Supply Chains and Antitrust Governance

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Antitrust regulations are meant to promote fair competition in the market, but balancing administrative and legal costs with enforcement can be difficult when multi-layered supply chains are involved. The canonical example of this challenge is the landmark *Illinois Brick* ruling, which limits antitrust damages to only the direct purchasers of a product; for instance, consumers can file antitrust claims against colluding retailers but not against colluding manufacturers – only retailers can file claims against manufacturers. This controversial ruling was meant to reduce legal costs, but it can clearly lead to missed enforcement opportunities.

In this paper we demonstrate how the *Illinois Brick* ruling interacts with contracts adopted in the supply chain and we show that otherwise equivalent supply chain arrangements can have markedly different effects. In particular, we find that wholesale price, minimum order quantity, revenue-sharing and quantity discount contracts lead retailers to take legal action against manufacturers in the event of collusive behavior. However, the wholesale price plus fixed fee contract structure (a.k.a. a two-part tariff or slotting fee contract) facilitates collusion among the manufacturers with retailers compensated by the fixed fee and not filing the antitrust litigation. We further demonstrate that collusion is more likely under high demand uncertainty and high competition at the retail level but is less likely under high competition at the manufacturer level. Our paper helps public enforcers identify market conditions conducive to antitrust violations.

Key words: Supply Chain Contracts, Antitrust, Illinois Brick Ruling, slotting Fees

1. Introduction

In 2007, a civil suit was filed against a group of cathode ray tube (CRT) manufacturers – including Samsung Electronics Co. Ltd., Philips Electronics NA, Panasonic Corp., LG Electronics Inc., and Toshiba Corp. – for fixing prices over the 12-year period from 1 March 1995 to 25 November 2007.[1] After a tedious damage discovery process spanning several years, a group of plaintiffs who had bought the overpriced CRTs through intermediaries (the so-called indirect purchaser plaintiffs)

[1] J. S. Tigar (US District Court Judge), "Case No. C-07-5944 JST, MDL No. 1917," 7 July 2016, http://bit.ly/2COS0U (accessed 20 April 2018).

reached settlements amounting to $576 million.[2] Although the California Northern District Court finally approved the settlements in 2016, it limited the monetary compensation to those states that had enacted "repealer" statutes in response to the U.S. Supreme Court judgment in a landmark case: *Illinois Brick Co. v. Illinois* (431 U.S. 720, 1977); hereafter we refer to this case more simply as "IB". The CRT case was just one of thousands of legal cases affected by this judgment.

The IB decision barred an indirect purchaser from suing and recovering antitrust damages based on a "pass-on" claim i.e., on claims of supracompetitive prices, charged by the upstream firms, being passed-on to them by the intermediary firms. The judgment noted that "whole new dimensions of complexity would be added to treble damages suits, undermining their effectiveness, if the use of pass-on theories were allowed" (431 U.S. 720). The indirect purchaser suits could transform "into massive multiparty litigations involving many distribution levels and including large classes of ultimate consumers remote from the defendant," resulting in an astronomical increase in administrative and legal costs. Hence the judgment barred purchasers from suing *unless* they directly suffered the antitrust injury.

Since its inception, the IB ruling has attracted considerable debate among scholars and practitioners alike. Strong arguments were advanced not only by the ruling's supporters (Litwin et al. 2010, Price 2013) but also by its opponents (Karon 2003) – including a recent call from the Trump administration for its repeal ("Trump DOJ's Next Target: the IB Indirect Purchaser Rule?", The National Law Review, Strimel and Ilter, 2018). Over the last 41 years, 28 U.S. states have introduced varying forms of IB repealers.[3] The other 24 states continue to support the IB ruling, recognizing its importance in limiting administrative burdens. On average, the cost of administering a settlement fund (as a percentage of the settlement amount) associated with indirect purchaser suits is more than 75% (2.42 percentage points) higher than the cost for direct purchaser suits (5.63% vs. 3.21%; see Davis and Lande 2012, p. 1307, table 11) .

Although the IB ruling reduced legal costs, at the same time it can enable firms to collude by attenuating incentives of its direct purchasers from filing antitrust suits (Schinkel et al. 2008). In other words, the ruling weakens the role of *private* enforcers (i.e., firms) in curbing, via lawsuits, the anticompetitive behavior of other firms. As a result, *public* enforcers (i.e., government entities)

[2] The settlements comprised agreements with Samsung for $225 million, Philips for $175 million, Panasonic for $70 million, Toshiba for $30 million, Hitachi for $28 million, LG for $25 million, Chunghwa for $10 million, and a joint agreement with Thomson and TDA for $13.75 million.

[3] M. A. Lindsay, "Overview of State RPM," American Bar Association, August 2012, http://bit.ly/2L5rReb (accessed 20 April 2018). Among these 28 states, four authorize their respective attorneys general (as *parens patriae*) to secure monetary relief for indirect damages, two allow the state (or any of its political subdivisions) to bring an action for indirect damages, and one state allows its courts to make additional orders or judgments as may be necessary to recover indirect damages.

must, via monitoring, step up their efforts. This raises a conundrum: how can the IB-related benefits of lower legal costs be retained without a significant increase in public enforcement costs?

This paper evaluates the implications of the *Illinois Brick* ruling for supply chain interactions through the lens of procurement contracts between a firm and its direct purchasers. A choice of contractual agreement between two supply chain members not only determines the supply chain's overall efficiency but is also instrumental in determining how the resulting profits are allocated (Cachon 2003). Furthermore, market conditions may lead to a preferential ranking (by supply chain members) among contractual agreements that might otherwise seem to be equivalent (Cachon and Kök 2010). Motivated by these observations, we compare the extent to which five common contractual structures – wholesale price, minimum order quantity, wholesale price plus fixed fee, revenue-sharing, and quantity discounts – facilitate anticompetitive (collusive) decision making among firms.[4] If these contract types do differ on that score, then public enforcers can enact simple rules that will improve their ability to select appropriate cases for investigation of antitrust violations and thereby reinforce the IB framework. Toward this end, we apply operations management (OM) lens to understand collusion-facilitating ability of the above-mentioned five contract structures.

We model a three-tier supply chain that consists of manufacturers, retailers (direct purchasers), and consumers (indirect purchasers) in the context of the IB ruling. For each of the five contractual structures, we study the propensity of manufacturers to collude. We find that the five contracts are quite distinctive in their ability to facilitate collusion. More specifically, no collusion is feasible under the wholesale price, minimum order quantity, revenue-sharing, and quantity discount contracts: retailers will take legal action against any collusive behavior by the manufacturers. In contrast, the *wholesale price plus fixed fee* (WPFF) structure facilitates collusion via a fixed payment from manufacturers to the retailers (sometimes referred to as the "slotting fees"). We also find that the WPFF structure's collusion-sustaining ability increases with demand uncertainty and with competition among retailers, but decreases with the competition among the manufacturers. Our main analysis considers a setting with symmetric manufacturers that compete with undifferentiated products under a given contract type. We find that the distinctive ability of the WPFF contract to facilitate collusion persists when the manufacturers compete with differentiated products. We find similar result even when manufacturers endogenously select the contract type in addition to contract terms.

Our paper makes contributions to multiple streams of the OM literature and also offers actionable insights that public enforcers can utilize to monitor antitrust violations more effectively. In the

[4] In the extant literature, these contract structures have been frequently studied to examine interactions in both the serial and non-serial supply chains (Tomlin 2009, Cachon and Kök 2010, Chen and Özer 2019).

OM contracting literature, an important sub-stream studies the exogenous conditions (e.g., market structure, participants' financial vulnerability) that lead to a preferential ranking (by supply chain members) among otherwise equivalent supply chain contracts (Cachon and Kök 2010, Jain et al. 2013). For instance, Cachon and Kök show that, while in a *serial* supply chain a retailer may dislike sophisticated contracts (e.g., quantity discount, WPFF) as they allow manufacturers to extract surplus; however, the retailer may actually prefer such contacts when they are offered by competing manufacturers. Our study extends this literature by highlighting that public policy regulations can also drive such differential preferences among seemingly equivalent contractual structures. In addition, we show that, although the wholesale price contract is not channel coordinating, it leads to higher consumer and total surplus than is achieved by more sophisticated coordinating contracts. This finding complements extant literature that supports the use of simple wholesale price contracts in practice (Jerath et al. 2007, Cui et al. 2017, Hwang et al. 2018). Finally, our paper also contributes to the extensive literature on the motivations for slotting fees that are commonly observed in various industries. We demonstrate that, in addition to such frequently studied factors as screening and information sharing advantage (see the comprehensive review by Bloom et al. 2000), slotting fees may serve to facilitate collusion within the IB ruling's ambit.

To the best of our knowledge, this is one of the first OM papers to study the interplay between supply chain interactions and antitrust regulations. We believe that our paper has implications for motivating future research on the interface of operations management and public policy, an important but understudied topic. The results reported here, much as those in Gui et al. (2015) and Kim (2015), underscore the virtue of using operations insights to strengthen the implementation of public policy.

From the perspective of actual practice, our results help public enforcers in effective case selection of business conduct, for monitoring of antitrust violations, that exploits the barring of indirect purchasers rule under the IB ruling. The results reported here imply that public enforcers can reduce their monitoring efforts of firms embedded in supply chain structures governed by wholesale price, minimum order quantity, revenue-sharing, and quantity discount contracts – that is, because those structures do not facilitate collusion. This finding can lead to significant administrative cost savings given that such contracts are widely prevalent in practice (Cachon, 2003; Chu and Sappington, 2009; Cui, 2017).[5] In addition, public enforcers can improve their case selection when considering WPFF relationships by focusing on supply chains characterized by a heavy use of slotting fees.

[5] See also P. Rasmussen, "What Are the Factors Driving MOQ?" East West, 12 July 2017, http://bit.ly/2J7t43R (accessed 20 April 2018).

2. Literature Review

This paper is closely related to three streams of literature: (i) the role of procurement contracts in supply chain performance, (ii) the interface of operations management and public policy, and (iii) slotting fees.

The literature on procurement contracts has assessed the efficacy of various contractual structures in achieving supply chain objectives including risk management and profitability. Cachon (2003) offers an excellent review that summarizes the ability of various contracts to enable supply chain coordination. Simple wholesale price contracts fail to coordinate the supply chain (Lariviere and Porteus 2001, Perakis and Roels 2007) while more sophisticated contracts such as quantity discount, WPFF, revenue-sharing, MOQ, and so forth, do. Cachon and Kök (2010) show that, while in a serial supply chain a retailer may dislike sophisticated (e.g., quantity discount, WPFF) contracts because they allow manufacturers to extract surplus, retailers may actually prefer such contacts when offered by competing manufacturers. Likewise, Corbett et al. (2004), Katok and Wu (2009), Jain et al. (2013), Chen and Özer (2018), and Tuncel et al. (2019) illustrate that differences in information-sharing structure, in the risk of information leakage, in the financial vulnerability of participating members, and in the behavioral biases of decision-makers may lead to different performance outcomes from these coordinating contracts. Our study extends this line of research by demonstrating that an exogenous regulatory framework can also result in preferential choices among otherwise equivalent coordinating contracts.

There could also be reasons to use (non-coordinating) wholesale price contracts. Hwang et al. (2018) show that, if the supply chain is unreliable, then wholesale price contracts can outperform unit-penalty and buy-back contract structures. Cui et al. (2017) demonstrate that, because of bounded rationality, the wholesale price contract structure can outperform more complex contracts; behavioral support for this finding is given by several laboratory experiments (see Katok and Wu 2009; Kalkancı et al., 2011, 2014). We complement this line of literature by establishing that the wholesale price contract structure may yield better social welfare outcomes (relative to WPFF contract) as it discourages anticompetitive behavior.

A related area in operations management suggests approaches to improving public policies. For instance, Gui et al. (2015) suggest improvements in implementing extended producer responsibility, Kim (2015) describe the conditions under which inspections are more effective when performed at random rather than at fixed intervals, Calvo et al. (2019) identify areas of potential improvement in the government monitoring of high-budget public projects and Shunko et al. (2014) detail the implications of tax policies for global supply chains. We contribute to this growing literature by bringing operations management perspective to strengthen public antitrust enforcement under a central antitrust regulation–*Illinois Brick*.

The topic of antitrust regulations has received relatively little attention in the operations management literature. Krishnan et al. (2010) show that, in response to a retailer's reduced sales efforts due to the supply chain innovation of "quick response" (QR) fulfillment, manufacturers may partake in anticompetitive actions – for instance, engaging in exclusivity terms when offering QR service. Cho (2013) and Yang et al. (2017) demonstrate that the effect of mergers and multi-channel distribution strategies on antitrust activities depends on the structure of a supply chain and the ensuing strategic decisions of its members. Krishnan et al. (2004) establish that coordinating contracts with return options (e.g., buy-back contracts) do not always result in antitrust behavior by participating supply chain members. In sum, these studies speak to antitrust regulators by analyzing specific supply chain features with aim of guiding the efforts of those regulators while our study examines the trade-offs arising from an extensively debated antitrust ruling through the lens of supply chain interactions.

The challenges stemming from the IB ruling have been examined in the fields of law and economics. One of the first papers that followed the IB decision (Landes and Posner 1979) presents an economic analysis in support of the ruling: the authors show that allowing indirect purchasers to sue "would probably retard rather than advance antitrust enforcement." In contrast, Blair and Harrison (1999) find that the ruling has created problems for antitrust enforcement owing to the variety of interpretations across states. Cavanagh (2004) provides a helpful review of these papers and describes a path forward for the IB ruling. In a study that is the closest to our paper Schinkel et al. (2008) use a stylized model with a wholesale price contract that embeds a maximum purchase quantity constraint. They find that the manufacturers can collude under the IB ruling by directly influencing the retailers' quantity decisions. We complement their work by focusing on frequently studied contractual settings in OM wherein the retailers determine their order quantities by maximizing their individual profits in equilibrium.

Finally, our paper is also related to research on slotting fees – a practice of fixed payments from manufacturer to retailer that began in the mid-1980s. Many reasons have been advanced to explain the prevalence of slotting fees; these explanations include demand signaling and screening (Chu 1992, Lariviere and Padmanabhan 1997), cost and risk sharing (Toto and Dominic 1990, Sullivan 1997), product assortment coordination (Aydın and Hausman 2009) the exercise of market power by retailers (Messinger and Chu 1995), and as a tool for manufacturers to gain competitive foreclosure (MacAvoy 1997). For a comprehensive survey of academic and practitioner views on the practice of slotting fees, the reader is referred to Bloom et al. (2000). Collectively, the extant literature brings to fore both the positive and negative implications of the slotting fee feature in supply chain interactions. We complement this literature by highlighting an additional factor that encourages a supply chain's use of slotting fees: we show that the firms may take advantage of this fixed payment practice to enact collusive actions under the IB ruling, thus, highlighting a potential negative use of slotting fees in practice.

3. Model Setup

We begin with a three-tier supply chain model consisting of two manufacturers (M_1 and M_2, the producers), two retailers (R_1 and R_2, the direct purchasers), and consumers (the indirect purchasers). The manufacturers produce perfect substitutes, at the constant (and identical) marginal production cost c, and do not face any capacity constraints. While operating under the IB ruling, we analyze five contracts (T) such that the manufacturers simultaneously offer the terms of procurement $\mathbf{v}$ to the retailers.

We assume that retailers are identical and face a standard, downward-sloping linear demand function with stochastic intercept (market potential) a. Given the contractual terms, the retailers place a purchase order with the manufacturers based on their expectation of demand. This assumption reflects the industry practice of placing procurement orders far in advance of the selling season, since managers usually face long lead times when *sourcing* (Cachon and Terwiesch 2003). Consequently, such setup involves considerable uncertainty about the sourced product's market potential. However, *pricing* decisions can be made much closer to the selling season. To capture this situation, the retailers set their profit-maximizing sales quantity (and, thus, indirectly the selling price through Cournot competition) for consumers after realization of the stochastic demand intercept. The sequence of events – which is similar to that in the models of Van Mieghem and Dada (1999), Chod and Rudi (2005), and Goyal and Netessine (2007) – is illustrated in Figure 1.

We use the Stackelberg–Nash equilibrium approach to characterize, for a given contractual structure, the retailers' purchase order quantities and selling prices, the retailers' and the manufacturers' profits, and the consumer surplus. As is typical in the Stackelberg equilibrium approach, we first solve for the retailers' optimal selling quantity problems (Stage 3 in Figure 1). Next we solve for the retailers' optimal purchase quantity decisions (Stage 2), and finally we solve the manufacturers' problem of setting the profit-maximizing procurement terms (Stage 1).

For each contractual structure, we examine a single-period interaction among the three-tier supply chain members to evaluate the contract's ability to facilitate collusion among the manufacturers. This is a natural setting in many situations where contracts are renewed periodically, in which case the contract terms are revised each year when new bids are solicited. One could alternatively evaluate a multi-period, repeated interaction setting characterized by short-term benefits for the manufacturer that defects from a cartel or for the retailer who files an antitrust suit.[6] In this paper,

[6] A direct purchaser can claim antitrust damages even if it pass-on the overcharges to the supply chain's downstream members (*Hanover Shoe, Inc. v. United Shoe Machinery Corp.*, 392 U.S. 481, 1968).

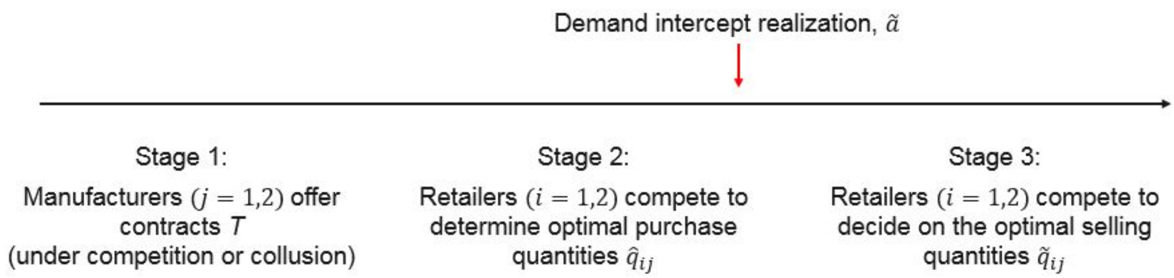

Figure 1 Decision Sequence

our focus is to evaluate the differential ability of the contract structures in facilitating collusion and to do so, we use simple single-period setting. Naturally, if a contract structure facilitates collusion in a single period, it will also facilitate collusion over repeated interactions. However, as Belavina and Girotra (2012) demonstrate, a thorough examination of multi-period contractual interactions within three-tier supply chains is a complex task even when only simple wholesale price contracts are involved. We therefore leave that task for future research.

Next we formalize the three stages presented in Figure 1.

3.1. Retailers' Problem

The retailers' inverse demand function is assumed to be $p = \tilde{a} - b(\tilde{q}_1 + \tilde{q}_2)$, where $\tilde{a}$ and b are parameters that capture (respectively) the realized demand intercept and information on price sensitivity. The term $\tilde{q}_i = \tilde{q}_{i1} + \tilde{q}_{i2} \le \hat{q}_i$ denotes the total sales of retailer i ($i = 1,2$), which cannot exceed that retailer's combined quantity $\hat{q}_i$ purchased from the two manufacturers in Stage 2. We denote the retailer i's purchased quantity from manufacturer j by $\hat{q}_{ij}$. In Stage 2, the market potential is unknown; we use $\bar{a}$ to denote its expected value. The two retailers compete to decide on the purchase quantities that maximize their respective expected profits π – that is, given the payment terms, under contract T, of the two manufacturers ($\mathbf{v} = [\mathtt{v}_1, \mathtt{v}_2]$). Formally, the two retailers determine their expected profit-maximizing purchase quantities $\hat{q}_{ij}$ by simultaneously solving the following optimization problems (for $i = 1,2$):[7]

$$\hat{q}_{i1}, \hat{q}_{i2} = \arg\max_{q_{i1}, q_{i2}} E_a \left[\sum_{j=1,2} (a - b(\tilde{q}_i + \tilde{q}_{\text{-}i}))\tilde{q}_{ij} - T(\mathtt{v}_j, q_{ij}, r_{ij}) \right], \tag{1}$$

$$\text{s.t. } \tilde{q}_{i1}(q_{i1}), \tilde{q}_{i2}(q_{i2}) = \arg \max_{z_{i1}, z_{i2} \ge 0} \sum_{j=1,2} r_{ij}(z_{i1}, z_{i2}, \tilde{q}_{\text{-}i}, \mathtt{v}_j), \text{ s.t. } z_{ij} \le q_{ij} \quad j = 1,2. \tag{2}$$

Here z denotes the retailer's selling quantity decision; and $T(\mathtt{v}, q, r)$ is the retailer's payment to its sourcing manufacturer, where $\mathtt{v}$ is the vector of a manufacturer's contract terms, q is the quantity

[7] We do not study cooperative decision-making among *retailers* because, in that case, the end consumers could – as direct buyers – file an antitrust action against the retailers.

of goods purchased from that manufacturer, r is the revenue generated by selling those goods, and $\tilde{q}_{ij}$ denotes the optimal sold quantity by the retailer i of the goods purchased from the manufacturer j. Note that only in the case of a revenue-sharing contract does the manufacturer's net payoff depend on the revenue generated by the sale of goods. In that case the revenue function is $r_{ij}(z_{i1}, z_{i2}, \tilde{q}_{\text{-}i}, \mathtt{v}_j) = (1-\alpha_j)(a - b(z_{i1} + z_{i2} + \tilde{q}_{\text{-}i}))z_{ij}$, where α denotes the manufacturer's share of the generated revenue and $\tilde{q}_{\text{-}i}$ the total quantity sold by the *other* retailer (i.e., retailer -i). For contracts that are not of the revenue-sharing type, α is set to zero. This payoff dependency under the revenue-sharing contract implies that, in the third stage, the retailers cannot sell more than the corresponding purchased quantities from the individual manufacturers. We capture this restriction on selling quantities through the constraint $z_{ij} \leq q_{ij}$. In contrast, under the remaining non revenue-sharing contracts, the retailers can pool the purchased quantities from the two manufacturers to determine the optimal selling quantities in stage 3, implying that the constraint on selling quantities in (2) should be $z_{i1} + z_{i2} \leq q_{i1} + q_{i2}$. It is easy to verify that the two constraints yield the same solution for (1) since the objective functions in (1) and (2) are functions of $z_{i1} + z_{i2}$ and $\tilde{q}_{i1} + \tilde{q}_{i2}$ respectively. Table 1 gives the functional form of T for each of the five contract structures. Under the wholesale price contract structure $(T(\mathtt{v} = \{w\}, q, r))$, for instance, the retailer's payment to the manufacturer is wq, where w is the offered wholesale price. Under a revenue-sharing contract $(T(\mathtt{v} = \{w, \alpha\}, q, r))$, the retailer's payment to the manufacturer is $wq + \alpha r$; here α denotes the manufacturer's share of generated revenue. Following Cachon and Kök (2010), we analyze a quadratic form of the quantity discount contract structure. Specifically, the contract definition ensures that no unit is sold below the marginal cost of production, thus avoiding aggressive discounting. Also, though the quadratic structure only captures a subset of all possible quantity-linked discount contracts, it is equivalent to the remaining three sophisticated contracts — revenue sharing, minimum order quantity, wholesale-price-plus-fixed-fee — in attaining supply chain coordination in a serial supply chain.

3.2. Manufacturers' Problem

Manufacturers decide on the payment terms of a contractual structure T while anticipating the quantity decisions of retailers. If the two manufacturers offer identical terms, then retailer i is indifferent between them. We therefore assume, without loss of generality, that in this case R_1 (resp. R_2) will procure its quantity from M_1 (resp. M_2) because of, say, geographic proximity. We next describe the manufacturers' problem when they behave as competitors. We mark the outcomes in this scenario with the superscript C. Next, we define the colluding manufacturers' problem that characterizes the anticompetitive outcomes (denoted by the superscript A and $\mathcal{A}$, respectively, for settings with and without the IB ruling) under settings with and without the IB ruling.

#	Contract Structure	v	T(v, q, r)
1	Wholesale Price (WP)	$\{w\}$	wq
2	Revenue Sharing (RS)	$\{w, \alpha\}$	$wq + \alpha r$
3	Quantity Discount (QD)	$\{w, \xi\}$	$wq - \xi q^2/2$ if $q \leq (w-c)/\xi$ $T(v, \frac{w-c}{\xi}, r) + c(q - \frac{w-c}{\xi})$ otherwise
4	Wholesale Price + Fixed Fee (WPFF)	$\{w, f\}$	$wq + f\mathbb{I}^{\dagger}(q > 0)$
5	Minimum Order Quantity (MOQ)	$\{w, q_{\text{min}}\}$	wq where $q \geq q_{\text{min}}$

† $\mathbb{I}(q > 0) = 1$ when q>0, 0 otherwise

Table 1 Payment Terms

Competing Manufacturers Scenario In the competitive scenario C, the two manufacturers simultaneously decide on the payment terms v_j that will maximize their respective profits Π_j $(j = 1, 2)$ while considering the retailers' reactions to the offered payment terms. Under the wholesale price contract structure, for example, the manufacturers will simultaneously decide on their respective profit-maximizing per-unit wholesale prices, $\text{v}_j = \{w_j\}$; similarly, under a revenue-sharing contract the manufacturers will simultaneously decide on the wholesale price and revenue share, $\text{v}_j = \{w_j, \alpha_j\}$. To analyze the manufacturers' decisions, we use a Stackelberg–Nash equilibrium framework with multiple leaders and multiple followers (Sherali 1984). Formally, the two manufacturers simultaneously solve the following problem in order to determine the respective payment terms v^C of a contract structure T:

$$\text{v}_j^C = \arg\max_{\text{v}_j} \Pi_j(\mathbf{v}) = E_a \left[\sum_{i=1,2} (T(\text{v}_j, \hat{q}_{ij}, \tilde{r}_{ij}) - c\hat{q}_{ij}) \right], \quad \text{s.t. } \pi_{1j}(\mathbf{v}) \geq 0, \pi_{2j}(\mathbf{v}) \geq 0; \tag{3}$$

where

$$\pi_{ij}(\mathbf{v}) = E\left[(a - b(\tilde{q}_i(\hat{q}_i) + \tilde{q}_{\text{-}i}(\hat{q}_{\text{-}i})))\tilde{q}_{ij}(\hat{q}_{ij}) - T(\text{v}_j, \hat{q}_{ij}, \tilde{r}_{ij}) \right], \tag{4}$$

$$\tilde{r}_{ij} = r_{ij}(\tilde{q}_{i1}(\hat{q}_{i1}), \tilde{q}_{i2}(\hat{q}_{i2}), \tilde{q}_{\text{-}i}(\hat{q}_{\text{-}i}), \text{v}_j). \tag{5}$$

Colluding Manufacturers Scenario under IB Ruling Under the IB ruling scenario, the two manufacturers when colluding will make a joint decision to maximize their combined profits even as the retailers continue to make *independent* simultaneous decisions on the purchase quantities.[8] A contractual structure can facilitate a collusive outcome if it enables the following two conditions.

[8] Any collusion among retailers to determine the purchasing quantities will allow the end consumers, as direct purchasers, to pursue antitrust litigation against those retailers, within the IB ruling.

First, it allows manufacturers to earn higher profits than under the competitive scenario (condition C1). Second, it ensures that retailers earn at least as much as they would have earned under the competitive scenario (condition C2). If condition C1 fails to hold then the manufacturers have no incentive to collude; if condition C2 fails then the retailers, as direct purchasers, will sue for recovery of losses due to the manufacturers' collusive action. Therefore, the manufacturers must account for these two conditions when making their joint decision about the payment terms of a contract T. Here, it is important to note that the retail-level competition is essential for the manufacturers to satisfy condition C2. In other words, if the market consists of only a single dominant retailer then the manufacturers can never satisfy condition C2. Formally, the manufacturers determine the optimal payment terms $\mathtt{v}^A$ under collusion by solving the following profit maximization problem:

$$\mathtt{v}_1^A, \mathtt{v}_2^A = \max_{\mathtt{v}_1, \mathtt{v}_2} E_a \left[\sum_{j=1,2} \sum_{i=1,2} \left(T(\mathtt{v}_j, \hat{q}_{ij}, \tilde{r}_{ij}) - c\hat{q}_{ij} \right) \right] \tag{6}$$

$$\text{s.t. } \Pi_1([\mathtt{v}_1, \mathtt{v}_2]) > \Pi_1([\mathtt{v}_1^C, \mathtt{v}_2^C]), \tag{C1}$$

$$\Pi_2([\mathtt{v}_1, \mathtt{v}_2]) > \Pi_2([\mathtt{v}_1^C, \mathtt{v}_2^C]), \tag{C1}$$

$$\pi_1([\mathtt{v}_1, \mathtt{v}_2]) \geq \pi_1([\mathtt{v}_1^C, \mathtt{v}_2^C]), \tag{C2}$$

$$\pi_2([\mathtt{v}_1, \mathtt{v}_2]) \geq \pi_2([\mathtt{v}_1^C, \mathtt{v}_2^C]); \tag{C2}$$

where $\pi_i(\mathbf{v}) = \pi_{i1}(\mathbf{v}) + \pi_{i2}(\mathbf{v})$.

Colluding Manufacturers Scenario in the absence of IB Ruling In the absence of IB ruling, the end consumers are now eligible to file an antitrust suit against the colluding manufacturers, which is in contrast to the IB ruling scenario wherein the consumers (as indirect purchasers) are legally barred to file such an antitrust case. As a result, the manufacturers must now satisfy an additional condition (C3) ensuring that the end-consumers' surplus CS under the collusion scenario is not lower than under the competitive scenario. If the manufacturers fail to meet this condition, the end consumers will sue to recover losses due to manufacturers' collusive actions. Formally, in the no IB ruling scenario, the manufacturers determine the optimal payment terms $\mathtt{v}^A$ under collusion by solving the following profit-maximization problem:

$$\mathtt{v}_1^A, \mathtt{v}_2^A = \max_{\mathtt{v}_1, \mathtt{v}_2} E_a \left[\sum_{j=1,2} \sum_{i=1,2} \left(T(\mathtt{v}_j, \hat{q}_{ij}, \tilde{r}_{ij}) - c\hat{q}_{ij} \right) \right] \tag{7}$$

$$\text{s.t. } \Pi_1([\mathtt{v}_1, \mathtt{v}_2]) > \Pi_1([\mathtt{v}_1^C, \mathtt{v}_2^C]), \tag{C1}$$

$$\Pi_2([\mathtt{v}_1, \mathtt{v}_2]) > \Pi_2([\mathtt{v}_1^C, \mathtt{v}_2^C]), \tag{C1}$$

$$\pi_1([\mathtt{v}_1, \mathtt{v}_2]) \geq \pi_1([\mathtt{v}_1^C, \mathtt{v}_2^C]), \tag{C2}$$

$$\pi_2([\mathtt{v}_1, \mathtt{v}_2]) \geq \pi_2([\mathtt{v}_1^C, \mathtt{v}_2^C]), \tag{C2}$$

$$CS([\mathtt{v}_1, \mathtt{v}_2]) \geq CS([\mathtt{v}_1^C, \mathtt{v}_2^C]); \tag{C3}$$

here $CS(\mathbf{v})$ denotes the end consumers' resultant surplus when the manufacturers' offer payment vector $\mathbf{v}$ to the retailers.

In real-world, the retailers (direct purchasers) and consumers (indirect purchasers) have to identify scenarios of losses, respectively violation of C2 and C3 conditions, due to the manufacturers' collusive decision making. The fundamental principle in quantifying such a loss is to estimate a 'counterfactual' profit in the competitive scenario, and use it as a benchmark for loss quantification (Komninos et al. 2009, Lloyd 2014, Notaro 2014). This quantification process involves many challenges including control for confounding factors, identification of appropriate benchmark period, and the length of it.

In the sections that follow, we shall frequently refer to manufacturers' and retailers' profit outcomes under competition, denoted by (C), under collusion with IB ruling, denoted by (A), and under collusion in the absence of IB ruling, denoted by $(\mathcal{A})$, using the following notation: $\Pi_j^k = \Pi_j(\mathtt{v}_j^k)$, $\pi_i^k = \pi_i(\mathbf{v}^k)$, $CS^C = CS(\mathbf{v}^k)$ for $k \in \{C, A, \mathcal{A}\}$ and $i, j = \{1, 2\}$. Here, we would like to note that our model naturally determines the split of collusion gains between the manufacturers through their joint decisions on the payment terms $\mathbf{v}$. As an alternative, one could apply the framework of cooperative game theory to study mechanisms for optimal split of collusion gains. Because our focus in this paper is on the collusion-facilitating ability of a contract structure and not on how the gains from that collusion should be divided, we do not adopt the cooperative game theory framework. Moreover, although that theory is useful for determining profit allocations, it is silent with regard to the actual decisions made (about quantities and prices), which are central to our context. For reference, a list of notations is provided in the appendix.

4. Results

In this section, we first study the manufacturers' and retailers' optimization problems when the demand curve is deterministic. We find this simplified setup helpful in evaluating collusion-facilitating ability of all five contract structures. Any contract that would fail to facilitate collusion under the deterministic demand scenario, would continue to do so in the general stochastic demand scenario. We then provide various extensions of the base model to establish robustness of our main insight. These extensions include scenarios involving stochastic demand, different market structures with multiple manufacturers and multiple retailers, asymmetric manufacturers offering differentiated products, and manufacturers endogenously selecting both the contract type and associated contract terms.

4.1. Relative Performance of the Contract Structures under competition

In the competitive setting, the two manufacturers make simultaneous independent decisions on the payment terms $\mathtt{v}$ for a given contract structure T. We analyze the manufacturers' decisions and the corresponding relative performance of the five focal contract structures using the manufacturers' profit optimization problem described in Section 3.2 (equation (3)). Our findings are presented formally in Proposition 1.

PROPOSITION 1. *When competing under deterministic demand curve, manufacturers are indifferent with regard to all five contract structures. Under each contract, the manufacturers will end up earning zero profits and the retailers will capture supply chain's profit. In particular, each manufacturer sets the payment term vector of the contract structures as follows:*

a. wholesale price, $\mathtt{v}^C = \{w = c\}$*;*

b. revenue-sharing, $\mathtt{v}^C = \{w = c,\ \alpha = 0\}$*;*

c. quantity discount, $\mathtt{v}^C = \{w = c,\ \xi = 0\}$*;*

d. wholesale price plus fixed fee, $\mathtt{v}^C = \{w = c,\ f = 0\}$*;*

e. minimum quantity order, $\mathtt{v}^C = \{w = c,\ q_{\min} = q^*\}$ *(here* q^* *denotes a centralized supply chain's profit-maximizing quantity).*

PROOF. *All proofs are given in the online Appendix.*

Proposition 1 demonstrates that, under competition, there is no reason for the manufacturers to prefer any one of the five contract structures over another. This finding runs counter to the extant literature, which argues that sophisticated contracts (e.g., quantity discount, revenue-sharing) perform differently – often better, but at times worse–in comparison to the simple wholesale price contract structure. Intuitively, in our setup, the two manufacturers engage in a Bertrand-like price competition to win procurement orders from the two retailers. Not surprisingly, the result is zero profits for the manufacturers under each contract structure, which renders them indifferent (under competition) with regard to these five contracts.

4.2. Relative Ranking of Contract Structures: With the IB Ruling

The IB ruling limits the ability of consumers to recover antitrust injury damages. That is, since the ruling bars an indirect purchaser from seeking recovery of antitrust damages, it follows that consumers can recover damages only from the anticompetitive actions of retailers (from which they purchase directly) and not from those of manufacturers (with respect to which they are indirect purchasers). So, provided that the retailers behave competitively when making their individual quantity decisions, *consumers* have no standing to file an antitrust suit in response to overcharges due to the manufacturers' collusive decision-making (as might occur in the case of a cartel). However, the *retailers* can sue (as direct purchasers) if the manufacturers' collusive decision-making reduces their respective individual profits as compared with the competitive decision-making scenario. Hence the manufacturers may seek to form a cartel if doing so enables them to earn higher profits while ensuring that the retailers earn no less than they would when the manufacturers compete. Here, similar to previous studies (such as Schinkel et al. 2008), we do not focus on the aspects of effectiveness in catching antitrust violations and proving it under the law. We similarly exclude from consideration the dynamic of collusive manufacturers trading off monetary gains against the likelihood of being caught and convicted. Likewise, at the retailers end, we exclude ethical considerations on their part to file an antitrust case against the colluding manufacturers. Our focus in this study, instead, is on whether the different contractual structures empower the manufacturers to collude by managing the retailers' financial considerations. We build on these observations to rank the contract structures in terms of the manufacturers' profit optimization problem under collusion, as given by equation (6) in Section 3.2. The two manufacturers will collude by deciding jointly on the payment terms v of a contract structure T. Proposition 2 characterizes the collusion-facilitating ability of the five contracts.

Proposition 2. *In the presence of the IB ruling, the manufacturers:*

a. *cannot form a cartel under a wholesale price, revenue-sharing, quantity discount, or minimum order quantity contract; under these structures, the retailers will pursue antitrust litigation to recover any anticompetitive injuries due to the manufacturers' collusive setting of payment terms.*
b. *can form a cartel under a WPFF contract.*

Proposition 2 implies that, in the presence of the IB ruling, manufacturers are no longer indifferent towards the five contractual structures. In particular, manufacturers prefer the WPFF structure over the other four contract types because it enables them to earn higher profits by forming a cartel.

Proposition 3. *The WPFF contract structure can facilitate collusion between manufacturers only when the payment terms include nonzero slotting fees (i.e., nonzero fixed payments) to the retailers. Moreover, under collusion:*

a. *the manufacturers set a higher wholesale price than under competition; and*
b. *both the consumer surplus and total surplus are lower than under competition.*

Proposition 3 stipulates the feature that any WPFF contract must have in order for collusion to be feasible: the presence of 'slotting fees'. Specifically, the contract offered by the manufacturers to the retailers includes a fixed fee f which is similar to the slotting fees observed in practice. Recall that, in the competitive setting, the manufacturers set this fixed fee term to zero. Furthermore, the per-unit selling price w charged under collusion is higher than the price charged under competition. The higher per-unit selling price not only enables manufacturers to earn a higher profit but also increases the total supply chain profit by limiting the retailers' order quantity $\hat{q}$. From the retailers' perspective, the higher w and the resultant lower $\hat{q}$ reduce their profits. However, an appropriately set slotting fee f can ensure that the retailers do not have any incentive to sue the manufacturers for forming a cartel. Here, it is important to note that the manufacturers could also earn similar higher profits by colluding under a wholesale price, revenue-sharing, quantity discount, or minimum order quantity contracts. However, under these other contracts, a cartel is not sustainable as any collusive action leads to an irreversible loss to the retailers. Namely, the embedded relationship between these contracts' payment terms and the retailers' quantity decisions does not accord the colluding manufacturers enough flexibility to influence the retailers' quantity decisions in a way that simultaneously allows for collusion gains and avoids the retailers' loss.

It is instructive to note here that the four remaining contracts can facilitate collusion *if* those contract structures are also augmented with the slotting fee feature. Intuitively, such an extension would impart an additional degree of flexibility to these contract structures which disentangles these contracts' limiting relationship among the retailers' quantity decisions, the manufacturers' collusion gains, and avoidance of the retailers' loss. At the same time, addition of the slotting fee feature results in a fundamental transformation of these contract structures. For example, such an addition transforms the WP contract to a WPFF contract. Going forward, we interpret all results of the studied contracts from the standpoint of their conventional purview rather than their transformed versions that incorporates the slotting fee feature.

The extant literature on slotting fees has identified several reasons for their existence: demand signaling, risk sharing, and as a means for retailers to exercise market power. Note that the parsimonious model studied in this section excludes the operating environment features, such as demand uncertainty and information asymmetry, that previous research has leveraged to explain the existence of slotting fees. Our findings reveal that slotting fees can also be explained as enablers of collusion subsequent to the IB ruling. That said, manufacturers can cite the aforementioned reasons – howsoever misleadingly – to justify the collusion-enabling fixed payments made to retailers.

In terms of social welfare, we find that, in the presence of the IB ruling, under the WPFF contract structure, the consumer surplus will be lower compared to that under competition. Furthermore, the loss in consumer surplus is higher compared to the gain in the supply chain profit due to the manufacturers' collusive decision-making. Consequently, the IB ruling results in a lower *total* surplus under the WPFF contract structure than under the other four structures, none of which facilitate collusion under the ruling.

In sum: we find that the IB ruling induces a preferential ranking, from the manufacturers' standpoint, among contract structures to which they would be indifferent in the absence of that ruling. Public enforcers of antitrust regulations can exploit this finding to improve case selection by focusing on supply chains that employ WPFF contracts with slotting fees. Next, we examine the collusion-facilitating ability of the studied contract structures in settings without the IB ruling.

4.3. Relative Ranking of Contract Structures: In the Absence of the IB ruling

In the absence of the IB ruling, any anticompetitive behavior may be reported either by the retailers (the direct purchasers) if they are overcharged and cannot pass the additional overcharge on to consumers, or by the consumers themselves (the indirect purchasers) if overcharges are passed on to them by retailers. As a result, to collude in such settings, the manufacturers must meet an additional condition such that consumers earn at least as much surplus as in the competitive scenario (as specified by the condition C3 in equation (7)). The manufacturers will jointly select the payment terms for a given contract T that can simultaneously satisfy all the three required conditions (C1–C3). Naturally, the four contract structures — Wholesale Price, revenue-sharing, Quantity Discount, and Minimum Order Quantity — that fail to form and sustain a collusion in the presence of IB ruling will also fail to form a collusion in the absence of IB ruling. These contract structures result in the retailers' loss when the manufacturers collude to increase their profits. As a response, the retailers would file an antitrust suit. Interestingly, the WPFF structure that enables collusion in the presence of IB ruling, fails to facilitate collusion in the absence of IB ruling. Under the WPFF contract, though the manufacturers are able to compensate retailers through fixed payments for any loss due to excessive wholesale prices, the equilibrium between the retailers leads to passing excessive prices to the end consumers, resulting in a decrease in consumer surplus. Consequently, collusion under the WPFF contract is not sustainable in the absence of IB ruling since the end consumers have an incentive to file an antitrust suit to recover economic damages. Proposition 4 formalizes these results for the no IB ruling setting.

Proposition 4. *In markets with no IB ruling, all five contracts are equivalent for the manufacturers since neither of them can facilitate collusion.*

We next turn to examine the effect of stochastic demand and market competition on the ability of WPFF contracts to facilitate collusion under the IB ruling.

4.4. Effect of Market Conditions on Cartel Formation

In Section 4.2 we showed that manufacturers cannot collude using contracts based on the wholesale price, revenue-sharing, quantity discounts, or a minimum order quantity discount. Although these contracts can increase manufacturer profits over the competitive scenario – the first necessary condition for collusion (condition C1; see Section 3.2) – each of them fails to satisfy the second necessary condition, C2: retailers must earn at least as much under collusion as under competition. The reason is that none of these four contracts has a mechanism, such as slotting fees, to compensate retailers for their collusion-related losses. A direct implication of this finding (from our deterministic demand scenario analysis) is that these contracts will also fail to satisfy condition C2 under more general scenarios that feature stochastic demand[9] and markets with multiple manufacturers and retailers. As a result, we focus hereafter on analyzing the WPFF contract.

4.4.1. Stochastic Demand Function We model the uncertain demand intercept parameter a using a continuous distribution function $F(\cdot)$ and density function $f(\cdot)$. Below, we formally present findings for the WPFF contract structure.

PROPOSITION 5. *The WPFF contract structure with slotting fee payment term can facilitate collusion under stochastic demand.*

Proposition 5, in conjunction with Proposition 2, implies that the WPFF contract structure facilitates manufacturers to collude under all demand scenarios. That said, in practice, manufacturers' incentives to collude will depend on the monetary gain that can be achieved due to collusion. A higher gain implies that, under collusion, manufacturers not only have a higher potential to increase their individual profits, but also have a greater flexibility in using fixed payments to mitigate retailers' incentive towards filing an antitrust lawsuit. Thus, a better understanding of factors that effect extent of gain under collusion would enable the antitrust public enforcers to effectively select product categories for monitoring anticompetitive actions. Towards this end, next we examine the effect of demand uncertainty on the manufacturers' incentives to collude. For that purpose, we examine how a supply chain's expected profits differ under competition versus collusion for various levels of demand uncertainty. This profit difference is determined by the retailers' cumulative order quantities (or, equivalently, by the supply chain order quantity, Q) under the two scenarios. Our next proposition characterizes the supply chain order quantities under competition and collusion as a solution of the respective implicit equations. Using these equations, we then numerically compute profits under demand uncertainty.

PROPOSITION 6. *When the demand intercept is stochastic $a \sim$ PDF $f()$ and CDF $F()$:*

a. The retailers' order quantities are given by the solutions of the following implicit equations:

$$\int_{\frac{3}{2}bQ^C}^{\infty} af(a)da - 3/2bQ^C\left(1-F\left(3/2bQ^C\right)\right) - c = 0, \qquad \text{(Competition)}$$

$$\int_{2bQ^A}^{\infty} af(a)da - 2bQ^A\left(1-F\left(2bQ^A\right)\right) - c = 0. \qquad \text{(Collusion)}$$

[9] Since each of the four remaining contracts fail to enable collusion in deterministic demand scenarios, irrespective of the demand parameters value, each of them will continue to fail in the general stochastic demand scenario which is a frequency-weighted combination of numerous deterministic demand scenarios

b. The retailers' combined order quantity under collusion is equal to the quantity that maximizes supply chain profit, which is less than the corresponding quantity under competition.

c. The expected selling price under collusion is higher than that under competition:

$$p^A - p^C = E_a\left[\frac{1}{4}\min\left(\frac{2a}{3b}, Q^C\right)\right] > 0.$$

Proposition 6 highlights that, much as in the deterministic demand scenario, colluding manufacturers are able to set payment terms that result in retailers purchasing lower quantities than in the competitive scenario. More specifically, the retailers' combined order quantity equals the supply chain's profit-maximizing quantity. Although the retailers behave competitively (i.e., they participate in neither vertical nor horizontal collusion), the manufacturers are still able to create a natural incentive for those retailers – using the slotting fees – to refrain from pursuing any legal actions against the manufacturers' upstream cartel. At the same time, the reduced combined order quantity causes the selling price to increase and thereby reduces consumer surplus.

Because quantities and prices are only defined implicitly, we next undertake a numerical study to gain additional understanding of how demand uncertainty affects manufacturers' incentives to collude. We start by calibrating the analysis with the aid of demand uncertainty parameters that reflect real-world levels of demand uncertainty for various retail products. Specifically, for the numerical analysis, we model the stochastic demand as a log-normal distribution and we estimate its parameters (mean and standard-deviation) using the ACNielsen Homescan panel data set (Albuquerque and Bronnenberg 2009, Hwang and Park 2015). This data set records the food and non-food purchases of registered panelists.

Using the compiled sample, we first normalize the monthly sales (in units) for 105 product categories by controlling for temporal trend and seasonality patterns. To do so, we build a linear prediction model for monthly sales. Specifically, we estimate monthly sales as $\widehat{Sales}_{kt} = Sales_{kt} - \alpha_a A_t - \alpha_t \mathbb{I}_t - \alpha_k \mathbb{I}_k$. Here $Sales_{kt}$ denotes the log-transformed sales of products in category k during month t; $\widehat{Sales}_{kt}$ denotes an estimate of it; A_t is the year of the month t; $\mathbb{I}_t$ is an indicator variable for the month t; and $\mathbb{I}_k$ is an indicator variable for the product category k. Next, we estimate demand parameters (μ and σ) by fitting log-normal distribution on $\exp(\widehat{Sales})$. Finally, we measure a product category's scale normalized uncertainty in demand by computing Coefficient of Variation (CV) of that category's fitted log-normal distribution. Formally, we measure $CV_k = \sqrt{e^{s_k^2} - 1}$, where CV_k denotes CV of category k and s_k denotes the standard deviation of the fitted log-normal distribution.

We find that – across all 105 product categories – the minimum, average, and maximum CV values are (respectively) 1.02, 2.43, and 4.54. We classify the products into groups characterized

Product-Type	Demand Uncertainty: Coefficient of Variation (CV)		
	Low (CV <= 2.01)	Medium (2.01 < CV <= 2.80)	High (CV > 2.80)
Food and Beverages	Baby Food, Cough and Cold Remedies, Ice, Ice Cream	Baked Goods-Frozen, Beer, Baking Mixes, Breakfast Foods-Frozen, Cheese, Fresh Meat, Fruid-Dried, Snacks, Yogurt	Cereal, Butter and Margarine, Carbonated Drinks, Eggs, Fresh Produce, Pet Food, Snacks
Non-Food	Cosmetics, Disposable Diapers, Electronics-Records-Tapes, Haircare, Photographic Supplies	Automotive, Batteries and Flashlights, Charcoal-Logs-Accessories, Oral Hygience, Glassware, Stationary and School Supplies	Paper Products

Table 2 Product Groupings – Representative Products

by low, medium, and high levels of demand uncertainty based on cut-offs at the 25th (CV = 2.01) and 75th (CV = 2.80) percentiles. Table 2 gives examples of products in each of these demand uncertainty categories. Next, we use our derived coefficients of variation to perform the numerical study. In Figure 2, Panel (a) plots the effect of an increase in demand uncertainty on the profit difference for a particular scenario defined by average demand $\mu = 4.14$, slope parameter $b = 0.05 \times \mu$, and per-unit product cost $c = 0.1 \times \mu$. The horizontal axis represents different CV levels; the vertical axis corresponds to relative differences (between the competition and collusion scenarios) in the expected supply chain profit Ω as the percentage of that profit in the competition scenario (i.e., $[(\Omega^A - \Omega^C)/\Omega^C] \times 100$).[10] Of course, one could argue that the observed relationship between demand uncertainty and the difference in supply chain profits depends on the selected values of μ, b, and c. We therefore verify robustness by using 100,000 random draws for the respective values of $\{\mu, \sigma, b, c\}$.

Panel (b) in Figure 2 plots the profit difference distribution statistics for the categories of products with low, medium, and high demand uncertainty. For each of the product categories, their respective box-plot reflects the 25th and 75th percentile threshold values of profit differences and the solid gray circle marks the average profit difference.

We find that the supply chain profit difference between the competition and collusion scenarios increases with demand uncertainty. In particular, for high demand uncertainty products the average profit difference is 16.4%, while for medium and low demand uncertainty products, the average profit difference is, respectively, 13.8% and 12.7%. The preceding analysis yields insights that public enforcers can use to improve their case selection for monitoring the incidence of anticompetitive actions. We find that manufacturers are more likely to collude in product categories for which demand uncertainty is higher. It follows that public enforcers can make the most efficient use of their limited resources by prioritizing cases of product categories characterized by high demand uncertainty over categories where product demand is more certain. Using examples from Table 2, we

[10] We draw 100,000 CV values that are uniformly distributed between the estimated minimum CV value (1.02) and maximum CV value (4.54). Corresponding to each of the drawn CV values, we compute the percentage of the relative profit difference using a random sample of 10,000 demand scenarios drawn from the log-normal distribution with $\mu = 4.14$ and $\sigma = \log(\text{CV}^2 + 1)$.

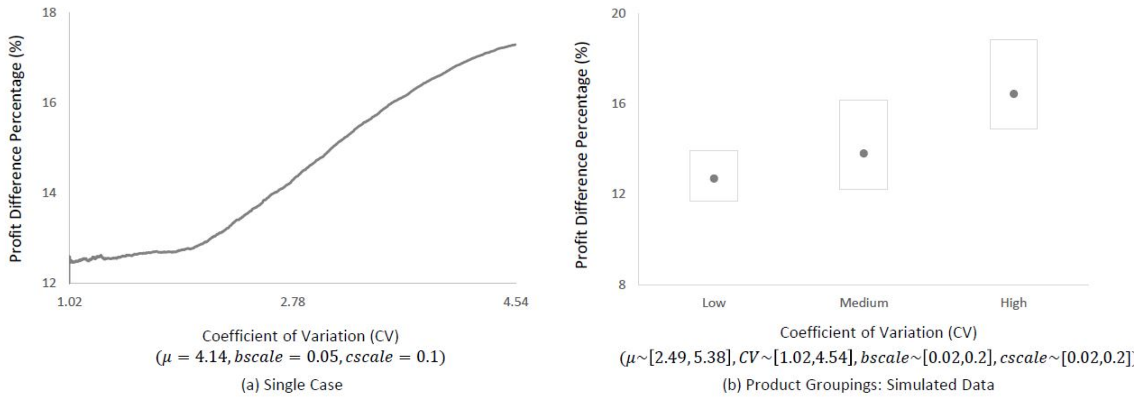

Figure 2 Competition versus Collusion – Effect of Demand Uncertainty on the Profit Difference

infer that, in the food and beverage category, products like carbonated drinks, eggs, fresh produce, and pet food are relatively more susceptible to anticompetitive behavior by manufacturers under the IB ruling because demand for those products is highly uncertain. At the other extreme, products such as baby food and ice cream are the least likely to merit antitrust scrutiny. In the non-food categories, paper (respectively, photographic and cosmetics) products are the most (respectively, the least) susceptible to anticompetitive actions by manufacturers.

4.4.2. Market Structure: Multiple Retailers The *number* of retail firms will naturally affect supply chain profits under competition. Consequently, number of retailers will also determine the comparative gain in supply chain profit under the collusion scenario and the required fixed payment to a retailer for mitigating the threat of an antitrust litigation. We formalize these effects in Proposition 7 by extending the deterministic demand model with two manufacturers and two retailers to the case of two manufacturers and $N = 2k$ retailers (where $k \in \mathbb{Z}^+$ and $k > 1$).[11]

PROPOSITION 7. *In a market with $N > 2$ retailers: (a) the WPFF contract structure facilitates collusion; and (b) the incentive for manufacturers to collude* increases *with the number of retailers.*

This proposition implies that manufacturers incentive to collude increases with an increase in the horizontal competition at the retail level. As competition increases, the retailers collectively end up increasing the supply of goods in the market; leading to lower prices, lower supply chain profit, and lower retailers' individual profits. By colluding, the manufacturers are effectively able to control retailers' supply to the market and, thus, drive the supply chain profits upwards. To sum up, as the number of retailers increases, not only the supply chain profit difference between the collusive and competitive scenarios increases, but also the manufacturers find it easier to create natural incentives for retailers to refrain from suing the cartel. Hence a greater number of retailers makes it more likely that manufacturers will form a cartel using WPFF contracts.

[11] If the two manufacturers offer identical payment terms, then each receives orders from $N/2$ retailers.

4.4.3. Market Structure: Multiple Manufacturers The number of manufacturers determines the individual profits earned by each manufacturer under collusion. In turn, those profits affect their incentives to form a cartel and to set payment terms cooperatively. Here we study the effect of multiple manufacturers on cartel formation by extending the deterministic demand model to a market with M manufacturers and N retailers, where $N = kM$ for $k \in \mathbb{Z}^+$.[12] In this case, one might well expect a result similar to Proposition 7, where more competition at manufacturers level imply a greater incentive to collude. Yet that intuition is misleading.

PROPOSITION 8. *In a market with M manufacturers: (a) the WPFF contract structure facilitates collusion; and (b) the incentive for manufacturers to collude* decreases *with the number of manufacturers.*

According to Proposition 8, manufacturers' incentives to collude decrease as the (horizontal) competition among them increases. This seemingly counterintuitive finding – namely, that collusion becomes less attractive with higher levels of competition – can be explained by the following insight. At the supply chain level, the gain from collusion are determined only by the level of competition at the retail level; and, also, retailers' individual profits are likewise a function only of that competition. Moreover for manufacturers, each one's share of the gain from collusion naturally decreases with an increase in competition. Therefore, manufacturers' incentive to collude decreases with increase in number of manufacturers.

5. IB Ruling and Collusion: Relative Ranking of Contracts under Alternative Settings

In this section we analyze the relative ranking of the studied five contracts in facilitating collusion under three alternative market settings. In Section 5.1 we analyze settings in which the two manufacturers offer differentiated products. Section 5.2 examines settings in which competing manufacturers can make endogenous choice of contract type, along with the associated payment terms. Finally, in Section 5.3 we analyze the setting wherein the retailers have limited ability to recognize losses due to the manufacturers' collusion and, as a consequence, may fail to take an action against the colluding manufacturers.

5.1. Differentiated Products

In Section 4, we study the relative ranking of the focal contracts when the manufacturers offer undifferentiated products and, naturally, face the highest competition and potential gains from collusion. We would expect that product differentiation would diminish the potential gain from

[12] Setting the number of retailers as a multiple of the number of manufacturers allows us to study the effect of multiple manufacturers through a symmetric equilibrium outcome.

collusion. Furthermore, Cachon and Kök (2010) find that the relative preference of the contractual structures between the competing manufacturers can vary with the level of product differentiation. Motivated by these observations, we examine the relative performance of the focal five contracts when the manufacturers compete with differentiated products.

To this end, we assume that the manufacturer j offers a product that faces the following demand curve: $p_j = \theta - q_j - \gamma q_{\text{-}j}$ where θ denotes the common market size for the two products and $0 < \gamma < 1$ captures the products' degree of differentiation. Using this modified demand curve, we first characterize the competitive equilibrium outcome that, in turn, provides a benchmark for the colluding manufacturers; both defining the required retailers' compensation under collusion and the potential of manufacturers' gain from collusion. We formalize the competitive equilibrium outcome payment terms result in Proposition EC.1 of the Online Appendix. We find that, when offering differentiated products, the manufacturers earn a non-zero profit, even under the competitive scenario (unlike the undifferentiated products setting).

Interestingly, as shown in Proposition 9, we find that only the WPFF contract structure can facilitate collusion among the manufacturers offering differentiated products. This result reaffirms that, in the remaining four contracts, the relationship between the payment terms and the ensuing quantity decisions is such that it precludes the manufacturers from extracting any collusion gains while, at the same time, compensating the retailers sufficiently towards any antitrust injuries.

Proposition 9. *When offering differentiated products, the manufacturers can collude using only the WPFF contract structure with the slotting fee feature. Furthermore, the manufacturers' propensity to collude decreases with the increase in products' differentiation level.*

5.2. Endogenous Choice of Contract Type

In the main analysis, we studied the symmetric manufacturers' decisions in the competitive and collusive settings for a given contract type T. If the manufacturers also have the flexibility to endogenously choose the contract type, then these outcomes may change. Note that the endogenous choice for the contract type equips the competing manufacturers with a wider set of feasible strategies, and therefore higher equilibrium profit. As a result, the manufacturers' propensity to collude may change too.

Interestingly, we find that the manufacturers cannot do better than with the WPFF contract type choice. Namely, the WPFF contract type can emulate the strategy set of any of the four contract types. For this reason, the WPFF contract weakly dominates the remaining four contract types. As a result, the two manufacturers endogenously opt to compete by offering the WPFF contracts to the retailers and attain the unique equilibrium payment terms $\{w = c, f = 0\}$. An immediate consequence of this persistent equilibrium outcome is that the WPFF contract can continue to facilitate collusion. In effect, we find that both the competitive and collusive decision-making outcomes are robust to the assumption on how competing contract types are determined: endogenously by the manufacturers or exogenously specified. In Proposition 10, we formalize these findings.

PROPOSITION 10. *When the competing manufacturers can endogenously choose both the contract type and associated payment terms, the WPFF contract type dominates the other four contract types (namely, wholesale price, revenue-sharing, quantity discount and minimum order quantity). Moreover, the manufacturers continue to earn zero profits under competition and can collude using the WPFF contract structure with the slotting fee feature.*

5.3. Retailers' Limited Ability to Recognize Antitrust Injuries

So far we have focused on scenarios where the retailers are always able to recognize an antitrust injury due to the manufacturers' collusive decision-making. Thus, the colluding manufacturers must ensure that the retailers earn at least as much as in the competitive setting (see condition C2 in the colluding manufacturers problem on page 11). In practice, however, the retailers may have limited ability to immediately recognize an antitrust injury, and may not file an antitrust suit on every occasion. From the manufacturers' perspective, this would imply that the consequence of violating the condition C2 is no longer a certain *but a possible* antitrust suit. Intuitively, the manufacturers may exploit this limitation on the retailers' part by colluding with a wider set of contractual structures, leading to higher enforcement agencies' monitoring costs. The cost would be highest if all five contracts equally allow the manufacturers to collude. We analyse such settings by internalizing the probabilistic outcome of violating condition C2 in the manufacturers' profit function, Π. Formally, the manufacturers' problem for collusion under the IB ruling is modified as follows:

$$\mathtt{v}_1^A, \mathtt{v}_2^A = \max_{\mathtt{v}_1, \mathtt{v}_2} E_a \left[\sum_{j=1,2} \sum_{i=1,2} \left(T(\mathtt{v}_j, \hat{q}_{ij}, \tilde{r}_{ij}) - c\hat{q}_{ij} \right) - \mathtt{p} \sum_{i=1,2} \left(\mathbb{I}_{[\pi_i(\mathbf{v}^C) - \pi_i(\mathbf{v}) > 0]} \beta(\pi_i(\mathbf{v}^C) - \pi_i(\mathbf{v})) \right) \right] \quad (8)$$

$$\text{s.t. } \Pi_1([\mathtt{v}_1, \mathtt{v}_2]) > \Pi_1([\mathtt{v}_1^C, \mathtt{v}_2^C]), \quad \text{(C1)}$$

$$\Pi_2([\mathtt{v}_1, \mathtt{v}_2]) > \Pi_2([\mathtt{v}_1^C, \mathtt{v}_2^C]), \quad \text{(C1)}$$

$$\pi_1([\mathtt{v}_1, \mathtt{v}_2]) \geq 0, \pi_2([\mathtt{v}_1, \mathtt{v}_2]) \geq 0,$$

where $\mathtt{p}$ denotes the likelihood of retailers filing an antitrust suit to recover damages from the colluding manufacturers' action, $\mathbb{I}_{[x>0]}$ denotes an indicator function which equals 1 if $x > 0$ and 0 otherwise, $\beta > 1$ denotes a penalty multiplier, capturing the notion that the legal costs and compensation of damages towards antitrust injuries are typically manifold compared to the collusion gains[13], and $\pi_i(\mathbf{v}^C)$ and $\pi_i(\mathbf{v})$ respectively denote the retailer i's profit under the competitive-equilibrium payment terms vector $\mathbf{v}^C = [\mathtt{v}_1^C, \mathtt{v}_2^C]$ and payment terms vector $\mathbf{v} = [\mathtt{v}_1, \mathtt{v}_2]$. Note that the modified objective function levies a penalty proportional to the likelihood that the retailers launch an antitrust suit if the retailers suffer a loss due to the manufacturers' collusive action (*akin* to violation of the condition C2).

We find that, even in the settings wherein the retailers have limited ability to recognize antitrust injuries, the WPFF contract dominates the remaining four contracts in facilitating collusion among the manufacturers. From the enforcement standpoint, these findings continue to suggest that the agencies should prioritize monitoring of supply chains that manage the procurement process via WPFF. Formally:

Proposition 11. *Let $\phi = \mathtt{p}\beta > 0$. We find that:*

a. *For a contract T $\exists$ $\bar{\phi}_T$ such that the manufacturers can collude under the contract T if $\phi \le \bar{\phi}_T$;*

b. *Under the WPFF contract, the manufacturers are more likely to collude, i.e., $\bar{\phi}_{\mathtt{WPFF}} > \bar{\phi}_{\mathtt{RS}} = \bar{\phi}_{\mathtt{QD}} = \bar{\phi}_{\mathtt{MOQ}} = \bar{\phi}_{\mathtt{WP}}$.*

6. Discussion

This paper examines the effects of a decades-old yet still influential U.S. Supreme Court antitrust ruling, *Illinois Brick*, according to which only immediate (direct) purchasers are entitled to sue for damages due to antitrust behavior. Essentially, as observed by the Court, the ruling saves the administration from incurring the astronomical costs that would result from a multitude of antitrust cases were *any* downstream indirect purchaser is permitted to file a claim for antitrust injuries. This ruling, however, can also encourage anticompetitive actions among the upstream firms. It can act as a legal shield for colluding firms if they can eliminate the threat of a lawsuit arising from the direct purchasers. Uncovering instances where the IB decision is being exploited in this way would require an increase in public enforcement efforts (e.g., monitoring by federal agencies). This finding presents a conundrum: how to retain the much desired judicial cost efficiency that resulted from excluding indirect purchasers, but at the same time not increasing the costs of complementary public enforcement? We address this challenge by adopting the supply chain perspective to identify interactions – between upstream firms and their direct purchasers – that flag the potential of IB ruling exploitation by the upstream firms to collude. Identifying such interactions should simplify public enforcement considerably by prioritizing case selection for monitoring and auditing purposes.

We use a three-tier supply chain model comprised of the manufacturers, retailers (direct purchasers), and consumers (product end users) to assess the collusion-facilitating ability of five commonly used supply chain contracts. The form and terms of a contractual agreement not only mold

[13] For example, in the U.S. under the Sherman Act of 1890, the compensation towards antitrust injuries can be trebled as a measure of deterrent (*The Yale Law Journal*, 1929).

the interactions among supply chain members by affecting their respective incentives, but also – in conjunction with exogenous conditions (e.g., market structure and demand uncertainty) – determine how the supply chain's collective profit is allocated. These embedded features collectively shape preferential ranking of contractual agreements among supply chain members.

We study five commonly used procurement contract structures – namely, the wholesale price, revenue-sharing, quantity discount, minimum quantity discount, and wholesale price plus fixed fee contracts. Collectively, they encompass a variety of contracts used in the extant OM literature to examine both the serial and non-serial supply chain settings. They also map to other contracts such as buy-back and linear channel rebate under deterministic demand scenario; a scenario that suffices, in our context, to determine collusion-facilitating ability of a contractual structure.

We find that five focal contracts are considerably distinct in their ability to facilitate collusion. In particular, no collusion is feasible under the wholesale price, minimum order quantity, revenue-sharing, and quantity discount contract. Under any of these contracts, retailers will take legal action if they observe collusive behavior by manufacturers. In contrast, the WPFF contract facilitates collusion with a fixed payment from manufacturers to retailers (also called, slotting fees). It is interesting that, although the quantity discount contract (by definition) includes a similar directional payment feature, this contract does *not* facilitate manufacturer collusion. The reason is that the contract's discount feature, unlike the slotting fee, is tied to the retailers' quantity decisions. In other words, the slotting fee feature imparts an additional flexibility to the manufacturers' in influencing the retailers' quantity decision, without tying it up with the allocation of the resultant supply-chain profit.

We find that the collusion-sustaining ability of WPFF contracts increases with demand uncertainty and competition among retailers, but decreases with competition among the manufacturers. Finally, we establish that the WPFF continues to be the preferred contract type for collusion under IB ruling in three alternative market settings: (i) the manufacturers offer differentiated products, (ii) the manufacturers make endogenous contract choices when competing, and (iii) the retailers exhibit limited ability to recognize antitrust injuries.[14] Public enforcers of antitrust regulations can exploit these findings to improve case selection by focusing on supply chains that manage the procurement process via WPFF contracts with the slotting fees feature, especially for categories of products whose demand is highly uncertain. Likewise, public enforcers should also focus on cases wherein the slotting fee feature appears in atypical form, for example augmenting other contract types (e.g., quantity discount), since it can be exploited to facilitate collusion.

[14] The analysis can be extended to show that the WPFF contract remains to be the preferred contract type for collusion in markets with no IB ruling and limited ability of consumers to recognize antitrust injuries

This paper contributes to the operations management literature in several ways. First, it shows that the preferences of supply chain members with regard to contractual agreements can be affected in unanticipated ways by the prevailing regulatory framework. This finding complements previous research documenting market structure and financial preferences as factors that result in differential preferences for otherwise equivalent contracts (Cachon and Kök 2010, Jain et al. 2013). Second, we show that, despite the failure to coordinate channel decisions, there may exist conditions under which the wholesale price contract may lead to an increase in consumer and total surplus compared to more sophisticated coordinating contracts. This result complements the growing literature that supports the use of simple wholesale price contracts in practice. Finally, our analysis postulates a novel reason for the existence of slotting fees in the real world. We find in particular that, besides such extensively studied factors as demand uncertainty, screening and information-sharing advantage, slotting fees may exist because they facilitate collusion among manufacturers within the IB ruling's ambit. Our finding highlights a potential negative use of the slotting fee feature in supply chain interactions.

This paper uses a parsimonious supply chain model to evaluate the collusion-facilitating ability of contract structures. In a similar vein, an interesting avenue that merits further exploration would be to identify supply chain features, such as the network structure of upstream members, that encourage or discourage firms from colluding in the post-IB setting. In addition, the result that slotting fees serve as a mechanism for collusion provides grounds for a comprehensive empirical work to test usage of slotting fees in various U.S. states that continue to persist with the IB ruling. Note that this paper does not speak to the controversy around the merits or demerits of debarring the indirect purchasers from lawsuits. Finally, we hope that this work will inspire other scholars to apply an Operations Management lens to strengthen antitrust regulation.

In conclusion, the IB-induced conundrum highlights the constant striving of policymakers worldwide to balance the responsibilities of public and private enforcers (Brodley 1995, Segal and Whinston 2006, McAfee et al. 2008). In the 2001 remarks of Mario Monti, European Commissioner for Competition Policy, creating that balance is a central tenet for framing antitrust reforms; such reform "should enable us to make the most of the complementary functions of the public and private enforcement of the competition rules."[15] On the one hand, antitrust regulation that favors greater participation by private enforcers burdens the judicial system and thus increases legal costs. On the other hand, if the role of private enforcers is restricted, then policymakers may either need to increase the level of regulatory monitoring (and hence bear higher administrative costs)[16] or suffer

[15] M. Monti, *Effective Private Enforcement of EC Antitrust Law*, Sixth EU Competition Law and Policy Workshop, June 2001, http://bit.ly/2N2NwIu (accessed 20 April 2018).

[16] In a recent report to the U.S. Congress, the Office of Management and Budget estimated the administrative cost of the country's 129 major regulations to be between $74 billion and $110 billion (in 2014 dollars) over the 10-year period from 2005 to 2014 (Competitive Enterprise Institute, Annual Survey, 2017).

the adverse consequences of anticompetitive behavior in the market. We hope that our paper helps reduce administrative burden of policy enforcement by exposing conditions that are likely to lead to collusive behavior.

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Appendix A: List of Notations

Table 3 summarizes the notation used in the paper.

Table 3 Notation

i; j	subscript to represent Retailer R; subscript to represent Manufacturer M
a	stochastic intercept of the downward-slopping linear demand function with the expected value as $\bar{a}$, and realized value as $\tilde{a}$
$f; F$	a's PDF; CDF
p	per unit selling price
b	price sensitivity parameter in demand function
c	constant marginal production cost
$\hat{q}_{ij}$	optimal purchased quantity
$\tilde{q}_{ij}$	optimal sold quantity
$\hat{q}_i$	retailer i's combined quantity purchased from the two manufacturers
$\tilde{q}_i$	retailer i's combined quantity sold in the market
Q	combined purchased quantity of the two retailers (*akin* supply chain quantity)
r_{ij}	revenue earned by the retailer i through selling quantities purchased from the manufacturer j
$T(\mathtt{v}, \hat{q}, r)$	Retailer's payment under contract T and payment terms $\mathtt{v}$
$\mathbf{v}$	payment vector denoting the two manufacturers' payment terms, $\mathbf{v} = [\mathtt{v}_1, \mathtt{v}_2]$
$\pi(\mathbf{v})$	Retailer profit
$\Pi(\mathbf{v})$	Manufacturer profit
Ω	Total Supply Chain Profit
$CS(\mathbf{v})$	Consumer surplus
C; A; $\mathcal{A}$	Superscript denoting competition scenario; collusion with the IB ruling scenario; collusion without the IB ruling scenario.
N; M	Number of competing retailers; number of competing manufacturers
θ	joint market potential of partially substitutable products
γ	partial substitutability parameter
$\mathtt{p}$	the retailers' likelihood to recognize collusion losses and, consequently, file an antitrust suit against the colluding manufacturers'
β	a penalty multiplier on the legal and compensation cost that the manufacturers' are liable to pay when facing the retailers antitrust suit