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Working Paper

Posted pricing as a plus factor

Working Paper, No. 565

Provided in Cooperation with:
Department of Economics, The Johns Hopkins University

Suggested Citation: Harrington, Joseph E. (2010) : Posted pricing as a plus factor, Working Paper, No. 565, The Johns Hopkins University, Department of Economics, Baltimore, MD

This Version is available at:
https://hdl.handle.net/10419/49883

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Posted Pricing as a Plus Factor*

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August 2010

Abstract

This paper identifies conditions under which an industry-wide practice of posted (or list) pricing is a plus factor sufficient to conclude that firms violated Section 1 of the Sherman Act. For certain classes of markets, it is shown that, under competition, all firms setting a list price with a policy of no discounting is contrary to equilibrium. Thus, if all firms choose posted pricing, it is to facilitate collusion by making it easier for them to coordinate their prices. It is then argued that the adoption of posted pricing communicates the necessary intent and reliance to conclude concerted action.

1 Introduction

To discuss collusion from both an economics and legal perspective, it is best to begin by defining what is meant by "collusion" because economists and lawyers speak of it in different ways. With regards to market conduct, economists have two categories of behavior: competition and collusion. Competitive (or non-collusive) behavior is consistent with a static Nash equilibrium for an oligopoly game. In particular, a firm's price (or quantity) maximizes current profit given the anticipated prices (or quantities) of its rivals. Collusive (or coordinated) behavior is an equilibrium for an infinitely or indefinitely repeated oligopoly game that produces prices in excess of those associated with a static Nash equilibrium (that is, prices are supracompetitive). Though a firm prices in excess of (or produces short of) that which maximizes current profit, it is in the firm's self-interest to do so because of the anticipated reaction by other firms in the future if it was to price lower (or produce more). It is then a feature of collusion that a firm's behavior hinges on what firms have done in the past.[1]

*I am grateful to Jon Baker, George Hay, and Bill Page for their thoughtful and constructive comments. I remain solely responsible for any mathematical errors and legal misinterpretations.

[1]For non-technical treatments of how economists think of collusion and how it relates to the law, see Baker (1993), Yao and DeSanti (1993), and Werden (2004).

For firms to be at an equilibrium - whether it involves competitive or collusive prices - they must have achieved mutual understanding regarding the strategies that they are pursuing. Collusion is distinguished according to how this mutual understanding is achieved. With *explicit collusion*, mutual understanding arises through express communication among firms. Generally, this takes the form of verbal communication in which firms reach an agreement as to the strategies they will deploy. *Tacit collusion* is when mutual understanding occurs without express communication. It is worth noting that while economic theory can describe when collusion is feasible (that is, supracompetitive prices can be sustained by an equilibrium), it has little to say about the likelihood of collusion (since whenever there is an equilibrium with collusion, there is also an equilibrium with competition) nor about the relative ease of tacit and explicit collusion because the current paradigm presumes an equilibrium and therefore cannot address whether collusion is achieved through explicit or tacit means.

In defining collusion from the economics perspective, the focus is on the outcome - are prices supracompetitive or not? - and the mechanism used to sustain that outcome. In contrast, collusion as defined by the law rests on whether firms have reached an agreement.

> By operationalizing the idea of an agreement, antitrust law clarified that the idea of an agreement describes a process that firms engage in, not merely the outcome that they reach. Not every parallel pricing outcome constitutes an agreement because not every such outcome was reached through the process to which the law objects: a negotiation that concludes when the firms convey mutual assurances that the understanding they reached will be carried out.[2]

When it comes to the law, there are three types of collusion (as it is defined by economists), not all of which violate Section 1 of the Sherman Act. *Conscious parallelism* is when supracompetitive prices are achieved without an agreement. An example often associated with adjacent gasoline or petrol stations is when one station raises its price to a supracompetitive level and the other station matches the price hike. While there may be mutual understanding regarding the underlying mechanism that stabilizes those supracompetitive prices (for example, any price undercutting results in a return to competitive prices), this understanding was not reached through any form of direct communication. *Express collusion* is when supracompetitive prices are achieved via express communication about an agreement.

> Cases that speak of "express" agreements ordinarily involve "direct," readily observable proof that the defendants have exchanged assurances that they will pursue a common course of action: e.g., a document that describes a collective commitment to pursue a course of conduct, or testimony through which one or more parties to a conspiracy describe how they formed the conspiracy and recount the conspiracy's goals.[3]

[2] Baker (1993), p. 179.
[3] Kovacic (1993), p. 19.

Conscious parallelism is legal because there is not thought to be an agreement, while express collusion is illegal.[4]

Residing between these two extremes is concerted action. *Concerted action* is when supracompetitive prices are achieved with communication - such as about intentions - but firms do not expressly propose and reach an agreement.

> The parties ... engage in a concerted practice by communicating and then act consistently with the communications. While American courts typically use "concerted action" interchangeably with "agreement," Interstate Circuit appears to recognize concerted action as a species of agreement that requires the concurrence of both a plan and an action in accordance with the plan.[5]

In Interstate Circuit (1939), the Court stated:

> It was enough that, knowing that concerted action was contemplated or invited, the distributors gave their adherence to the scheme and participated in it. ... [A]cceptance by competitors, without previous agreement, of an invitation to participate in a plan, the necessary consequence of which, if carried out, is restraint of interstate commerce, is sufficient to establish an unlawful conspiracy under the Sherman Act.[6]

In their attempt to avoid prosecution under the Sherman Act, steel manufacturers assiduously avoided talk of any agreement about prices during their regular meetings (Page, 2009a). Instead, they made statements as to whether prices were "fair and reasonable" and suggesting prices to be charged. In spite of the lack of express communication as to an agreement, participants admitted to achieving mutual understanding and they were convicted.

In comparing the economic and legal definitions, conscious parallelism and concerted action are types of tacit collusion which differ in how mutual understanding is reached. Thus, tacit collusion, as defined by economists, is not necessarily illegal. In this paper, the concern is with tacit collusion and when we can conclude it was achieved through concerted action, rather than conscious parallelism, and thus is prosecutable under the Sherman Act.

Given the legal standard, the challenge faced in prosecuting tacit collusion is providing "direct or circumstantial evidence that reasonably tends to prove that [the parties] had a conscious commitment to a common scheme designed to achieve an unlawful objective."[7] What has to be established is that firms have a "unity of purpose or a common design and understanding, or a meeting of minds"[8] which "tends to exclude the possibility of independent action".[9] The problem is then "how

[4] As we will discuss in Section 5, Richard Posner has famously argued that one might be able to conclude there is an agreement under what is considered conscious parallelism.

[5] Page (2007), p. 439.

[6] Interstate Circuit, Inc., et al.v. United States Paramount Pictures Distributing Co., Inc., et al. v. Same, 306 U.S. 208 (1939).

[7] Monsanto Co. v. Spray-Rite Serv. Corp., 465 U.S. 752 (1984).

[8] American Tobacco Co. v. United States, 328 U.S. 781 (1946).

[9] Monsanto Co. v. Spray-Rite Serv. Corp., 465 U.S. 752 (1984).

far may we move away from direct, detailed, and reciprocal exchanges of assurances on a common course of action and yet remain within the statutory and conceptual boundaries of an agreement."[10]

This task has proven to be difficult though not entirely insurmountable. While this paper is not the place to describe the various successful arguments for proving Section 1 violations when evidence of express communication regarding an agreement is lacking,[11] there is one line of attack that is especially relevant to what will occur in this paper. This approach involves foregoing trying to establish that there was a "meeting of the minds" through tacit means, and focusing instead on those practices which are suspected of facilitating mutual understanding with regards to coordinated pricing.

> I am convinced that the difference between unlawful "tacit collusion" and lawful oligopolistic interdependence is not to be found in any phrase that describes the state of mind of the industry participants. Once we are outside the boundary of a formal agreement, whatever degree of "assurance", "meeting of the minds", "conscious commitment to a common scheme", etc., that exists in a situation of tacit collusion can exist to the same extent in a situation of (lawful) classic oligopoly. Rather, if there is to be a category of unlawful tacit collusion which is to be distinguished from classic oligopoly, the difference must lie, not in the state of mind of the competitors, but on the specific elements of behavior that brought about that state of mind.[12]

Pursuant to this approach, a practice that has arisen in several cases is the public announcement by firms of a policy to set a list price with no discounting off of that list price, which we will refer to as *posted pricing*. This practice was a central feature in a case brought against General Electric and Westinghouse in the market for turbine generators, which are high expenditure custom-ordered equipment commonly purchased by power generating companies.

> In May 1963 ... General Electric announced a new pricing policy for turbine generators. One facet of the policy was the publication of a new and more simplified pricing book that permitted rival Westinghouse rather easily to compute the "book" price of any generator on which the two firms might be asked to bid. GE also announced a standard multiplier it would apply to the book price on each bid, and it communicated its intent not to deviate from the standard "book price times announced multiplier" procedure in bidding. The multiplier itself varied over time, but changes were publicly announced by General Electric. Consequently, what might otherwise have been a very complex coordination problem was reduced to a matter of Westinghouse's knowing how to calculate the

[10] Phillip E. Areeda, *Antitrust Law* 9-12 (1986); cited in Kovacic (1993), p. 18-9.
[11] On that topic, the reader is referred to Kovacic (1993).
[12] Hay (2000), pp. 127-128.

> so-called book price and following GE's price leadership with respect to the multiplier. ... [T]he two companies are said to have applied identical multipliers to identical book prices on their turbogenerator bids for the next 12 years - until the practices were challenged by federal antitrust authorities. In sharp contrast to the history of the 1950s and early 1960s [when they explicitly colluded], GE and Westinghouse effected no generator price decreases during this period. General Electric led a number of price increases, with Westinghouse typically following by announcing an identical multiplier increase within four days (although on one occasion the lag was three months). Thus, by linking price leadership to a simplification of the methods for computing bid prices, General Electric successfully avoided the pricing coordination breakdown that had materialized even with outright collusion in earlier periods.[13]

In response to this and other practices, the U.S. Department of Justice planned to file a civil antitrust suit but then the parties settled with a modification of the 1962 consent decree from the previous Section 1 case against these firms. The DOJ's view was:

> [Though] there was no evidence of any formal communication or agreement between GE and Westinghouse, ... the independent yet parallel adoption of the new policy by GE and Westinghouse had brought about a meeting of the minds and *facilitated* the elimination of price competition.[14]

Another case in which this practice arose was the private suit *Wall Products Co. v. National Gypsum Co.* The major producers of gypsum wallboard had a policy of not offering discounts off of their list price, though there with some exceptions. Due to declining demand and excess industry capacity, this policy unravelled in 1964-65 with ever-increasing discounts and a drastic decline in profits. In response, United States Gypsum Company (USG) mailed an announcement to its customers on November 17, 1965 which stated:

> Any discounts of gypsum board and/or plaster products previously extended to meet competition will be withdrawn as of December 15, 1965. As a constructive move, we have decided to sell our gypsum products solely on the basis of our published prices.[15]

In its decision, the U.S. District Court stated:

> The USG witnesses unanimously testified that the success of the new pricing policy was dependent on the other major competitors following

[13] Scherer (1980), p. 182.
[14] Hay (2000), p. 115.
[15] *Wall Products Co. v. National Gypsum Co.* (1971), 326 F. Supp. 295.

> suit. As Mr. Watt [Vice-President of Marketing at USG] said, the great danger of this announcement was "the possibility that the other producers would go right on making or meeting lower prices."[16]

Shortly after this announcement, all major suppliers followed USG's lead by adopting the same no-discounting policy with the same effective date. Georgia-Pacific and National made their announcement one week later, with five other suppliers following suit within two weeks. The U.S. District Court concluded:

> That during the period from December 15, 1965 until January 1, 1968, USG, National and Kaiser combined and conspired among themselves and with others, to stabilize and maintain the price level of gypsum wallboard through a course of interdependent conscious parallel action pursuant to a tacit understanding by acquiescence coupled with assistance whereby they mutually agreed to, and did in fact, effective December 15, 1965, withdraw all deviations from list or published prices of gypsum wallboard ...[17]

In both the turbine generator and gypsum wallboard cases, the practice of direct concern was the contemporaneous public adoption of a policy to set list prices and not offer discounts. There was no evidence of an express agreement to adopt this new pricing policy, nor regarding the list prices to be set. The open question I seek to address here is whether circumstances can be identified under which the parallel adoption of posted pricing is sufficient to establish a violation of Section 1 of the Sherman Act. A critical step in doing so will be to rule out reasons for adopting posted pricing unrelated to collusion. For if there is a legitimate rationale then it will not be possible to "exclude the possibility of independent action". Towards that end, the various effects of posted pricing are described in Section 2, which are: i) reducing consumer search costs; ii) reducing firms' selling costs; iii) reducing the responsiveness of price to cost and demand conditions; and iv) affecting the manner in which firms compete. As (i) and (ii) can provide a legitimate rationale for the adoption of posted pricing, market situations are identified for which these effects are minimal. To explore (iii) and (iv), a model is developed in Section 3 which is then analyzed in Section 4 to determine when competitive firms will adopt posted pricing. (For those who'd rather avoid the mathematical modelling and analysis in Sections 3 and 4, a summary of the results are at the start of Section 4.) Using that economic analysis, Section 5 applies some recent legal arguments by William Page (2007, 2010) to make the case for concerted action when there is parallel adoption of posted pricing. Section 6 concludes with a few remarks about drawing the judicial line regarding when communication conveys a collusive agreement.

[16] Ibid
[17] Ibid

2 Catalog of Effects of Posted Pricing

Posted pricing has a long history. Quakers were an early proponent (Kent, 1983) on the grounds that customers should be charged a "fair price" and since what is fair does not vary with the customer then all customers should receive the same price. With the advent of department stores and sales being conducted by paid employees (compare this to the owner-run general store), it became desirable to centralize pricing authority. By the mid-19th century, Bon Marche in Paris (Miller, 1993) and Macy's in New York (Hower, 1943) were charging a fixed price for goods. Clearly, posted pricing has a history quite independent of any role it might play in facilitating collusion. It is then critical to distinguish the many instances in which posted pricing is legitimate from when it is not.

In considering the various effects of posted pricing, the alternative is to have, to some degree, transaction-specific pricing, whereby price may vary with customer traits, the particulars of the product demanded, and the time at which the customer requests a price quote.[18] Transaction-specific pricing can involve a range of institutions ranging from the seller making a take-it-or-leave-it offer to the buyer (as they do with posted pricing but where now the price is tailored to the transaction) to back-and-forth negotiation between the buyer and seller. In our formal analysis, the former is assumed and there will be some discussion of the robustness of results to the latter. The general discussion in this section applies quite broadly to transaction-specific pricing.

There are four possible effects of moving from transaction-specific pricing to posted pricing: i) reducing consumer search costs; ii) reducing firms' selling costs; iii) reducing the responsiveness of price to cost and demand conditions; and iv) affecting the manner in which firms compete. The first two effects relate to buyers and sellers incurring lower costs to transact.

By having a set price, it is potentially easier for a consumer to collect price information compared to some other institutions such as bargaining. These lower consumer search costs from posted pricing can benefit consumers in three ways. First, even if the prices charged are the same and a consumer considers the same set of sellers (that is, conduct the same set of searches), lower search costs mean a consumer has engaged in less time and effort in collecting this information, and thereby benefits. Consider, for example, the retail automobile market where buyers and sellers negotiate over price. A buyer engages in a time-consuming and, depending on the person, mentally-draining negotiation in order to learn a car's price. An auto retailer posting a non-negotiable price avoids those consumer costs.[19] There is then a

[18] To some degree, these features can be built into a posted pricing scheme by specifying a formula mapping product features into price or having seasonal pricing. But even if this is done, price will be less sensitive to these factors under posted pricing.

[19] It has been argued in previous research that firms may offer a mixture of formats - some posting price, some negotiating over price - because of buyer heterogeneity in the skill or cost of bargaining among buyers. Unskilled bargainers will buy from posted price firms - at relatively high prices - and skilled bargainers will buy from those which negotiate. See, for example, Arnold and Lippman (1998) and Desai and Purohit (2004).

pro-competitive benefit from posting prices in that it reduces consumer search costs. Second, a reduction in search costs will generally mean its optimal for consumers to engage in more search. Thus, even each firm's price is unchanged with posted pricing (compared to the preceding pricing institution), conducting more search means a consumer will find a better deal because the minimum observed price will, on average. Third, competing firms may be inclined to price lower in response to the anticipation that consumers will search more, in which case consumers again benefit.[20]

If firms are not colluding, they too can benefit from the reduction in consumer search costs brought about by posted pricing. By making it easier for consumers to search, more consumers are attracted to the market because they anticipate finding a better deal. Firms can then benefit from larger demand. This effect potentially provides a rationale for firms to adopt posted pricing which is predicated on reducing market frictions, rather than facilitating collusion.

Posted pricing can also act to reduce firm selling costs. Consider again the case of auto retailing. If price is to be determined through buyer-seller bargaining then a sales representative needs to be skilled in the art of negotiation. But when there is posted pricing - as occurs through the use of such web sites as Autobytel.com - an auto dealer's sales representative does not negotiate price, though must still sell the merits of the car and the dealership. For the firm, posted pricing reduces training expenditure, lowers the wages they have to pay to attract skilled sales representatives, and results in more transactions per employee as each transaction takes less time since there is no negotiation over price. Firms directly benefit from these lower selling costs. Consumers may also benefit if these lower selling costs translate into lower prices. As with lower consumer search costs, lower selling costs provide a pro-competitive benefit and a rationale for firms to adopt posted pricing apart from aiding collusion.

As the preceding discussion suggests, there are clearly some markets - perhaps most markets - for which the savings in consumer search and firm selling costs from posting prices are likely to be significant, and thereby deliver pro-competitive benefits and provide a legitimate basis for this practice. Most retail markets in developed countries have naturally evolved to having posted pricing, presumably for these reasons. The point seems obvious and not worth belaboring.

What I want to claim is that there are also markets for which the reduction in consumer search and firm selling costs from posted pricing - as opposed to transaction-specific pricing - are likely to be trivial, and thus do not provide a pro-competitive benefit nor a competitive rationale for firms setting list prices with a no discounting policy. One such example is the market for turbine generators, which was previously discussed. It is reasonable to presume that a purchasing agent for an electric power company would receive a price quote from both GE and Westinghouse, whether those suppliers post prices or a purchasing agent must go through a series of price negotiations with employees of GE and Westinghouse. The expenditure associated with the product is sufficiently large to warrant investing the time to get a price

[20] See, for example, Anderson and Renault (1999) who find that prices fall when search costs are lower. In that paper - and related ones which endogenize price in a market with search costs - the pricing institution is kept fixed (which happens to be posted pricing) and an exogenous search cost is changed.

quote. In that case, consumers will have the same information irrespective of the pricing format used by sellers. Furthermore, any savings in search costs are small relative to the expenditure involved and thus are not a first-order effect. From the suppliers' perspective, there is still a need for a well-trained sales force even with posted pricing. Though there is no price negotiation, there are many non-price traits to sell a customer on, including product features, quality, warranty, delivery time, and after-sales support. Again, the savings in time and training from posting prices are likely to be minimal. It would then seem that this market is one for which posted pricing would generate little in terms of savings in consumer search and firm selling costs.

Moving beyond examples, it is useful to identify those factors which determine the extent of savings in consumer search and firm selling costs from the adoption of posted pricing. First, the fewer suppliers there are, the more likely that a consumer will learn all suppliers' prices whether or not firms engage in posted pricing, in which case pro-competitive benefits from posted pricing are less. Second, the larger expenditure associated with the product (whether due to a high price per unit or high volume), the more attractive is it to engage in intense search regardless of the firms' pricing format in that the expected benefit from a lower price is likely to be large relative to the search costs. Third, the more differentiated and less-standardized the product, the more valuable it is for firms to have a well-trained skilled sales force, even if they post prices. Fourth, the more frequent the purchase, the more that consumers and firms will, through experience, reduce negotiation costs so that less is saved with posted pricing. For example, a purchasing agent who buys an input every quarter will have smaller consumer search cost savings from posted pricing than a consumer who buys an electronic product every few years. In sum, savings in consumer search and firm selling costs are likely to be lowest when consumers are industrial buyers making large frequent purchases of a non-standardized product from a limited set of suppliers. In contrast, markets involving standardized low expenditure products with many suppliers are likely to have significant pro-competitive benefits from posted pricing because of the reduction in consumer search and firm selling costs. While the redeeming feature of lower consumer search and firm selling costs from posting price is then apt to be quite ubiquitous in retail markets, they may be of much less relevance when customers are industrial buyers.

Let us hereon consider markets for which the savings in consumer search and firm selling costs are minimal, which leaves two effects to be evaluated. First, posted pricing reduces the responsiveness of price to cost and demand conditions. By setting a list price for some period of time and not offering discounts, price is less sensitive to changes in input prices, customer characteristics, capacity constraints, and the like. Second, posted pricing affects the manner in which firms compete. A firm is likely to end up charging a different price if its rivals are posting price compared to when they are setting transaction-specific prices. The direction of that effect is not obvious and thus requires formal analysis.

3 General Model

Consider a duopoly setting in which, in each period, there is one unit of demand. Firm i's cost to supplying this unit - denoted c_i - is drawn from $[\underline{c}, \overline{c}]$ according to cdf F. F is twice continuously differentiable with positive density on $(\underline{c}, \overline{c})$ and mean μ. Assume firms' costs are independent across firms and time. Cost could vary over time because of changes in input prices or customer heterogeneity along with the identity of the consumer changing from period to period.

Prior to choosing its price, a firm makes a longer-run decision regarding its pricing format. It can have one of two formats which we refer to as *posted price* and *quoted price*. As with GE's price book, the idea of a posted price is that it is fixed over some extended length of time. In the context of our model, this means that price is chosen prior to learning the cost for the current period's demand. For example, the price book or multiplier may be adjusted annually, while there is a customer arriving each week. In contrast, a quoted price format means that price is consumer-specific, and thus is set after a firm learns its cost for the current period's customer. What is critical is that a firm's price under the quoted price format is more sensitive to the cost of serving a particular customer at a particular point in time than the posted price format.

The extensive form is as follows:

Price Format Subgame: Firms simultaneously choose between the posted price and quoted price formats.

Price Subgame: .

Stage 1: If a firm chose the posted price format then it chooses its price.

Stage 2: Firms realize their costs. Costs are private information.

Stage 3: If a firm chose the quoted price format then it chooses its price knowing its cost and, when the other firm chose the posted price format, the other firm's price as well. If both firms chose the quoted price format then they simultaneously choose price, each knowing only its own cost.

If both firms chose the posted price format then they make simultaneous price decisions based on their prior beliefs on costs. If they both chose the quoted price format then they make simultaneous price decisions given each firm knows only its own cost, which is exactly the informational setting in Spulber (1995). Finally, if, say, firm 1 posts price and firm 2 quotes price then firm 1 chooses price as a first-mover (given its prior beliefs on firms' costs) and firm 2 chooses its price after learning its cost and firm 1's price. Consistent with the case of low consumer search costs, it is assumed that consumers observe both firms' prices, regardless of the price format used.

The solution concept is perfect Bayes-Nash equilibrium. For each of the four price subgames - both have the posted price format, both have the quoted price format,

and they have mixed formats - we solve for a Bayes-Nash equilibrium. The price format game is then the simple 2×2 game:

Price Format Subgame

		Firm 2	
		Posted Price	*Quoted Price*
Firm 1	*Posted Price*	π^{PP}, π^{PP}	π^{PQ}, π^{QP}
	Quoted Price	π^{QP}, π^{PQ}	π^{QQ}, π^{QQ}

where π^{RS} is the equilibrium expected profit earned by a firm that chose format $R \in \{P, Q\}$ and its rival chose format $S \in \{P, Q\}$, where P denotes posted price and Q denotes quoted price. Let p^{RS} be the associated equilibrium price. If there is an equilibrium for each of the price subgames - so that the payoffs in the Price Format Subgame are defined - then there will be a perfect Bayes-Nash equilibrium as follows:

- If $\pi^{PP} \geq \pi^{QP}$ then both having posted prices is an equilibrium outcome.
- If $\pi^{QQ} \geq \pi^{PQ}$ then both having quoted prices is an equilibrium outcome.
- If $\pi^{PP} \leq \pi^{QP}$ and $\pi^{QQ} \leq \pi^{PQ}$ then one firm having posted prices and the other firm having quoted prices is an equilibrium outcome.

The one remaining element to model is the determination of which firm ends up selling to the current period's customer. In Section 4.1, it is assumed the firms' products are identical in which case the firm with the lower price sells with probability one. In Section 4.2, we allow for differentiated products by assuming the probability of selling depends continuously on the price difference and is decreasing in the amount by which a firm's price exceeds its rival's price.

Before moving on to the analysis, it is worth discussing this set-up when firms' costs are deterministic and common knowledge. Under that assumption, the game is the standard two-period endogenous move game which has been analyzed many times before (see, for example, Amir and Stepanova, 2006, and references cited therein). Each firm decides whether to set its price in period 1 (corresponding to posting price in our model) - in which case it is a price leader if the other firm chose to price in period 2 - or in period 2 (corresponding to quoting price in our model) - in which case it is a price follower if the other firm chose to price in period 1. If both firms chose to price in the same period then it is a simultaneous-move price game. With firms choosing prices, their decision variables are strategic complements and thus there is an advantage to being a second mover. Equilibrium is characterized by one firm pricing in period 1 and the other firm pricing in period 2. Intuitively, the first-mover prices above the Nash equilibrium price for the simultaneous-move game so as to induce the second-mover to price higher, given that the latter's best reply function is increasing in its rival's price. This benefits both firms relative to when there is no price leader.

Thus, without cost variability, it is not an equilibrium for firms to set prices simultaneously and thus not an equilibrium for both to post prices. With cost variability

- as is presence in our model - there is an additional benefit to quoting price (that is, moving second) in that a firm's price can be responsive to its cost. This certainly suggests that we should not find it to be an equilibrium for both firms to post prices and that it may even be the case that equilibrium involves both firms quoting price, with no firm taking the role of price leader. Why this result is not immediate - and, in fact, it'll take some structure to deliver it - is that, from the perspective of a posted price firm, its rival's price is now stochastic (being driven by its stochastic cost) when its rival moves second by quoting price. This significantly complicates the analysis in comparing pricing incentives when posting and quoting price, given the other firm quotes price. However, by putting plausible structure on demand, we can show that this complication does not disturb the pricing incentives in the deterministic cost case and thus it will be inconsistent with equilibrium for both firms to post prices.

4 Economic Analysis

The economic analysis considers the endogenous choice of the pricing format, with each firm deciding between having a fixed price (posted price) and a transaction-specific price (quoted price), while assuming consumer search and firm selling costs are small. When firms have homogeneous products, I show that it is strictly more profitable for a firm to use the quoted price format than the posted price format, regardless of its rival's format. This implies that any firm posting price is inconsistent with competition. When firms have differentiated products, it is shown that the industry-wide adoption of posted pricing is inconsistent with competition. In sum, the parallel adoption of posted pricing is not in a firm's best interests, unless it leads to firms coordinating their prices.

4.1 Homogeneous Products

The existence and characterization of perfect Bayes-Nash equilibria for when products are homogeneous can easily be shown by pulling together existing results in the literature. Specifically, we draw heavily upon Spulber (1995) and Arozamena and Weinschelbaum (2009); both of whom draw upon Maskin and Riley (1984) for existence of equilibrium when both firms have the quoted price format. In Section 4.1.1 we solve for equilibrium in prices for each of the three possible price format subgames: both firms post price, both firms quote prices, and firms have different formats. With those equilibrium payoffs, the price format subgame is then solved in Section 4.1.2.

4.1.1 Price Subgames

- Both firms have the posted price format

Consider the case when both firms post prices. As there is no private information - each firm chooses its price prior to learning its cost - this is the classical Bertrand price game except that expected cost, μ, replaces deterministic cost. Thus, firm 1's

expected profit is:

$$\pi_1^{PP}(p_1, p_2) = \begin{cases} p_1 - \mu & \text{if } p_1 < p_2 \\ \left(\frac{1}{2}\right)(p_1 - \mu) & \text{if } p_1 = p_2 \\ 0 & \text{if } p_1 > p_2 \end{cases}$$

The unique Nash equilibrium has each set price equal to expected cost - $p^{PP} = \mu$ - and earn zero expected profit.

- Both firms have the quoted price format

Suppose both firms quote prices. The price subgame is exactly as analyzed in Spulber (1995) except that we assume unit demand, while there it is assumed market demand is strictly decreasing in price. In Proposition 2, Spulber (1995) establishes the existence of a unique symmetric Bayes-Nash equilibrium, and that a firm's equilibrium price is strictly increasing in its cost. As straightforward inspection reveals that the proof of Proposition 2 also works with unit demand, this result applies here as well.

Letting $\phi : [\underline{c}, \overline{c}] \to \Re_+$ denote the symmetric equilibrium price function, it is defined by

$$\phi(c) = \arg\max (p - c)\left[1 - F\left(\phi^{-1}(p)\right)\right], \ \forall c \in [\underline{c}, \overline{c}]. \tag{1}$$

Given, say, firm 2 uses ϕ, if firm 1 charges a price of p_1, it has the lowest price - and sells to the customer - if and only if $\phi(c_2) > p_1$. Since ϕ is strictly increasing, this condition is equivalent to $c_2 > \phi^{-1}(p_1)$ and, therefore, the probability that firm 1 sells is $1 - F\left(\phi^{-1}(p_1)\right)$, as stated in (1). The first-order condition (FOC) is:

$$\begin{aligned} 1 - F\left(\phi^{-1}(p)\right) - (p - c) F'\left(\phi^{-1}(p)\right)\left(\frac{\partial \phi^{-1}(p)}{\partial p}\right) &= 0 \\ 1 - F\left(\phi^{-1}(\phi(c))\right) - (\phi(c) - c) F'\left(\phi^{-1}(\phi(c))\right)\left(\frac{\partial \phi^{-1}(\phi(c))}{\partial p}\right) &= 0 \\ 1 - F(c) - (\phi(c) - c) F'(c)\left(\frac{1}{\phi'(c)}\right) &= 0 \end{aligned}$$

ϕ is then the unique solution to the differential equation,

$$\phi(c) - c = \phi'(c)\left(\frac{1 - F(c)}{F'(c)}\right) \tag{2}$$

with boundary condition $\phi(\overline{c}) = \overline{c}$. Since $\phi' > 0$ then (2) implies $\phi(c) > c \ \forall c < \overline{c}$. Firms then have positive expected profit when they have the quoted price format:

$$\int (\phi(c) - c)[1 - F(c)] F'(c)\, dc > 0.$$

- Mix of posted price and quoted price formats

Suppose firm 1 chose the posted price format and firm 2 chose the quoted price format. Firm 1's strategy is then simply a price - as it chooses its price before learning its cost - while firm 2's strategy maps the space of cost levels for firm 2 and price levels for firm 1 into its own price space.

Let us first solve for firm 2's equilibrium strategy. If $p_1 > c_2$ then firm 2 sets a price just below p_1 and sells with probability one. If we assume that ties go to the firm with the quoted price format then firm 2's equilibrium price is p_1 when $p_1 > c_2$. If $p_1 \leq c_2$, then firm 2 prices at or above its cost and firm 1 sells with probability one. Thus, firm 2's equilibrium strategy can be stated as:

$$\psi_2^{PQ}(p_1, c_2) = \begin{cases} p_1 & \text{if } p_1 > c_2 \\ c_2 & \text{if } p_1 \leq c_2 \end{cases}$$

As firm 1 sells if and only if its price is less than firm 2's cost, its optimization problem is

$$\max_{p_1} \int (p_1 - c_1)\left[1 - F(p_1)\right] F'(c_1)\, dc_1 = \max_{p_1} (p_1 - \mu)\left[1 - F(p_1)\right],$$

which has a unique solution if $F'' \geq 0$ or F'' is not too negative.

4.1.2 Price Format Subgame

In characterizing what happens when firms are choosing a price format, let us begin by comparing a firm's profit between the two price formats, given its rival chooses the quoted price format. The ensuing analysis uses results from Arozamena and Weinschelbaum (2009).

For when firm 1 posts price, it was shown above that firm 1 sells if and only if its price is less than firm 2's cost; in other words, it is "as if" firm 2 is pricing at its cost. Firm 1's expected profit is then

$$(p_1 - \mu)\left[1 - F(p_1)\right]. \tag{3}$$

For the same price for firm 1, now consider expected profit if it quotes price (once again assuming firm 2 quotes price):

$$\int (p_1 - c_1)\left[1 - F\left(\phi^{-1}(p_1)\right)\right] F'(c_1)\, dc_1 = (p_1 - \mu)\left[1 - F\left(\phi^{-1}(p_1)\right)\right]. \tag{4}$$

Since $\phi^{-1}(p) < p$ - that is, the cost for which firm 2 prices at p (with the quoted price format) is less than p - then

$$1 - F\left(\phi^{-1}(p_1)\right) > 1 - F(p_1).$$

Hence, for any p_1, (4) exceeds (3) and therefore, expected profit is higher when firm 1 chooses the quoted price format, given firm 2 chose the quoted price format. This result comes from firm 2 pricing less aggressively when firm 1 also quotes price compared to when it posts price. Thus, if firm 1 were to choose the same price under the quoted price format as it would have chosen under the posted price format, its

expected profit will be higher because firm 2 doesn't price as low. In addition, with the quoted price format, firm 1 is able to adjust its price to its cost, in which case expected profit is then even higher. In sum, $\pi^{QQ} > \pi^{PQ}$.

When products are homogeneous, the price format subgame is then:

Price Format Subgame

		Firm 2	
		Posted Price	*Quoted Price*
Firm 1	*Posted Price*	$0, 0$	π^{PQ}, π^{QP}
	Quoted Price	π^{QP}, π^{PQ}	π^{QQ}, π^{QQ}

where $\pi^{QQ} > \pi^{PQ}$ and $\pi^{QP} > 0$. Thus, quoting price strictly dominates posting price and, therefore, perfect Bayes-Nash equilibrium implies that both firms have the quoted price format. Intuitively, a firm gains a tremendous advantage by quoting price when its rival posts price as it can simply undercut the posted price and make a sale for sure. Thus, a firm surely want to quotes price when its rival posts price. It also means that if the other firm quotes price, a firm is at a great disadvantage if it posts price.

Theorem 1 *If products are homogeneous then both firms choose the quoted price format at a perfect Bayes-Nash equilibrium.*

4.2 Differentiated Products

In this section, I consider when firms' products are differentiated so that a firm has a positive probability of making a sale even when its price is higher than its rival. Let us continue to assume there is one customer per period who buys from either firm 1 or firm 2. The stochastic process describing the consumer's purchase decision is assumed to depend only on the price difference. Let $\beta(\Delta) : \Re \to [0, 1]$ denote the probability that a firm sells when the difference between its rival's price and its own price is Δ. For example, suppose the quality differential between firm 2 and firm 1 is the random variable ν with cdf H, and a consumer buys from firm 1 iff $\nu < p_2 - p_1$; then $\beta(\Delta) = H(\Delta)$. The following assumptions are made.

A1 $\beta(\Delta) + \beta(-\Delta) = 1$, $\forall \Delta \in \Re$.

A2 $\beta(\cdot)$ is twice continuously differentiable.

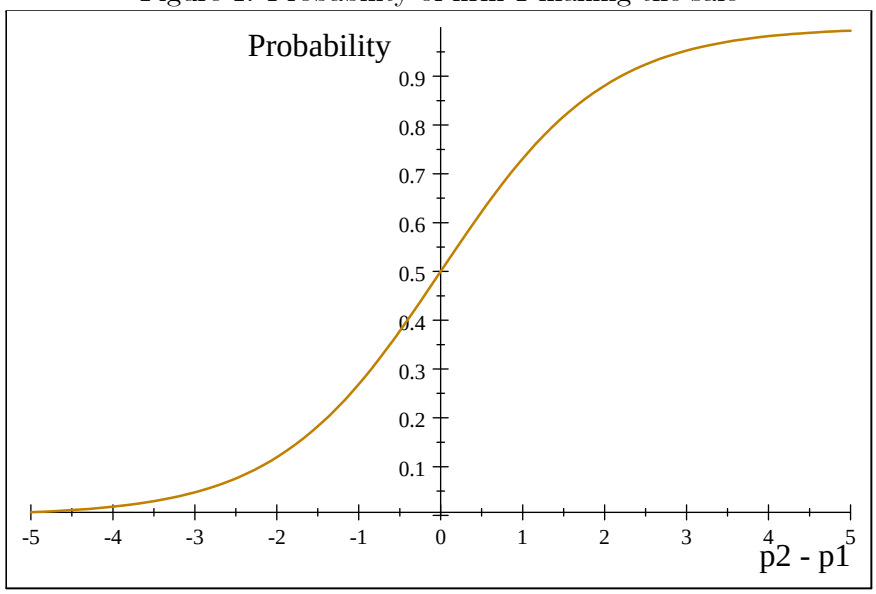
A3 $\beta'(\Delta) > 0$, $\forall \Delta \in \Re$.

A4 $\beta''(\Delta) \geq 0$ if $\Delta \leq 0$, $\beta''(0) = 0$, and $\beta''(\Delta) \leq 0$ if $\Delta \geq 0$.

A1 states that a consumer buys from either firm 1 or firm 2, and implies $\beta(0) = 1/2$. A3 has the natural property that a lower price by a firm raises its probability of making the sale. By A4, β is weakly convex then weakly concave with the inflection point at $\Delta = 0$. It follows from A3 and A4 that the probability of purchase is most sensitive to the price difference when firms have identical prices: $\beta'(0) \geq \beta'(\Delta), \forall \Delta$.

An example satisfying A1-A4 is the logistic, $\beta(\Delta) = 1/\left(1 + e^{-\Delta}\right)$, which is shown in Figure 1. Also, it'll simplify proofs if it is assumed the density function on a firm's cost, F', is symmetric around its mean μ.

Figure 1: Probability of firm 1 making the sale



Suppose both firms have the posted price format. A symmetric equilibrium price is defined by:

$$p^{PP} \in \arg\max (p - \mu)\, \beta\left(p^{PP} - p\right).$$

Assume the FOC is sufficient for an optimum:

$$\beta(0) - \left(p^{PP} - \mu\right)\beta'(0) = 0 \Rightarrow p^{PP} = \mu + \frac{\beta(0)}{\beta'(0)} = \mu + \frac{1}{2\beta'(0)}.$$

The second-order condition (SOC) for firm 1 is:

$$-2\beta'(p_2 - p_1) + (p_2 - \mu)\,\beta''(p_2 - p_1) < 0.$$

Note that it holds in equilibrium as firms charge identical prices and $\beta''(0) = 0$. Furthermore, it holds if β is close to linear over the relevant domain (that is, price differences pertinent to determining whether a price pair is an equilibrium).

Next consider when firm 1 posts price and firm 2 quotes price. Define $\psi_2^{PQ}(p_1, c_2)$ as firm 2's best reply function given firm 1's price and firm 2's cost.

$$\psi_2^{PQ}(p_1, c_2) \in \arg\max (p - c_2)\left[1 - \beta(p - p_1)\right].$$

The FOC is:

$$1 - \beta\left(\psi_2^{PQ}(p_1, c_2) - p_1\right) - \left(\psi_2^{PQ}(p_1, c_2) - c_2\right)\beta'\left(\psi_2^{PQ}(p_1, c_2) - p_1\right) = 0. \qquad (5)$$

The SOC is

$$-2\beta'(p_2-p_1)-(p_2-c_2)\beta''(p_2-p_1)<0,$$

and again is satisfied when β is close to linear. Take the total derivative of (5) with respect to p_1 to derive $\partial\psi_2^{PQ}(p_1,c_2)/\partial p_1$:

$$\frac{\partial\psi_2^{PQ}(p_1,c_2)}{\partial p_1}=\frac{\beta'\left(\psi_2^{PQ}(p_1,c_2)-p_1\right)+\left(\psi_2^{PQ}(p_1,c_2)-c_2\right)\beta''\left(\psi_2^{PQ}(p_1,c_2)-p_1\right)}{2\beta'\left(\psi_2^{PQ}(p_1,c_2)-p_1\right)+\left(\psi_2^{PQ}(p_1,c_2)-c_2\right)\beta''\left(\psi_2^{PQ}(p_1,c_2)-p_1\right)}.$$

To ensure

$$\frac{\partial\psi_2^{PQ}(p_1,c_2)}{\partial p_1}>0,$$

it is assumed

$$\beta'\left(\psi_2^{PQ}(p_1,c_2)-p_1\right)+\left(\psi_2^{PQ}(p_1,c_2)-c_2\right)\beta''\left(\psi_2^{PQ}(p_1,c_2)-p_1\right)>0. \tag{6}$$

Note that it implies

$$\frac{\partial\psi_2^{PQ}(p_1,c_2)}{\partial p_1}\in(0,1).$$

(6) can also be shown to imply that firm 2's optimal price is increasing in its cost:

$$\frac{\partial\psi_2^{PQ}(p_1,c_2)}{\partial c_2}>0.$$

A sufficient condition for (6) to hold is that $\beta(\cdot)$ is not too far from being linear over the relevant price range.

Given firm 2's best reply function, consider firm 1's problem in the PQ-subgame:

$$p_1^{PQ}\in\arg\max\int_{\underline{c}}^{\overline{c}}(p_1-\mu)\beta\left(\psi_2^{PQ}(p_1,c_2)-p_1\right)F'(c_2)\,dc_2.$$

We want to show that, in equilibrium, firm 1's posted price is higher when firm 2 quotes price compared to when firm 2 posts price: $p_1^{PQ}>p^{PP}$. If that is the case then firm 2's expected profit is higher with the quoted price format - that is, $\pi_2^{PQ}>\pi^{PP}$ - since its expected profit is increasing in its rival's posted price. Furthermore, firm 2 benefits from the quoted price format by being able to adjust its price to its cost. From this result we'll conclude that both firms choosing a posted price format is not part of a perfect Bayes-Nash equilibrium. The proof of the following lemma is in the appendix.

Lemma 2 *If (6) holds then* $p_1^{PQ}>p^{PP}$.

Finally, we can use Lemma 2 to show that, given firm 1 has the posted price format, firm 2's expected profit is higher when it chooses the quoted price format. Note that firm 2's expected profit from the posted price format and price p_2 is

$$(p_2-\mu)\left[1-\beta\left(p_2-p^{PP}\right)\right].$$

From choosing the quoted price format and price p_2, it is

$$(p_2 - \mu)\left[1 - \beta\left(p_2 - p_1^{PQ}\right)\right].$$

The latter exceeds the former because $p_1^{PQ} > p^{PP}$. Under the quoted price format, firm 2's expected profit is actually even higher as it can condition its price on its cost, in which case expected profit is

$$\int \max_{p_2} (p_2 - c_2)\left[1 - \beta\left(p_2 - p_1^{PQ}\right)\right] F'(c_2)\, dc_2.$$

Theorem 3 *Both firms having the posted price format is inconsistent with perfect Bayes-Nash equilibrium.*

4.3 Case of Buyer-Seller Negotiation

The main finding of the economic analysis is that all firms choosing the posted price format is inconsistent with competition when the savings in consumer search costs and firm selling costs are small. In deriving this result, it was assumed that the alternative to posting price is making a customer-specific fixed price offer. A different alternative is for the seller and buyer to negotiate. This raises the question of whether posted pricing is inconsistent with equilibrium if firms had to choose between negotiation and the posted price format. As we argue below, our results are robust to that alteration when products are homogeneous, but the question remains open for the case of differentiated products.

Consider when firms offer identical products. As shown in Section 4.1, if both firms have the posted price format then each will earn zero expected profit. Now suppose a seller negotiated with buyers. As long as negotiation does not always give all of the surplus to the buyer - for example, the firm with the lower cost in the current period is bargained down to a price below the higher cost firm but not all the way down to its own cost - then expected profit is positive to a firm who chooses a negotiation format, regardless of the pricing format chose by its rival. Thus, it is not an equilibrium for both firms to choose the posted price format even when the alternative is negotiating with buyers.

With the case of differentiated products, there is no such immediate proof because firms earn positive profit under the posted price format. The determination of the robustness of Theorem 3 to introducing buyer-seller negotiation is left to future research. There is also some reason to think that the result may not be robust; that is, a firm may prefer the posted price format to buyer-seller negotiation. For the case of a monopoly, it has been shown that offering a fixed price to all buyers yields higher expected profit than negotiating with buyers and engaging in price discrimination (Riley and Zeckhauser, 1983). Of course, just because it is optimal for a monopolist to post price, it does not follow that it is optimal for a duopolist to do so. Indeed, that is not the case when firms have homogeneous products, as argued above.

5 Legal Analysis

There are three steps to the analysis in this section. First, I review the legal argument that an agreement can be inferred without express communication if it can be shown that firms communicate their intent to raise prices and their reliance on each other to do the same. This communication is a plus factor that establishes concerted action. Second, it is argued that such communication of intent and reliance is achieved when each firm takes an action that is only in its best interests if it would subsequently lead to coordinated pricing. Third, using the economic analysis of Section 4, this legal argument is used to conclude that, under certain circumstances, the parallel adoption of posted pricing meets the standard laid out in the second step and thereby is a violation of Section 1 of the Sherman Act.

The starting point to our analysis is the lack of evidence that firms have engaged in express communication regarding an agreement. The challenge is then finding plus factors that allow one to dismiss observed behavior as conscious parallelism.

> The lower courts and, now, Twombly have made clear that when firms coordinate their actions by conscious parallelism they act independently as a matter of law. The plaintiff must thus produce a "plus factor," that is, some evidence that is not only consistent with agreement, but also inconsistent with independent or merely interdependent conduct.[21]

Useful for identifying plus factors is considering what is sufficient to conclude that firms have engaged in concerted action. Under the principle of concerted action, firms, while not expressly engaging in an agreement, do, in some manner, communicate a plan and then follow through with it. Applying the work of Black (2005), William Page argues:

> [F]irms' actions become concerted when the firms have achieved the conditions of conscious parallelism by communication of their intent to raise prices and their reliance on one another to do the same. Crucially, the rivals need not have exchanged promises of assurances of their actions; it is enough that they have communicated their intent to act and their reliance on others to do so. ... Communication of intent and reliance is a tangible, culpable action that differs from the actions of firms in an ordinary competition or in a simple conscious parallelism. The character of the communications and their proximity to parallel action in conformity with the communications distinguish them from other, benign exchanges.[22]

A plus factor can then be a practice that communicates the intent and reliance among firms to coordinate pricing. Towards identifying such plus factors, let us review how express communication achieves intent and reliance. Suppose a firm is aware of

[21] Page (2009b), p. 445.
[22] Page (2009b), pp. 451, 452.

how supracompetitive pricing results from conscious parallelism, as is described in any industrial organization textbook. If a firm proposes to its rival that they price in the described manner of conscious parallelism and the rival accepts this invitation then, in fact, they are not engaging in conscious parallelism for there is an agreement. The literal interpretation of their expressions leads to the mutual understanding that we think of as an agreement because a firm finds it in its best interests to do as it has expressed as long as it is believed by the other firm. In other words, this communication produces an agreement because the words have meaning as to what firms intend to do. A firm proposes to coordinate pricing because it believes that if the other firm accepts this proposal then said coordinated pricing will ensue. Similarly, the other firm accepts this proposal because it believes that, by doing so, coordinated pricing will ensue.

Now suppose there is an action that would be in a firm's best interests to take only if it believed it would subsequently lead to coordinated pricing. Furthermore, it is in the best interests of a rival firm to respond by taking the same action only if it believed it would result in coordinated pricing. Just as the verbal invitation to coordinate prices is made because its acceptance is expected to result in coordinated pricing, a firm takes this action because the other firm's similar response is expected to result in coordinated pricing. Whether it is the spoken word or the implemented action, each is made with the anticipation that firms will coordinate their prices. Of course, whether they succeed or not is a distinct manner. What is essential is that firms anticipate coordinated pricing when making a verbal proposal to do so or taking an action that is in a firm's best interests only if it resulted in coordinated pricing.

In a related manner, Richard Posner has proposed that conscious parallelism can, in some instances, be thought as a contractual arrangement and thus warrant prosecution (though he also recognizes that this approach is not consistent with current judicial practice).

> [O]ne seller communicates his "offer" by restricting output, and the offer is "accepted" by the actions of this rivals in restricting their outputs as well. It may therefore be appropriate in some cases to instruct a jury to find an agreement to fix prices if it is satisfied that there was a tacit meeting of the minds of the defendants on maintaining a noncompetitive pricing policy. ... What is being proposed is less the alteration of the substantive contours of the law than a change in evidentiary requirements to permit illegal price fixing to be found in circumstances in which an actual meeting of the minds on a noncompetitive price can be inferred even though explicit collusion cannot be proved.[23]

As a member of the Seventh Circuit Court, Judge Posner also articulated this view in High Fructose Corn Syrup (2002).

> Section 1 of the Sherman Act forbids contracts, combinations, or conspiracies in restraint of trade. This statutory language is broad enough,

[23] Posner (2001), pp. 94-95, 98.

> as we noted in *JTC Petroleum Co. v. Piasa Motor Fuels, Inc.*, 190 F.3d 775, 780 (7th Cir. 1999), to encompass a purely tacit agreement to fix prices, that is, an agreement made without any actual communication among the parties to the agreement. If a firm raises price in the expectation that its competitors will do likewise, and they do, the firm's behavior can be conceptualized as the offer of a unilateral contract that the offerees accept by raising their prices.[24]

At least as described, Posner's example is problematic because the inference of an agreement to coordinate pricing is just one of several that can be drawn. A firm raising its price and the other firm responding in kind could just as well as reflect competitive pricing in response to a rise in cost or demand. Either of those factors would induce the first firm to raise price, while a competitive response by its rival would be to also raise price. If there are several reasonable inferences that can be drawn from these actions then one has failed to "exclude the possibility of independent action" in which case an agreement cannot be inferred. The approach I am deploying is more stringent in that it requires that the *only* reasonable inference is that firms plan to coordinate pricing because firms' actions are consistent with their best interests *only if* coordinated pricing ensues. It is worth noting that an attractive feature of this approach is that drawing an inference of conspiracy from these actions will not deter legitimate behavior since a requirement for drawing such an inference is that there is no legitimate rationale for these actions.[25]

I now turn to applying this approach to when posted pricing is the practice in question.

Recommendation: An agreement is inferred when:

1) Prior to the adoption of posted pricing, firms routinely sold at prices below any publicly announced list price.

2) The adoption of posted prices is consistent with a firm's best interests only if it anticipates that firms will subsequently coordinate their pricing.

3) Following the adoption of posted prices, prices are higher and more uniform across firms.

4) The market is characterized by conditions (number of firms, entry barriers, etc.) that make collusion (as defined by economists) feasible.

(2) provides communication of intent and reliance, as has been argued. By the analysis in Section 4, we know that (2) is not vacuous for, when the savings in consumer search and firm selling costs from a firm posting price are minimal, it is

[24] *In Re High Fructose Corn Syrup Antitrust Litigation Appeal of A & W Bottling Inc et al*, United States Court of Appeals, Seventh Circuit, 295 F3d 651, 2002.

[25] "[T]he question remains whether permitting an inference of conspiracy from the fact of such publication would significantly deter important legitimate conduct." *In re* Coordinated Pretrial Proceedings in Petroleum Prods. Antitrust Litig., 906 F.2d 432 (9th Cir. 1990).

not profitable for firms to post prices if they anticipate pricing competitively; only if posted pricing can assist in coordinated pricing is such behavior optimal. However, let us remind the reader of the caveat discussed in Section 4.3 and the need for additional economic analysis.

(1) provides context to enhance the clarity of the communication in (2), the relevance of which was noted in Esco (1965).

> [I]t remains a question for the trier of fact to consider and determine what inference appeals to it (the jury) as most logical and persuasive, after it has heard all the evidence as to what these competitors had done before such meeting, and what actions they took thereafter, or what actions they did not take.[26]

When its rivals are expected to engage in discounting, it is clearly against a firm's interests to fix its price at some publicly announced level, as doing so makes it exceedingly easy for rivals to undercut the firm's price and capture sales. Thus, if it has been common practice to offer discounts off of a list price, the adoption of a fixed publicly announced price can only be in a firm's best interests if it anticipates rivals discontinuing the activity of discounting.

Consistent with the arguments made in Container (1969), (3) and (4) provide evidence that the adoption of posted pricing had the effect of allowing firms to coordinate their prices, and serves to support the theoretical argument that it could only have been done for that purpose. The practice in question in Container (1969) was the repeated private exchange of customer-specific prices among firms. As stated by Justice Fortas:

> Theoretical probability, however, is not enough unless we are to regard mere exchange of current price information as so akin to price-fixing by combination or conspiracy as to deserve the per se classification. I am not prepared to do this, nor it is necessary here. In this case, the probability that the exchange of specific price information led to an unlawful effect upon prices is adequately buttressed by evidence in the record.[27]

If posted pricing successfully facilitated collusion then corroborative evidence is that firms' prices are higher and more strongly correlated (as, for example, was found in the turbine generator market). Finally, as specified in (4), it is important to establish that market conditions are consistent with collusion being stable, according to economic theory and empirical evidence.[28]

I have argued that, under certain conditions, the adoption of posted pricing can provide the requisite communication of intent and reliance to conclude concerted action among firms. One critique is that the communication is not private among firms, and public messages are too ambiguous to provide what is necessary to lead to mutual understanding among firms.

[26] *Esco Corp. v. United States* 340 F.2d 1000 (9th Cir. 1965).

[27] United States v. Container Corporation of America, 393 US 333 (1969).

[28] For a summary of these conditions, see Motta (2004).

> [C]oncerted action under Section 1 of the Sherman requires, beyond evidence of parallel conduct, evidence that rivals have communicated their intentions to act in a certain way and their reliance on each other to follow suit. To convey the requisite information, the communication must ordinarily be private and repeated, and must relate to present or future prices. These considerations apply in the case of facilitating practices as well. In the rural gas station hypothetical, for example, coordination of prices would be more difficult if the stations did not post their prices on signs as well as at the pump. Thus, public price posting is literally a facilitating practice that involves price communication. But courts would certainly not find that posting prices on signs amounted to a plus factor, because it also has the legitimate purpose of informing consumers of rivals' prices. Public "signaling" and "monitoring" of prices are too ambiguous in their effects to amount to plus factors, because they cannot convey the necessary intent and reliance.[29]

While these are valid points regarding the *potential* ambiguity of public signals, the heart of the matter is not whether signals are public or private but rather whether the signal's content is clear. When a signal is meaningful to different agents and for different reasons, there is ambiguity as to what is a firm's intent in sending it. But not all public signals suffer from such a lack of clarity. That publicly announced prices could lead to an inference of conspiracy was recognized as a possibility in Petroleum Products (1990).

> [T]he tankwagon prices or dealer discounts are not of immediate significance to anyone other than the oil companies and their franchised dealers. ... [T]he dealers were individually notified concerning any changes in the tankwagon prices or in the level of dealer discount. In light of this fact, it appears that the public dissemination of such information served little purpose other than to facilitate interdependent or collusive price coordination. ... [W]e believe that the evidence concerning the purpose and effect of price announcements, when considered together with the evidence concerning the parallel price restorations, is sufficient to support a reasonable and permissible inference of an agreement, whether express or tacit, to raise or stabilize prices.[30]

The Ninth Circuit Court was making the point that, because the public announcement of prices was of value only to sellers, it was not to be treated differently from a private announcement among sellers. This is quite analogous to the preceding argument made with respect to posted pricing. While a policy of publicly announcing fixed prices *could* be of value to buyers, in some instances it is not (specifically, where consumer search costs are low) and, in those cases, a firm's public announcement of

[29] Page (2010), pp. 25-6.

[30] *In re* Coordinated Pretrial Proceedings in Petroleum Prods. Antitrust Litig., 906 F.2d 432 (9th Cir. 1990).

list prices (with a policy of no discounting) is information that is useful only to its rivals.

6 Concluding Remarks

Posted pricing is a common feature of many markets, and may be used to lessen consumer search costs or selling costs incurred by firms. While there are then legitimate reasons for firms to stick to selling at list price, there are also cases - such as the markets for turbine generators and gypsum wallboard - for which posted pricing was implemented for the purpose of coordinating firms' prices. One objective of this paper was to identify market conditions under which the use of posted pricing is inconsistent with competition. When the adoption of posted pricing has little effect on consumer search costs and firm selling costs, it was shown that the industry-wide adoption of setting a list price with no discounting is contrary to firms' interests when they compete. Therefore, the adoption of posted pricing is optimal for firms only if it results in coordinated pricing. While this finding may be sufficient to convince economists that the adoption of posted pricing is evidence of collusion, it does not, by itself, establish that firms have an agreement to restrain trade. It was then argued that the adoption of posted pricing communicates the necessary intent and reliance to coordinate prices which is required to infer concerted action.

Critical to drawing this inference is the argument that if some practice is only in a firm's best interests when it anticipates coordinated pricing then the adoption of that practice is an invitation to coordinate pricing, and the subsequent adoption of that same practice by a rival firm signals its acceptance of that invitation. From this interpretation, an agreement is inferred. The courts have long recognized that there can be an agreement without express communication but there remains the matter of drawing the line between communication that conveys an agreement and communication for which any such conveyance is ambiguous.

On the "too ambiguous" side of the spectrum is the scenario posed by Posner (2001), whereby a firm raises its price (as an invitation to set supracompetitive prices) and its rival responds in kind (as an acceptance of that invitation). Getting closer to the legal-illegal divide is the public exchange of price intentions. In the Airline Tariff Publishing Company (ATPCO) case, the U.S. Department of Justice argued that airlines were coordinating their prices through a form of riskless price leadership.[31] An airline would announce a fare change with a "future first ticket date" which was the first date at which tickets could be sold at the new fare. The fare change was disseminated by ATPCO to all airlines and consumers through computer reservation systems. With such a mechanism, a price leader who wanted all airlines to raise fares could announce a future price increase and wait to learn whether it was matched by other airlines. If it was, the price change would remain in the system and become active at the first ticket date. If it was not matched then the airline would retract the price change. As transactions could not take place at this new fare until the first ticket date and the airline was not committed to the fare change, these prices were argued to

[31] For details, see Borenstein (1993).

be a means for firms to communicate and coordinate their prices, rather than prices at which to sell seats. The airlines claimed that this information was pro-competitive because consumers benefitted from it. As the matter was resolved with a consent decree prohibited the practice for 10 years, there was no judicial ruling as to whether this practice communicates an agreement. Note that announcing future prices sheds some of the ambiguity of the Posnerian signalling scenario because consumers cannot transact at these prices; they are purely intentions about future prices.

Moving into clearly demarcated illegal territory is the repeated private exchange of price information. In Container (1969),

> ... all that was present was a request by each defendant of its competitor for information as to the most recent price charged or quoted, whenever it needed such information and whenever it was not available for another source. Each defendant on receiving that request usually furnished the data with the expectation that it would be furnished reciprocal information when it wanted it.

The anticipated reciprocity of sharing price information, which would not typically occur under competition, attested to an agreement.[32] In contrast to the Posnerian and ATPCO scenarios, the price exchange was private and thus could not have been beneficial to consumers. This practice then gets closer to the issues raised in this paper in that it is difficult to rationalize sharing price information with rival firms unless it served to coordinate pricing.

[32] However, the Court did not conclude that this information sharing practice was a per se violation, and relied upon evidence of its effect to find a Section 1 violation.

7 Appendix: Proof of Lemma 2

To prove $p_1^{PQ} > p^{PP}$, we'll show $\frac{\partial \pi_1^{PQ}(p_1)}{\partial p_1} > 0, \forall p_1 \leq p^{PP}$ and thus firm 1's optimal price exceeds p^{PP} when it posts price and firm 2 quotes price. A lower bound on $\frac{\partial \pi_1^{PQ}(p_1)}{\partial p_1}$ is derived by evaluating it when $\frac{\partial \psi_2^{PQ}(p_1,c_2)}{\partial p_1}$ is set equal to zero. In that case, the incentive of firm 1 to raise price in order to increase firm 2's price is neutralized. We then show that this lower bound on $\frac{\partial \pi_1^{PQ}(p_1)}{\partial p_1}$ is non-negative and, since in fact $\frac{\partial \psi_2^{PQ}(p_1,c_2)}{\partial p_1} > 0$, it follows that $\frac{\partial \pi_1^{PQ}(p_1)}{\partial p_1} > 0$. In short, reasonable properties on the curvature of $\beta(\cdot)$ preserve the first-mover effect to raise price which holds for the deterministic cost case extends when cost is stochastic.

Take the first derivative of firm 1's expected profit with respect to its price:

$$\begin{aligned} \frac{\partial \pi_1^{PQ}(p_1)}{\partial p_1} &= \int_{\underline{c}}^{\overline{c}} \Big[\beta\left(\psi_2^{PQ}(p_1,c_2) - p_1\right) \\ &\quad - (p_1 - \mu)\,\beta'\left(\psi_2^{PQ}(p_1,c_2) - p_1\right)\left(1 - \frac{\partial \psi_2^{PQ}(p_1,c_2)}{\partial p_1}\right)\Big] F'(c_2)\,dc_2. \end{aligned} \tag{7}$$

Before moving on in the analysis, let us convey why it is non-trivial to show that moving first by posting price results in the firm setting a higher price. Consider (7) evaluated at $p_1 = p^{PP}$:

$$\begin{aligned} \frac{\partial \pi_1^{PQ}(p^{PP})}{\partial p_1} &= \int_{\underline{c}}^{\overline{c}} \Big[\beta\left(\psi_2^{PQ}(p^{PP},c_2) - p^{PP}\right) \\ &\quad - (p^{PP} - \mu)\,\beta'\left(\psi_2^{PQ}(p^{PP},c_2) - p^{PP}\right)\left(1 - \frac{\partial \psi_2^{PQ}(p^{PP},c_2)}{\partial p_1}\right)\Big] F'(c_2)\,dc_2. \end{aligned} \tag{8}$$

If $\pi_1^{PQ}(p_1)$ is well-behaved then we need the preceding expression to be positive for firm 1 to optimally price above p^{PP}. When $c_2 = \mu$, the integrand in (8) is positive since $\psi_2^{PQ}(p^{PP},c_2) = p^{PP}$:

$$\begin{aligned} & \beta\left(\psi_2^{PQ}(p^{PP},\mu) - p^{PP}\right) - (p^{PP} - \mu)\,\beta'\left(\psi_2^{PQ}(p^{PP},\mu) - p^{PP}\right)\left(1 - \frac{\partial \psi_2^{PQ}(p^{PP},\mu)}{\partial p_1}\right) \\ = \;& \beta(0) - (p^{PP} - \mu)\,\beta'(0)\left(1 - \frac{\partial \psi_2^{PQ}(p^{PP},\mu)}{\partial p_1}\right) \\ = \;& \beta(0) - (p^{PP} - \mu)\,\beta'(0) + (p^{PP} - \mu)\,\beta'(0)\left(\frac{\partial \psi_2^{PQ}(p^{PP},\mu)}{\partial p_1}\right) \\ = \;& (p^{PP} - \mu)\,\beta'(0)\left(\frac{\partial \psi_2^{PQ}(p^{PP},\mu)}{\partial p_1}\right) > 0 \end{aligned}$$

as

$$\beta(0) - (p^{PP} - \mu)\,\beta'(0) = 0$$

is the equilibrium condition defining p^{PP}. The problem in signing (8) is that, for values of c_2 other than μ, the integrand in (8) could be positive or negative and, if it is negative for some values of c_2, then it is not immediately clear that, after integrating over all values for c_2, (8) is positive. To show that the integrand in (8) can be negative, begin by re-arranging the integrand,

$$\beta\left(\psi_2^{PQ}\left(p^{PP},c_2\right)-p^{PP}\right)-\left(p^{PP}-\mu\right)\beta'\left(\psi_2^{PQ}\left(p^{PP},c_2\right)-p^{PP}\right) \tag{9}$$
$$+\left(p^{PP}-\mu\right)\beta'\left(\psi_2^{PQ}\left(p^{PP},c_2\right)-p^{PP}\right)\left(\frac{\partial\psi_2^{PQ}\left(p^{PP},c_2\right)}{\partial p_1}\right).$$

The third term is positive, which is the first-mover effect that induces firm 1 to set a higher price. Take the derivative of the first two terms with respect to c_2:

$$\left[\beta'\left(\psi_2^{PQ}\left(p^{PP},c_2\right)-p^{PP}\right)-\left(p^{PP}-\mu\right)\beta''\left(\psi_2^{PQ}\left(p^{PP},c_2\right)-p^{PP}\right)\right]\left(\frac{\partial\psi_2^{PQ}\left(p^{PP},c_2\right)}{\partial c_2}\right),$$

and evaluate at $c_2=\mu$:

$$\begin{aligned}&\left[\beta'\left(\psi_2^{PQ}\left(p^{PP},\mu\right)-p^{PP}\right)-\left(p^{PP}-\mu\right)\beta''\left(\psi_2^{PQ}\left(p^{PP},\mu\right)-p^{PP}\right)\right]\left(\frac{\partial\psi_2^{PQ}\left(p^{PP},\mu\right)}{\partial c_2}\right)\\ =\ &\left[\beta'(0)-\left(p^{PP}-\mu\right)\beta''(0)\right]\left(\frac{\partial\psi_2^{PQ}\left(p^{PP},\mu\right)}{\partial c_2}\right)=\beta'(0)\left(\frac{\partial\psi_2^{PQ}\left(p^{PP},\mu\right)}{\partial c_2}\right)>0.\end{aligned}$$

Hence, for ε small and positive, the sum of the first two terms in (9) is negative for c_2 below but close to μ:

$$\beta\left(\psi_2^{PQ}\left(p^{PP},\mu-\varepsilon\right)-p^{PP}\right)-\left(p^{PP}-\mu\right)\beta'\left(\psi_2^{PQ}\left(p^{PP},\mu-\varepsilon\right)-p^{PP}\right)<0.$$

Hence, (9) could be positive or negative.

Returning to the objective of showing that $p_1^{PQ}>p^{PP}$, a sufficient condition is:

$$\frac{\partial\pi_1^{PQ}(p_1)}{\partial p_1}>0,\forall p_1\in\left[\mu,p^{PP}\right]. \tag{10}$$

To prove (10), it'll be necessary to suppose $\frac{\partial\psi_2^{PQ}(p_1,c_2)}{\partial p_1}>0$ and $\frac{\partial\psi_2^{PQ}(p_1,c_2)}{\partial c_2}>0$, both of which hold assuming (6).

First note that if $p_1=\mu$ then

$$\frac{\partial\pi_1^{PQ}(\mu)}{\partial p_1}=\int_{\underline{c}}^{\overline{c}}\beta\left(\psi_2^{PQ}(\mu,c_2)-\mu\right)F'(c_2)\,dc_2>0.$$

Hence, from hereon assume $p_1>\mu$. Since $\frac{\partial\psi_2^{PQ}(p_1,c_2)}{\partial p_1}>0$ then it follows from (7) that

$$\frac{\partial\pi_1^{PQ}(p_1)}{\partial p_1}>\int_{\underline{c}}^{\overline{c}}\left[\beta\left(\psi_2^{PQ}(p_1,c_2)-p_1\right)-(p_1-\mu)\beta'\left(\psi_2^{PQ}(p_1,c_2)-p_1\right)\right]F'(c_2)\,dc_2. \tag{11}$$

Since $\beta'(0) \geq \beta'(\Delta)\ \forall \Delta$ then it follows from (11) that

$$\frac{\partial \pi_1^{PQ}(p_1)}{\partial p_1} > \int_{\underline{c}}^{\overline{c}} \left[\beta\left(\psi_2^{PQ}(p_1, c_2) - p_1\right) - (p_1 - \mu)\beta'(0)\right] F'(c_2)\, dc_2 \equiv \Omega(p_1). \quad (12)$$

Consider $\Omega(p_1)$ evaluated at $p_1 = p^{PP}$:

$$\begin{aligned}
\Omega\left(p^{PP}\right) &= \int_{\underline{c}}^{\overline{c}} \left[\beta\left(\psi_2^{PQ}\left(p^{PP}, c_2\right) - p^{PP}\right) - \left(p^{PP} - \mu\right)\beta'(0)\right] F'(c_2)\, dc_2 \qquad (13)\\
&= \int_{\underline{c}}^{\overline{c}} \left[\beta\left(\psi_2^{PQ}\left(p^{PP}, c_2\right) - p^{PP}\right) - \left(\mu + \frac{1}{2\beta'(0)} - \mu\right)\beta'(0)\right] F'(c_2)\, dc_2\\
&= \int_{\underline{c}}^{\overline{c}} \left[\beta\left(\psi_2^{PQ}\left(p^{PP}, c_2\right) - p^{PP}\right) - \frac{1}{2}\right] F'(c_2)\, dc_2
\end{aligned}$$

where recall $p^{PP} = \mu + \frac{1}{2\beta'(0)}$. From (12), if $\Omega\left(p^{PP}\right) \geq 0$ then $\partial \pi_1^{PQ}\left(p^{PP}\right)/\partial p_1 > 0$. By (13), $\Omega\left(p^{PP}\right) \geq 0$ if and only if

$$\int_{\underline{c}}^{\overline{c}} \beta\left(\psi_2^{PQ}\left(p^{PP}, c_2\right) - p^{PP}\right) F'(c_2)\, dc_2 \geq \frac{1}{2}. \quad (14)$$

To establish (14), we'll need to derive how firm 2's best reply responds to its cost. Take the total derivative of (5) with respect to firm 2's cost:

$$\begin{aligned}
0 &= -\beta'\left(\psi_2^{PQ}(p_1,c_2) - p_1\right)\left(\frac{\partial \psi_2^{PQ}(p_1,c_2)}{\partial c_2}\right) + \beta'\left(\psi_2^{PQ}(p_1,c_2) - p_1\right)\left(1 - \frac{\partial \psi_2^{PQ}(p_1,c_2)}{\partial c_2}\right)\\
&\quad - \left(\psi_2^{PQ}(p_1,c_2) - c_2\right)\beta''\left(\psi_2^{PQ}(p_1,c_2) - p_1\right)\left(\frac{\partial \psi_2^{PQ}(p_1,c_2)}{\partial c_2}\right)
\end{aligned}$$

$$\begin{aligned}
&\beta'\left(\psi_2^{PQ}(p_1,c_2) - p_1\right) =\\
&\frac{\partial \psi_2^{PQ}(p_1,c_2)}{\partial c_2}\left[2\beta'\left(\psi_2^{PQ}(p_1,c_2) - p_1\right) + \left(\psi_2^{PQ}(p_1,c_2) - c_2\right)\beta''\left(\psi_2^{PQ}(p_1,c_2) - p_1\right)\right]
\end{aligned}$$

$$\frac{\partial \psi_2^{PQ}(p_1,c_2)}{\partial c_2} = \frac{\beta'\left(\psi_2^{PQ}(p_1, c_2) - p_1\right)}{2\beta'\left(\psi_2^{PQ}(p_1, c_2) - p_1\right) + \left(\psi_2^{PQ}(p_1, c_2) - c_2\right)\beta''\left(\psi_2^{PQ}(p_1, c_2) - p_1\right)}. \quad (15)$$

Therefore, $\frac{\partial \psi_2^{PQ}(p_1,c_2)}{\partial c_2} > 0$ if (6) holds. Since

$$p^{PP} = \psi_2^{PQ}\left(p^{PP}, \mu\right)$$

and $\frac{\partial \psi_2^{PQ}(p_1,c_2)}{\partial c_2} > 0$, it follows that

$$\psi_2^{PQ}\left(p^{PP}, c_2\right) - p^{PP} \begin{cases} < 0 & \text{if } c_2 < \mu \\ = 0 & \text{if } c_2 = \mu \\ > 0 & \text{if } c_2 > \mu \end{cases} \quad (16)$$

Since

$$\beta''(\Delta)\begin{cases} \geq 0 & \text{if } \Delta < 0 \\ = 0 & \text{if } \Delta = 0 \\ \leq 0 & \text{if } \Delta > 0 \end{cases}$$

then it follows from (16) that

$$\beta''\left(\psi_2^{PQ}\left(p^{PP}, c_2\right) - p^{PP}\right)\begin{cases} \geq 0 & \text{if } c_2 < \mu \\ = 0 & \text{if } c_2 = \mu \\ \leq 0 & \text{if } c_2 > \mu \end{cases} \tag{17}$$

Using (17), we conclude from (15),

$$\frac{\partial \psi_2^{PQ}\left(p^{PP}, c_2\right)}{\partial c_2}\begin{cases} \leq \frac{1}{2} & \text{if } c_2 < \mu \\ = \frac{1}{2} & \text{if } c_2 = \mu \\ \geq \frac{1}{2} & \text{if } c_2 > \mu \end{cases} \tag{18}$$

By definition, we have

$$\psi_2^{PQ}\left(p^{PP}, c_2\right) = \begin{cases} p^{PP} - \int_{c_2}^{\mu}\left(\frac{\partial \psi_2^{PQ}\left(p^{PP}, c_2\right)}{\partial c_2}\right) dc_2 & \text{if } c_2 < \mu \\ p^{PP} & \text{if } c_2 = \mu \\ p^{PP} + \int_{c_2}^{\mu}\left(\frac{\partial \psi_2^{PQ}\left(p^{PP}, c_2\right)}{\partial c_2}\right) dc_2 & \text{if } c_2 > \mu \end{cases} \tag{19}$$

Using (18) in (19), we have a lower bound on $\psi_2^{PQ}\left(p^{PP}, c_2\right)$:

$$\psi_2^{PQ}\left(p^{PP}, c_2\right)\begin{cases} \geq p^{PP} + \frac{1}{2}(c_2 - \mu) & \text{if } c_2 < \mu \\ = p^{PP} & \text{if } c_2 = \mu \\ \geq p^{PP} + \frac{1}{2}(c_2 - \mu) & \text{if } c_2 > \mu \end{cases}$$

and therefore

$$\psi_2^{PQ}\left(p^{PP}, c_2\right) - p^{PP} \geq \frac{1}{2}(c_2 - \mu).$$

Since β is increasing, we then have

$$\beta\left(\psi_2^{PQ}\left(p^{PP}, c_2\right) - p^{PP}\right) \geq \beta\left(\frac{1}{2}(c_2 - \mu)\right). \tag{20}$$

We can now prove that (14) holds. By (20), a sufficient condition for (14) to be true is

$$\int_{\underline{c}}^{\overline{c}} \beta\left(\frac{1}{2}(c_2 - \mu)\right) F'(c_2)\, dc_2 \geq \frac{1}{2}. \tag{21}$$

Next note that

$$\begin{aligned}\int_{\underline{c}}^{\overline{c}} \beta\left(\frac{1}{2}(c_2-\mu)\right) F'(c_2)\, dc_2 &= \int_{\underline{c}}^{\mu} \beta\left(\frac{1}{2}(c_2-\mu)\right) F'(c_2)\, dc_2 + \int_{\mu}^{\overline{c}} \beta\left(\frac{1}{2}(c_2-\mu)\right) F'(c_2)\, dc_2 \\ &= \int_{\mu}^{\overline{c}} \left[1-\beta\left(\frac{1}{2}(c_2-\mu)\right)\right] F'(c_2)\, dc_2 + \int_{\mu}^{\overline{c}} \beta\left(\frac{1}{2}(c_2-\mu)\right) F'(c_2)\, dc_2 \\ &= \int_{\mu}^{\overline{c}} F'(c_2)\, dc_2 = \frac{1}{2}.\end{aligned}$$

where the second equality follows from A1 and the symmetry of F'. Hence, (21) is true.

Having shown

$$\frac{\partial \pi_1^{PQ}\left(p^{PP}\right)}{\partial p_1} > 0,$$

we still need to show that

$$\frac{\partial \pi_1^{PQ}(p_1)}{\partial p_1} > 0, \forall p_1 \in \left[\mu, p^{PP}\right).$$

What we have is:

$$\frac{\partial \pi_1^{PQ}(p_1)}{\partial p_1} > \Omega(p_1), \ \forall p_1 > \mu; \text{ and } \Omega\left(p^{PP}\right) \geq 0$$

Since

$$\Omega'(p_1) = -\int_{\underline{c}}^{\overline{c}} \beta'\left(\psi_2^{PQ}(p_1, c_2) - p_1\right)\left(1 - \frac{\partial \psi_2^{PQ}(p_1, c_2)}{\partial p_1}\right) F'(c_2)\, dc_2 - \beta'(0) < 0$$

then $\Omega\left(p^{PP}\right) \geq 0$ implies

$$\Omega(p_1) > 0, \ \forall p_1 \in \left[\mu, p^{PP}\right),$$

and, therefore,

$$\frac{\partial \pi_1^{PQ}(p_1)}{\partial p_1} > 0, \forall p_1 \in \left[\mu, p^{PP}\right).$$

We conclude that firm 1's optimal posted price, given firm 2 quotes price, exceeds p^{PP}. This means that $p_1^{PQ} > p^{PP}$ so that, given firm 1 posts price, firm 1's price is higher when firm 2 has the quoted price format than when firm 2 has the posted price format.

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