, t_1; h, H).$$

Given $B(m_1, t_1; m_2, t_2)$ is increasing in the reserve price, Lemma 2 implies

$$qB(h, t_1; l, L) + (1-q)\, B(h, t_1; h, H) > qB(l, t_1; l, L) + (1-q)\, B(l, t_1; h, H),\ t_1 \in \{L, H\}.$$

A seller then prefers to convey it as high cost regardless of its type. Hence, a separating equilibrium does not exist.

With buyers approaching both sellers, a seller's announcement does not affect the probability of being selected – so there is no inclusion effect – but it does affect how aggressively a buyer negotiates. A seller will always want to signal that it is more likely to have a high-cost distribution because it induces a buyer to set a higher reserve price. When all buyers negotiate with both sellers, announcements are then uninformative.[34]

V(iii). *General Case*

Thus far, it has been shown that a separating equilibrium may exist when $b = 1$, and only pooling equilibria exist when $b = 0$. The next result considers when buyers are heterogeneous regarding how many sellers are approached.[35]

[34] By a similar argument, one can show that semi-pooling equilibria do not exist.
[35] Recall that κ is required to be sufficiently small in Theorem 4 only to ensure that that the optimal reserve price is increasing in the number of sellers who make high-cost announcements (Lemma 2).

Theorem 4. If κ is sufficiently small and a separating equilibrium exists for $b = 1$ then there exists $b^* \in (0,1)$ such that a separating equilibrium exists if and only if $b \in \left[b^*, 1\right]$

Announcements about cost can be informative when they influence a buyer's decision as to which seller to approach to negotiate a deal, which we have referred to as the inclusion effect. A low-cost seller can find it worthwhile to make a low-cost announcement because the resulting increase in the number of buyers it attracts offsets the enhanced aggressiveness of those buyers. For equilibrium announcements to be informative, there must then be enough volume from one-seller buyers (b is sufficiently high) so that the inclusion effect is sufficiently strong.

VI. COLLUSION

Having established that cost announcements can impact transaction prices when sellers compete, we now turn to examining the incentives for the sellers to collude. Section VI(i) explores how coordination on cost announcements affects sellers' profits. Although it is not immediate that such collusion is profitable (because it does not directly raise transaction prices), we are able to show that coordination on cost announcements can jointly improve sellers' profits due to a positive externality from making buyers less aggressive. However, contrary to typical price fixing schemes, collusion can raise social welfare. Using a standard Folk Theorem argument, Section VI(ii) characterizes sufficient conditions for coordination on cost announcements to be implementable in an infinitely repeated game.

VI(i). *Profitability of Coordination on Announcements*

Prior to learning its type, consider a seller's expected profit under competition:

$$E\left[\pi^{\text{comp}}\right] \equiv b\left[\begin{array}{c} q^2(1/2)A(l,L;l)+q(1-q)A(l,L;h) \\ +(1-q)^2(1/2)A(h,H;h) \end{array}\right] \\ +(1-b)[q^2B(l,L;l,L)+q(1-q)B(l,L;h,H) \\ +q(1-q)B(h,H;l,L)+(1-q)^2B(h,H;h,H)] \tag{11}$$

where

$$A(m_1,t_1;m_2) \equiv \int_{\underline{v}}^{\overline{v}} \int_{\underline{c}_t}^{R^1_{m_1m_2}(v)} \left(R^1_{m_1m_2}(v)-c\right) dF_{t_1}(c)\, dG(v) \tag{12}$$

is the expected profit per unit to a seller of type t_1 whose announcement is m_1 when the other seller's announcement is m_2 and a buyer approaches only that seller.[36] $B(m_1, t_1; m_2, t_2)$ is the corresponding expected profit per unit from a buyer who approaches both sellers (and is defined in (10)). The first bracketed expression pertains to the fraction b of market volume from buyers who negotiate with only one seller. With probability q, the seller is low cost and chooses announcement l which signals to buyers that it has a low-cost distribution. Of these buyers, it will attract half of them when the other seller also chooses a low-cost announcement (which occurs with probability q) and all of them when the other seller chooses a high-cost announcement (which occurs with probability $1-q$). In that case, the expected profit earned on each unit is $A(l, L; l)(=A(l, L; h))$. Now suppose that this seller is a high-cost type, which occurs with probability $1-q$, and thereby chooses announcement h. For the buyers who approach only one seller, the seller will not attract any of them when the other seller chose a low-cost announcement, and will get half of them when the other seller chooses a high-cost announcement. A high-cost announcement then attracts, in expectation, $(1-q)/2$ of those buyers, and the seller earns expected profit of $A(h, H; h)$ per unit. The second bracketed expression in (11) is the expected profit coming from the fraction $1-b$ of market volume from buyers who negotiate with both sellers.

The expected profit of a seller from using the collusive strategy (2) and coordinating on high-cost announcements, is

$$\begin{aligned} E\left[\pi^{\text{coll}}\right] \equiv\; & b\left[q(1/2)A(h,L;h)+(1-q)(1/2)A(h,H;h)\right] \\ & +(1-b)[q^2B(h,L;h,L)+q(1-q)B(h,L;h,H) \\ & +q(1-q)B(h,H;h,L)+(1-q)^2B(h,H;h,H)]. \end{aligned} \tag{13}$$

For the fraction b of market volume from buyers who approach one seller, each seller will end up negotiating with half of those buyers and earn expected profit per unit of $A(h, t; h)$ when its type is t. For the fraction $1-b$ of market volume from buyers who bargain with both sellers, a seller earns $B(h, t_1; h, t_2)$ per unit when its type is t_1 and the other seller's type is t_2.

Subtracting (11) from (13) and re-arranging, the incremental profit from collusion is:

$$\begin{aligned} & E\left[\pi^{\text{coll}}\right]-E\left[\pi^{\text{comp}}\right] \\ & =b\left[\begin{array}{l} \left(\frac{q}{2}\right)A(h,L;h)+\left(\frac{1-q}{2}\right)A(h,H;h) \\ -\left(\frac{q^2}{2}\right)A(l,L;l)-q(1-q)A(l,L;h)-\left(\frac{(1-q)^2}{2}\right)(1/2)A(h,H;h) \end{array}\right] \\ & \quad +(1-b)\left\{q^2\left[B(h,L;h,L)-B(l,L;l,L)\right]+q(1-q)\left[B(h,L;h,H)-B(l,L;h,H)\right]\right. \\ & \quad \left.+q(1-q)\left[B(h,H;h,L)-B(h,H;l,L)\right]+(1-q)^2\left[B(h,H;h,H)-B(h,H;h,H)\right]\right\}. \end{aligned} \tag{14}$$

[36] As expected profit does not depend on the other seller's type, t_2 is absent from $A(m_1, t_1; m_2)$.

Consider the first bracketed term of $E\left[\pi^{\text{coll}}\right]-E\left[\pi^{\text{comp}}\right]$ which is the profit differential (per unit) associated with the fraction b of market volume from buyers who approach one seller. Re-arranging that term yields

$$\begin{aligned}&\left(\frac{q^2}{2}\right)\left[A(h,L;h)-A(l,L;l)\right]+\left(\frac{q(1-q)}{2}\right)\left[A(h,L;h)-A(l,L;h)\right]\\&+\left(\frac{q(1-q)}{2}\right)\left[A(h,H;h)-A(l,L;h)\right]\end{aligned}\tag{15}$$

When both sellers are high-cost types then, whether colluding or not, they make high-cost announcements. Given expected profit is the same under collusion and competition, there is no term in (15) corresponding to the event when both are high-cost types. The first term in (15) pertains to when both sellers are low-cost types which occurs with probability q^2. In that case, a seller attracts half of the volume under both collusion and competition, and makes additional expected profit per unit under collusion equal to

$$\begin{aligned}&A(h,L;h)-A(l,L;h)\\&=\int_{\underline{v}}^{\overline{v}}\int_{\underline{c}_L}^{R_{ll}^1(v)}\left(R_{hh}^1(v)-R_{ll}^1(v)\right)dF_L(c)\,dG(v)+\int_{\underline{v}}^{\overline{v}}\int_{R_{ll}^1(v)}^{R_{hh}^1(v)}\left(R_{hh}^1(v)-c\right)dF_L(c)\,dG(v).\end{aligned}\tag{16}$$

The first term in (16) is when the seller's cost is less than $R_{ll}^1(v)$. As collusion has both sellers choosing a high-cost announcement (rather than a low-cost announcement when competing), a seller ends up selling at $R_{hh}^1(v)$ instead of $R_{ll}^1(v)$. Because buyers set a higher reserve price compared to when firms do not coordinate their announcements, the seller earns higher profit of $R_{hh}^1(v)-R_{ll}^1(v)$ conditional on selling, which we refer to as the *price-enhancing effect*. The second term in (16) is when the seller's cost lies in $\left[R_{ll}^1(v), R_{hh}^1(v)\right]$. Choosing a low-cost announcement under competition would result in not making a sale because the seller's bid (which equals its cost) would exceed the buyer's reserve price of $R_{ll}^1(v)$. In contrast, under collusion, sellers choose high-cost announcements which induces a buyer to set the higher reserve price of $R_{hh}^1(v)$ and, given it exceeds the seller's cost, results in a transaction at a price of $R_{hh}^1(v)$. Thus, collusion produces profit of $R_{hh}^1(v)-c$, while competition would have yielded zero profit. Also note that the consummation of this additional transaction makes the buyer better off by the amount $v-R_{hh}^1(v)$. This effect we refer to as the *transaction-enhancing effect*.

Next consider the case when the seller is a low-cost type and the other seller is a high-cost type. Under competition, the seller attracts all buyers and earns $A(l, L; h)$ per unit, while under collusion it earns a higher profit per unit of $A(h,L;h)$ but only attracts half of the buyers. The second term in (15) captures the half of the market that the seller attracts under both collusion and competition. On those buyers, the profit per unit is higher by $A(h, L; h)-A(l, L; h)$, and the associated profit gain is $b(1/2)[A(h, L; h)-A(l, L; h)]$. However, this gain is offset by an expected loss of $b(1/2)A(l, L; h)$ corresponding to the half of buyers who no longer solicit a bid from the seller under collusion. That profit loss appears in the third term in (15). But the seller gets those lost buyers back when the tables are turned and it is now a high-cost type and the other seller is a low-cost type. In that event, it would not have attracted any buyers under competition but gets half of the buyers under collusion and earns expected profit of $b(1/2)A(h, H; h)$. That profit gain is also in the third term in (15). Hence, the net profit impact is $b(1/2)[A(h, H; h)-A(l, L; h)]$, which gives us the third term in (15). Referred to as the *business-shifting effect*, it is the change in profit associated with half of the buyers no longer soliciting a bid from a firm when it is a low-cost type (under competition) and now soliciting a bid when it is a high-cost type (under collusion). This profit change could be positive or negative. While, *ceteris paribus*, it is better for a seller to attract a buyer when it is a low-cost type, the buyer's reserve price is lower. If the third term is non-negative then (15) is positive which means that collusion increases expected profit earned on buyers who solicit one offer. If the third term is negative then the sign of (15) is ambiguous.

Returning to the incremental profit from collusion in (14), the second bracketed expression pertains to the fraction $1-b$ of market volume from buyers who solicit bids from both sellers. $B(h, t_1; h, t_2) - B(\phi(t_1), t_1; \phi(t_2), t_2)$ is the difference in expected profit per unit for a type t_1 seller under collusion and under competition. In that expression, note that h is the announcement when sellers collude, and $\phi(t_i)$ is the type-revealing announcement when sellers compete so $\phi(L) = l$ and $\phi(H) = h$. It can be shown that

$$
\begin{aligned}
& B(h, t_1; h, t_2) - B(\phi(t_1), t_1; \phi(t_2), t_2) \\
&= \int_{\underline{v}}^{\overline{v}} \int_{R^2_{\phi(t_1)\phi(t_2)}(v)}^{R^2_{hh}(v)} \int_{\underline{c}_{t_1}}^{R^2_{\phi(t_1)\phi(t_2)}(v)} \left(c_2 - R^2_{\phi(t_1)\phi(t_2)}(v)\right) dF_{t_1}(c_1)\, dF_{t_2}(c_2)\, dG(v) \\
&\quad + \int_{\underline{v}}^{\overline{v}} \int_{R^2_{\phi(t_1)\phi(t_2)}(v)}^{R^2_{hh}(v)} \int_{R^2_{\phi(t_1)\phi(t_2)}(v)}^{c_2} \left(c_2 - c_1\right) dF_{t_1}(c_1)\, dF_{t_2}(c_2)\, dG(v) \\
&\quad + \int_{\underline{v}}^{\overline{v}} \int_{R^2_{hh}(v)}^{\overline{c}_{t_2}} \int_{\underline{c}_{t_1}}^{R^2_{\phi(t_1)\phi(t_2)}(v)} \left(R^2_{hh}(v) - R^2_{\phi(t_1)\phi(t_2)}(v)\right) dF_{t_1}(c_1)\, dF_{t_2}(c_2)\, dG(v) \\
&\quad + \int_{\underline{v}}^{\overline{v}} \int_{R^2_{hh}(v)}^{\overline{c}_{t_2}} \int_{R^2_{\phi(t_1)\phi(t_2)}(v)}^{R^2_{hh}(v)} \left(R^2_{hh}(v) - c_1\right) dF_{t_1}(c_1)\, dF_{t_2}(c_2)\, dG(v).
\end{aligned} \tag{17}
$$

When $(t_1, t_2) = (H, H)$, all four terms are zero because, whether colluding or competing, they announce they are high-cost types so the outcome is the same. For any other type pairs, each of these four terms is positive.[37] The first and third terms are driven by the price-enhancing effect: Collusion raises the buyer's reserve price which increases the price seller 1 receives from $R^2_{\phi(t_1)\phi(t_2)}(v)$ to c_2 (in the first term) and to $R^2_{hh}(v)$ (in the third term). The second and fourth terms capture the transaction-enhancing effect: By inducing the buyer to have a higher reserve price of $R^2_{hh}(v)$, seller 1 sells for a price of c_2 (in the second term) and $R^2_{hh}(v)$ (in the fourth term). There are no business-shifting effects given that these buyers solicit bids from both sellers. Coordination on list prices then always increases profits earned from buyers who solicit bids from both sellers.

$E\left[\pi^{\text{coll}}\right]-E\left[\pi^{\text{comp}}\right]$ is a weighted average of (17) with weight $1-b$, which was just shown to be positive, and (15) with weight b, for which the sign is ambiguous. It follows that if $E\left[\pi^{\text{coll}}\right]-E\left[\pi^{\text{comp}}\right]>0$ for b=1 then $E\left[\pi^{\text{coll}}\right]-E\left[\pi^{\text{comp}}\right]>0$ for all values of b. In the next section, we offer a parametric model for which collusion is profitable.

The welfare effects of coordination on cost announcements operate very differently than they do when firms coordinate on prices or bids. Generally, welfare goes down when sellers coordinate on prices or bids because some surplus-enhancing transactions no longer occur. In contrast, welfare can be *higher* when there is coordination of cost announcements because there are *more* transactions. The transaction-enhancing effect captures the increase in the volume of transactions because buyers set a higher reserve price when sellers coordinate on conveying high-cost announcements. In brief, coordination on prices or bids makes sellers less aggressive and that reduces the volume of surplus-enhancing transactions, while coordination on cost announcements makes buyers less aggressive and that expands the volume of surplus-enhancing transactions. That welfare can be higher is shown in Section VII.[38]

[37] As long as $R^2_{hh}(v) > R^2_{lh}(v)$; see Lemma 2.

[38] Standard with auction theory, our model assumes that a transaction does not occur if the lowest bid exceeds the buyer's reserve price. If one supposes a buyer would meet its input needs through other means, we could allow a buyer to have an outside option of buying the input on the spot market at some known price p. The only difference that makes is that a buyer's reserve price is now based on p rather than v. For example, as long as $p < v$, the expected payoff to a buyer who meets one seller with cdf F is: $(v-R)F(R)+(v-p)(1-F(R))= v-p+(p-R)F(R)$. The buyer's expected payoff without the outside option is $(v-R)F(R)$. Hence, the optimal reserve price with the outside option is the same as that without the outside option once p is substituted for v. A similar transformation occurs for a buyer who meets with two sellers. If all buyers face the same spot price then, effectively, there is just one buyer type, which is fine because our results do not require buyer heterogeneity; that feature is present for reasons of generality. We expect our main findings to still hold with this outside option though the welfare results might be a bit different. In our current model, the transaction-enhancing effect comes from having a transaction valued at $v-c$ occurring that would not have occurred otherwise. Now, the transaction-enhancing effect takes the form of a seller selling to the buyer instead of purchasing the outside option, and that realizes a gain in surplus of $p-c$ which measures the cost savings to society.

VI(ii). *Coordination on Announcements as an Equilibrium*

Though announcements do not constrain transaction prices, coordination on high-cost announcements influences transaction prices because it induces buyers to negotiate less aggressively as they believe sellers have high cost (in expectation). While we have shown that such coordination can be profitable to sellers, it has not yet been established that it is an equilibrium for sellers to collude. A variant of the usual Folk Theorem argument suffices to establish the stability of collusion.

Suppose the situation between buyers and sellers repeats itself infinitely often and $\delta \in (0, 1)$ is the common discount factor of sellers. Each period, a seller acquires some partial private information on its cost for the upcoming period. This information acquisition is represented by a seller's learning its type. With that knowledge, it then chooses its announcement. Each period it receives new information about its cost which is represented by independently drawing a new type.[39]

Although we could continue treating κ as an exogenous parameter, here we propose a path to endogenizing it. Suppose there is an exogenous Markov process by which a cartel is born (so firms adopt the collusive strategy) and dies (so firms revert to using the competitive strategy). Let f (for 'form') denote the probability that a cartel forms out of a competitive industry, and d (for 'die') denote the probability that a cartel dies and transforms into a competitive industry.[40] Assume time is $-\infty, \ldots 0, \ldots, +\infty$ and we are at time $t = 0$. As buyers live for only one period and do not observe the history, the probability they assign to firms' colluding is the steady-state probability that there is a cartel, which is defined by

$$\kappa = \kappa(1-d) + (1-\kappa)f \Leftrightarrow \kappa = \frac{f}{f+d}.$$

The strategy profile for sellers is as follows. If sellers are in the competitive state then each chooses an announcement according to the separating (stage game) strategy (1). If sellers are in the cartel state and: i) they have always chosen high-cost announcement h while in the cartel state then, as

[39] If a period is, say, a quarter then a firm knows its cost distribution for the next three months and, based on those beliefs, chooses an announcement. Over the ensuing three months, a seller gets a cost draw whenever a buyer arrives at the seller and it is that cost that is relevant when bargaining with the buyer.

[40] While it would be appealing to endogenize cartel birth and death, such a task is beyond the scope of this project. There is very little theoretical research that endogenizes cartel formation and collapse within an infinitely repeated game. With a Bertrand price game, stochastic demand can cause cartel collapse when it results in the lack of existence of collusive equilibria; see Rotemberg and Saloner [1986]. That research does not model cartel formation. Harrington and Chang [2009, 2015] assume exogenous cartel birth, as done here, and endogenize cartel death with stochastic demand in the context of the Prisoners' Dilemma.

described in (2), they choose announcement h regardless of type; and ii) for any other history, they revert to the competitive state and choose an announcement according to (1). Once in the competitive state – whether due to exogenous collapse or a deviation (which will not occur in equilibrium) – firms have a probability f in each period of transiting to the cartel state.[41]

Let V^{coll} denote the value (i.e., expected present value of profits) to a seller when in the cartel state, and V^{comp} denote the value in the competitive state. They are recursively defined by:

$$V^{\text{coll}} = E\left[\pi^{\text{coll}}\right] + (1-d)\delta V^{\text{coll}} + d\delta V^{\text{comp}} \tag{18}$$

$$V^{\text{comp}} = E\left[\pi^{\text{comp}}\right] + (1-f)\delta V^{\text{comp}} + f\delta V^{\text{coll}}. \tag{19}$$

Solving (18)-(19) yields

$$V^{\text{coll}} = \frac{(1-(1-f)\delta)\, E\left[\pi^{\text{coll}}\right] + d\delta E\left[\pi^{\text{comp}}\right]}{(1-\delta)\,(1-\delta(1-d-f))}. \tag{20}$$

$$V^{\text{comp}} = \frac{(1-\delta(1-d))\, E\left[\pi^{\text{comp}}\right] + f\delta E\left[\pi^{\text{coll}}\right]}{(1-\delta)\,(1-\delta(1-d-f))} \tag{21}$$

Using (20)-(21) and simplifying, the incremental value to being in the cartel state is:

$$V^{\text{coll}} - V^{\text{comp}} = \frac{E\left[\pi^{\text{coll}}\right] - E\left[\pi^{\text{comp}}\right]}{1-\delta(1-d-f)}. \tag{22}$$

Given the strategy for the infinitely repeated game, the equilibrium conditions for firms to collude are:

$$\begin{aligned} &b\left(\frac{1}{2}\right) A(h,t;h) + (1-b)\left[qB(h,t;h,L) + (1-q)B(h,t;h,H)\right] \\ &\quad + \delta\left((1-d)V^{\text{coll}} + dV^{\text{comp}}\right) \\ &\geq bA(l,t;h) + (1-b)\left[qB(l,t;h,L) + (1-q)B(l,t;h,H)\right] + \delta V^{\text{comp}},\ t \in \{L,H\}. \end{aligned} \tag{23}$$

[41] Alternatively, we could assume that reaching the competitive state because of a deviation results in a per period probability g of returning to the cartel state and allow g to differ from f. For example, $g = 0$ captures infinite reversion to a stage game Nash equilibrium. As ensuing results are robust to $g \in [0, f]$, it is assumed $g = f$ in order to reduce notation and make for simpler expressions.

The expression on the LHS of the inequality is the payoff for choosing a high-cost announcement (as prescribed by the collusive strategy), and on the RHS is the payoff from instead choosing a low-cost announcement. Note that when a seller deviates by choosing a low-cost announcement, it is ensured of attracting all buyers because the other seller is anticipated to post a high-cost announcement. Hence, we have $bA(l, t; h)$ on the RHS and $b\left(\frac{1}{2}\right)A(h, t; h)$ on the LHS.

Rearranging (23) and substituting using (22), (23) becomes:

$$\left(\frac{\delta(1-d)}{1-\delta(1-d-f)}\right)\left(E\left[\pi^{\text{coll}}\right]-E\left[\pi^{\text{comp}}\right]\right)$$
$$\geq b\left[A(l,t;h)-\left(\frac{1}{2}\right)A(h,t;h)\right]$$
$$+(1-b)\left[q\left(B(l,t;h,L)-B(h,t;h,L)\right)+(1-q)\left(B(l,t;h,H)-B(h,t;h,H)\right)\right].$$
(24)

If collusion is more profitable than competition (so that the LHS is positive) then this equilibrium condition always holds for a high-cost type.[42] Under competition, a high-cost type's current expected profit is lower when it chooses a low-cost announcement, and that remains the case when firms coordinate their announcements. Hence, short-run profit (as well as the continuation payoff) is *lower* to a high-cost type if it were to deviate to a low-cost announcement. In contrast, it is possible for a low-cost type to earn higher current expected profit by deviating to a low-cost announcement and attracting all buyers. For (24) to be assured of holding for a low-cost type, the LHS must then be sufficiently great.

The LHS of (24) is the difference in the future value between setting the collusive announcement h and deviating with announcement l. If we let the probability of cartel birth and death become very small and firms to become very patient then

$$\lim_{d,f\to 0,\,\delta\to 1}\frac{\delta(1-d)}{1-\delta(1-d-f)}=+\infty.$$

Thus, as long as collusion is profitable, $E\left[\pi^{\text{coll}}\right] > E\left[\pi^{\text{comp}}\right]$, it is an equilibrium for firms to coordinate on high-cost announcements when the likelihood of cartel birth and death are sufficiently low and firms are sufficiently patient.

[42] It can be shown that the second bracketed term on the RHS is negative for both cost types, and the first term is negative for a high-cost type. As then the RHS is negative for a high-cost type, (24) holds because the LHS is positive.

VII. COLLUSION FOR A CLASS OF PARAMETRIC DISTRIBUTIONS

Coordination of cost announcements requires that collusion is *feasible* (i.e., announcements are informative under competition, see Theorem 3), collusion is *profitable* (i.e., (14) is positive), and collusion is *stable* (i.e., it is an equilibrium outcome in an infinitely repeated game, which is the case when (14) holds). In this section, we show these conditions are satisfied for a particular class of distributions on costs and values.

Assume $b = 1$ (so all buyers negotiate with one seller) and $\kappa = 0$ (so the prior probability of collusion is zero). By the analysis in Section VI, the ensuing results will approximate the case when b is close to one and κ is close to zero.[43] Suppose valuations and costs have support [0, 1]. Valuations are uniformly distributed: $G(v) = v$. The cdf for a low-cost type is $F_L(c) = c^\alpha$ and for a high-cost type is $F_H(c) = c^\beta$, where $0 < \alpha < \beta$ so the inverse hazard rate ranking is satisfied: $h_L(c) = c/\alpha > c/\beta = h_H(c)$. Recall that a seller is a low-cost type with probability q.[44]

Theorem 5. Under the assumptions of Section VII, collusion is feasible if and only if

$$(25)\qquad \underline{q}(\alpha,\beta) \equiv \frac{\frac{\beta^{\alpha+1}}{(\beta+1)^{\alpha+1}} - 2\frac{\alpha^{\alpha+1}}{(\alpha+1)^{\alpha+1}}}{\frac{\beta^{\alpha+1}}{(\beta+1)^{\alpha+1}} - \frac{\alpha^{\alpha+1}}{(\alpha+1)^{\alpha+1}}} \leq q \leq \frac{\frac{\beta^{\beta+1}}{(\beta+1)^{\beta+1}} - 2\frac{\alpha^{\beta+1}}{(\alpha+1)^{\beta+1}}}{\frac{\beta^{\beta+1}}{(\beta+1)^{\beta+1}} - \frac{\alpha^{\beta+1}}{(\alpha+1)^{\beta+1}}} \equiv \overline{q}(\alpha,\beta)$$

and is profitable if $\alpha < 1$.

Given these distributions, the necessary and sufficient conditions for a separating equilibrium to exist that are provided in Theorem 3 take the form in (25). It can be shown that $\alpha < \beta$ implies the RHS of (35) exceeds the LHS. For example, $[\underline{q}(0.5, 2), \overline{q}(0.5,2)] = [0.453, 0.857]$. A sufficient condition for collusion to be profitable is that the low-cost distribution is concave, $\alpha < 1$.

For when $(\alpha, \beta) \in [0, 1] \times [0,2]$, Figure 1 reports the range of values for q, $\underline{q}(\alpha, \beta) - \overline{q}(\alpha, \beta)$, such that collusion is feasible and profitable (where the latter holds because $\alpha < 1$).[45] Depending on the values for (α, β), there can be a wide range of values for q such that firms can effectively and profitably coordinate their announcements.

[43] If $\kappa > 0$ or $b < 1$ then there is no longer closed-form solutions for optimal reserve prices and, therefore, no closed-form solutions for $\underline{q}$ and $\overline{q}$.
[44] The proofs of all results in this section are provided in the Online Appendix.
[45] $\overline{q}(\alpha, \beta)$ and $q(\alpha, \beta)$ are constrained to lie in [0,1]. Hence, more exactly, Figure 1 reports $\max\{\min\{q(\alpha, \beta), 1\}, 0\} - \min\{\max\{\overline{q}(\alpha, \beta), 0\}1\}$.

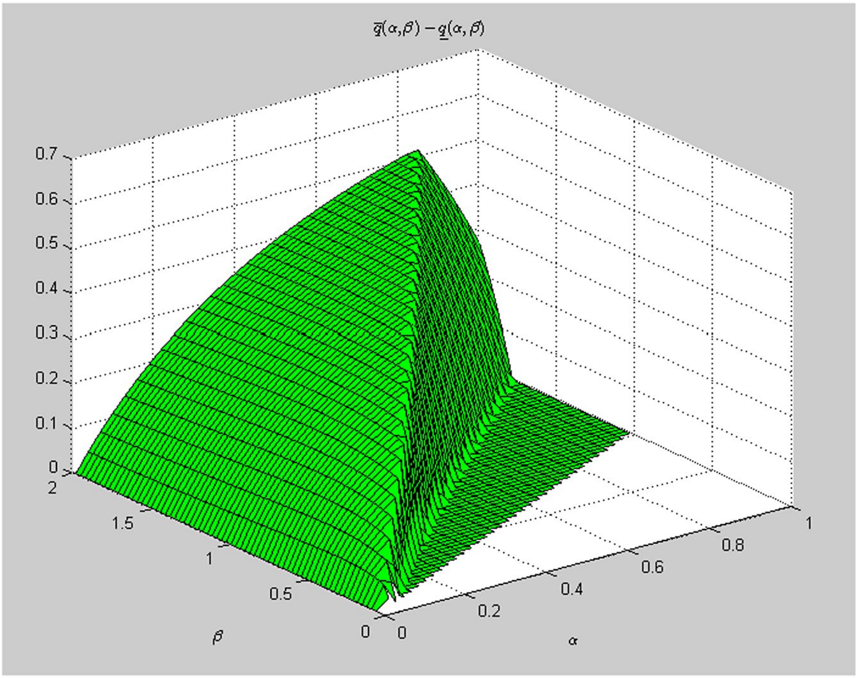

Figure 1
Range of Values for q for which Collusion is Feasible and Profitable

Let us now show that collusion can raise welfare. Let $\Delta(q)$ denote the difference between expected total surplus under collusion and under competition, where its dependence on q is made explicit.[46] For $(\alpha, \beta) \in [0, 1]\times[0, 2]$, Figure 2 reports the maximum welfare difference,

$$\overline{\Delta}(\alpha, \beta) \equiv \max \left\{ \Delta(q) : q \in \left[\underline{q}(\alpha, \beta), \overline{q}(\alpha, \beta) \right] \right\},$$

and the minimum welfare difference,

$$\underline{\Delta}(\alpha, \beta) \equiv \min \left\{ \Delta(q) : q \in \left[\underline{q}(\alpha, \beta), \overline{q}(\alpha, \beta) \right] \right\}.$$

Figure 2 shows $\Delta(\alpha, \beta) > 0$ for most values of (α, β) so collusion *improves* welfare for some values of q. In addition, for some values of (α, β), Figure 3 shows $\Delta(\alpha, \beta) > 0$ so welfare is higher under collusion for all values of q (for

[46] In the Online Appendix, the expression for $\Delta(q)$ is provided.

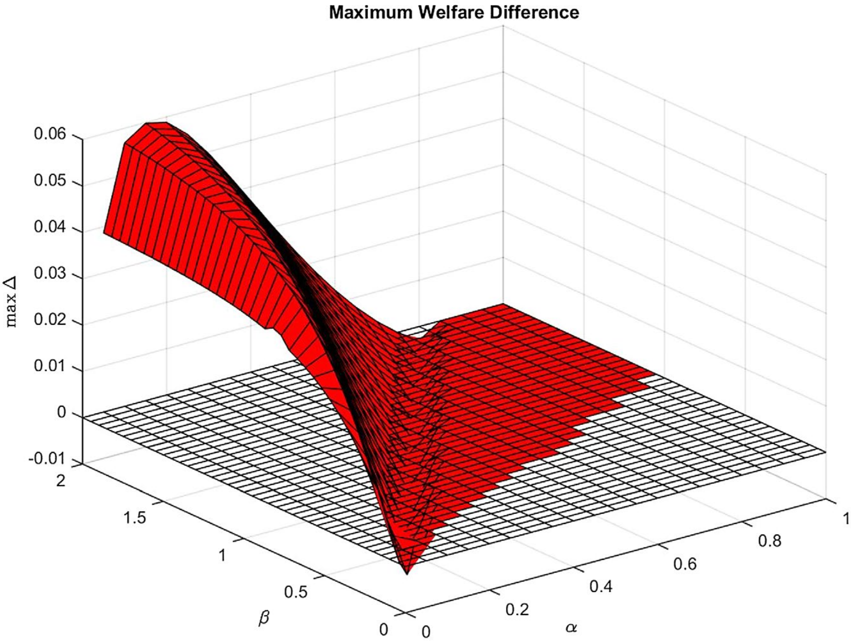

Figure 2
Maximum Welfare Difference Between Collusion and Competition

which collusion is feasible and profitable). By reducing the aggressiveness of buyers, collusion enhances the total surplus in the market by resulting in more Pareto-improving transactions (which is the transaction-enhancing effect) and that can more than compensate for the higher cost under collusion (due to the business-shifting effect).

VIII. CONCLUDING REMARKS

This paper offers the first theory of collusion based on influencing buyers' conduct rather than constraining sellers' offerings to buyers. It was shown that coordination of cost announcements – such as through list prices – can be an effective form of collusion even though sellers are left unconstrained in the prices they offer buyers. By coordinating on announcements that convey they have high cost in expectation, sellers can induce buyers to bargain less aggressively, and that will deliver supracompetitive prices. Notably, sellers continue to set prices in a competitive manner. As opposed to coordination of prices, coordination of cost announcements can raise welfare because buyers are made less aggressive and that results in more surplus-enhancing transactions.

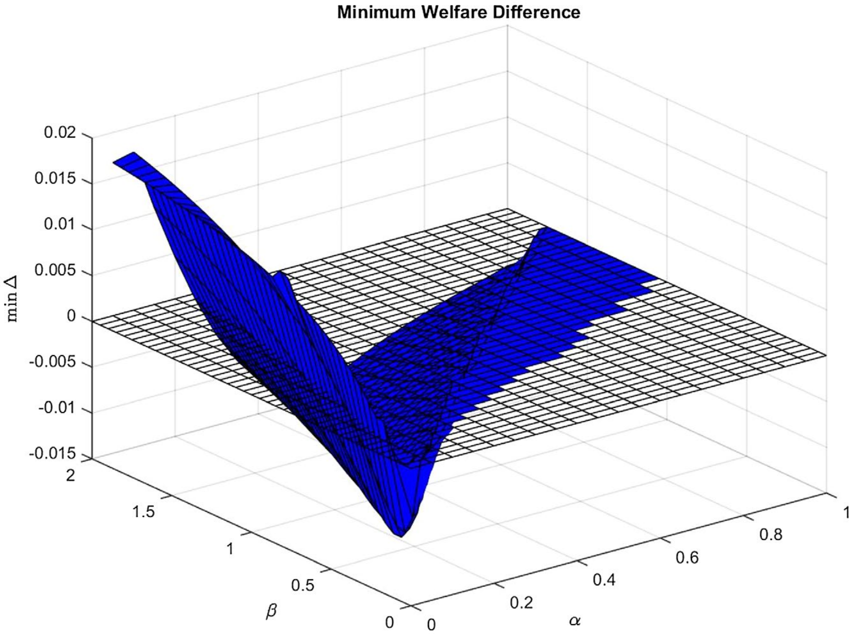

Figure 3
Minimum Welfare Difference Between Collusion and Competition

While cartels in cement, fiberglass insulation, and urethane coordinated on list prices, more typical for intermediate goods cartels it is to coordinate on the final prices offered to buyers. When competition involves negotiation with buyers and discounts off of list prices, sellers in some cartels coordinated on list prices and agreed not to offer discounts, so list prices became sellers' final prices.[47] With some other cartels, sellers coordinated on both list prices and discounts, and thereby agreed to final prices.[48] A natural question to ask is why sellers would choose to coordinate only on list prices rather than go that additional step and coordinate on final prices, especially given that express communication on either list or final prices is likely to be per se illegal. As a clue to shedding light on that issue, note that coordination on list prices makes buyers less aggressive, while coordination on final prices makes rival sellers less aggressive. If the pressure on a seller's price is largely coming from buyers' bargaining power then it may be sufficient to coordinate on list prices so as to make buyers less aggressive. If instead the pressure is largely from other sellers then it would seem critical

[47] For example, the turbine generators cartel of 1963-74; see Harrington [2011].
[48] For example, the citric acid cartel of 1991-95; see Harrington [2006].

to coordinate on sellers' final prices (which, in our model, means bids). Future research will flesh out that conjecture in order to understand how market conditions – such as the strength of buyer power and the intensity of seller competition – relate to the form of collusive practices.

APPENDIX

A1. Proof of Lemmas 1 and 2

First, it can be verified that given $h_L(c) > h_H(c)$, we have $h_L(c) > h_\kappa(c) > h_H(c)$ if $\kappa \in (0, 1)$.

To show Lemma 1, the first-order conditions of (4) and (6) are given by

$$v - R^1_{m_1m_2}(v) = h_L(R^1_{m_1m_2}(v)), \quad \forall \left(m_1, m_2\right) \in \{(l,l), (l,h), (h,l)\}$$
$$v - R^1_{hh}(v) = h_\kappa(R^1_{hh}(v))$$

It is easily verified that

$$R^{1\prime}_{m_1m_2}(v) = \frac{1}{1 + h'_L(R^1_{m_1m_2}(v))} > 0, \quad \forall \left(m_1, m_2\right) \in \{(l,l), (l,h), (h,l)\}$$

So $R^1_{m_1m_2}(v)$ is increasing in v, $\forall \left(m_1, m_2\right) \in \{(l,l), (l,h), (h,l)\}$.

To show that $R^1_{hh}(v) > R^1_{ll}(v)(= R^1_{lh}(v) = R^1_{hl}(v))\,\forall v$, suppose the negation so that $R^1_{hh}(v) \leq R^1_{ll}(v)$ for some v. It follows that

$$0 \leq -\left(R^1_{hh}(v) - R^1_{ll}(v)\right) = h_\kappa(R^1_{hh}(v)) - h_L(R^1_{ll}(v)) \leq h_\kappa(R^1_{hh}(v)) - h_L(R^1_{hh}(v)) < 0$$

which is a contradiction.

Next to show Lemma 2, when $\left(m_1, m_2\right) \in \{(l,l), (h,h)\}$, the first-order condition from (5) and (7) are given by

$$v - R^2_{ll}(v) = h_L(R^2_{ll}(v)) \tag{26}$$

$$v - R^2_{hh}(v) = h_\kappa(R^2_{hh}(v)) \tag{27}$$

So we have $R^2_{ll}(v) = R^1_{ll}(v)$ and $R^2_{hh}(v) = R^1_{hh}(v)$. When $\left(m_1, m_2\right) \in \{(l,h), (h,l)\}$, say, when $\left(m_1, m_2\right) = (l,h)$, the first-order condition from (5) becomes

$$0 = \left(1 - F_H(R^2_{lh})\right) f_L(R^2_{lh}) \left[\left(v - R^2_{lh}\right) - h_L\left(R^2_{lh}\right)\right]$$
$$+ \left(1 - F_L(R^2_{lh})\right) f_H(R^2_{lh}) \left[\left(v - R^2_{lh}\right) - h_H\left(R^2_{lh}\right)\right].$$

Given the assumption that $h_L\left(R^2_{lh}\right) > h_H\left(R^2_{lh}\right)$, we have

$$\left(v - R^2_{lh}\right) - h_L\left(R^2_{lh}\right) < 0 < \left(v - R^2_{lh}\right) - h_H\left(R^2_{lh}\right), \tag{28}$$

As $\left(v - R^2_{ll}\right) - h_L\left(R^2_{ll}\right) = 0$ (from (26)) then (28) implies $\left(v - R^2_{lh}\right) - h_L\left(R^2_{lh}\right) < \left(v - R^2_{ll}\right) - h_L\left(R^2_{ll}\right)$. As $\left(v - R^2_{hh}\right) - h_\kappa\left(R^2_{hh}\right) = 0$ (from (27)) then

(28) implies $\left(v-R_{hh}^2\right)-h_\kappa\left(R_{hh}^2\right)<\left(v-R_{lh}^2\right)-h_H\left(R_{lh}^2\right)$. Those two conditions imply $R_{lh}^2+h_L\left(R_{lh}^2\right)>R_{ll}^2+h_L\left(R_{ll}^2\right)$ and $R_{hh}^2+h_\kappa\left(R_{hh}^2\right)>R_{lh}^2+h_H\left(R_{lh}^2\right)$. When κ is sufficiently small, we have $R_{hh}^2+h_\kappa\left(R_{hh}^2\right)>R_{hh}^2+h_H\left(R_{hh}^2\right)>R_{lh}^2+h_H\left(R_{lh}^2\right)$ by continuity of $h_\kappa\left(R_{hh}^2\right)$ in κ.

Given that $h_t'(z)\geqslant 0$, we have the strict monotonicity of $z+h_t(z)$, $t\in\{L,H\}$. Thus $\exists\kappa>0$ such that if $\kappa\in[0,\kappa]$ then $R_{hh}^2(v)>R_{lh}^2(v)>R_{ll}^2(v),\forall v$.

A2. Proof of Theorems 3 and 4

Let us first prove Theorem 4. Recall that $A(m_1,t_1;m_2)$ is the expected profit per unit to a seller of type t_1 whose announcement is m_1 when the other seller's announcement is m_2 and a buyer approaches only that seller. When the seller chooses a low-cost announcement, its expected payoff is independent of the other seller's announcement as buyers believe firms are competing: $A(l,t_1;l)=A(l,t_1;h)$. However, when the seller's announcement conveys it is high cost then the payoff does depend on the other seller's announcement, for if it is a low-cost message then buyers believe sellers are competing and when it is a high-costs message then buyers are uncertain about whether they face competition or collusion: $A(h,t_1;l)\neq A(h,t_1;h)$.

When it chooses its announcement, a seller knows that a fraction b of market volume is from buyers who approach only one seller (and that those buyers will choose the seller with the low-cost announcement) and a fraction $1-b$ of market volume is from buyers who approach both sellers. In that case, a type L seller optimally chooses announcement l if and only if

$$\begin{aligned}W(l,L,b)\equiv{}& b\left[\left(\frac{q}{2}\right)A(l,L;l)+(1-q)A(l,L;h)\right]\\&+(1-b)\left[qB(l,L;l,L)+(1-q)B(l,L;h,H)\right]\\&\geq b\left(\frac{1-q}{2}\right)A(h,L;h)+(1-b)\left[qB(h,L;l,L)+(1-q)B(h,L;h,H)\right]\equiv W(h,L,b).\end{aligned}\tag{29}$$

A type H seller optimally chooses announcement h if and only if

$$\begin{aligned}W(h,H,b)\equiv{}& b\left(\frac{1-q}{2}\right)A(h,H;h)+(1-b)\left[qB(h,H;l,L)+(1-q)B(h,H;h,H)\right]\\&\geq b\left[\left(\frac{q}{2}\right)A(l,H;l)+(1-q)A(l,H;h)\right]+(1-b)\left[qB(l,H;l,L)+(1-q)B(l,H;h,H)\right]\\&\equiv W(l,H,b)\end{aligned}\tag{30}$$

From Section IV(ii), if $b=0$ then (29) does not hold (as a type L seller prefers to choose announcement h) though (30) does hold. Suppose that (29)-(30) are satisfied when $b=1$. Combining these conditions for $b=0$ and $b=1$ delivers:

$$\begin{aligned}W(l,L,1)-W(h,L,1)>0>W(l,L,0)-W(h,L,0)\\W(h,H,1)-W(l,H,1)>0>W(l,H,0)-W(h,H,0)\end{aligned}\tag{31}$$

By the linearity of the conditions in (31) with respect to b, it follows that there exists $b^* \in (0,1)$ such that (29)-(30) hold if and only if $b \in \left[b^*, 1\right]$.

Turning to the proof of Theorem 3, set $b = 1$. Using (12) in (29)-(30), those conditions can be re-arranged to conclude that a separating equilibrium exists if and only if $q \in [\underline{q}, \overline{q}]$ where

$$\frac{\int_{\underline{v}}^{\overline{v}} \int_{\underline{c}_L}^{R_{hh}(v)} \left(R_{hh}(v) - c\right) dF_L(c)\, dG(v) - 2 \int_{\underline{v}}^{\overline{v}} \int_{\underline{c}_L}^{R_{ll}(v)} \left(R_{ll}(v) - c\right) dF_L(c)\, dG(v)}{\int_{\underline{v}}^{\overline{v}} \int_{\underline{c}_L}^{R_{hh}(v)} \left(R_{hh}(v) - c\right) dF_L(c)\, dG(v) - \int_{\underline{v}}^{\overline{v}} \int_{\underline{c}_L}^{R_{ll}(v)} \left(R_{ll}(v) - c\right) dF_L(c)\, dG(v)} \equiv \underline{q} \leq q \leq \overline{q}$$

$$\equiv \frac{\int_{\underline{v}}^{\overline{v}} \int_{\underline{c}_H}^{R_{hh}(v)} \left(R_{hh}(v) - c\right) dF_H(c)\, dG(v) - 2 \int_{\underline{v}}^{\overline{v}} \int_{\underline{c}_H}^{R_{ll}(v)} \left(R_{ll}(v) - c\right) dF_H(c)\, dG(v)}{\int_{\underline{v}}^{\overline{v}} \int_{\underline{c}_H}^{R_{hh}(v)} \left(R_{hh}(v) - c\right) dF_H(c)\, dG(v) - \int_{\underline{v}}^{\overline{v}} \int_{\underline{c}_H}^{R_{ll}(v)} \left(R_{ll}(v) - c\right) dF_H(c)\, dG(v)}$$

(32)

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