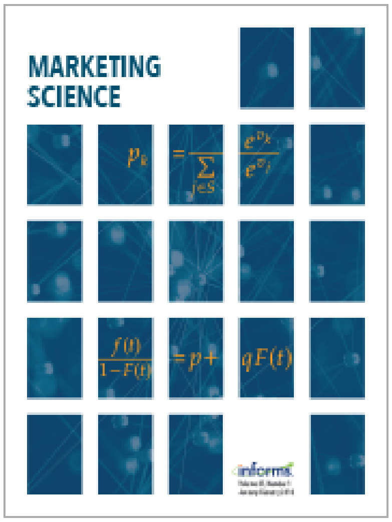


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# Equilibrium Returns Policies in the Presence of Supplier Competition

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The pioneering Pasternack returns-policy model analyzed channel coordination with a single supplier catering to a retailer facing stochastic demand for a perishable product with a fixed price, and the model showed that giving partial returns of unsold stock to the retailer is the optimal policy for the entire supply chain. The result thus begs the question as to why manufacturers of perishable commodities widely accept full returns of unsold stock as the norm. We model the environment as one where two capacity-constrained manufacturers compete for shelf space with the same retailer, and we show that a complete-credit returns policy is in fact the only possible equilibrium of the game. Our results obviate the need for knowing the exact functional form of the demand distribution in order to compute the returns credit, as Pasternack's results would require. From a retailer's standpoint, we establish a simple procurement strategy and show that it is optimal. The same game with price-only contracting has a pure-strategy equilibrium when the supplier capacities are below a threshold value and a mixed-strategy equilibrium when the supplier capacities cross this threshold but are still so limited that no single supplier can with certainty supply all the quantity demanded.

*Key words*: channel coordination versus channel competition; newsvendor problem; vertical control; returns policies; perishable goods; procurement strategy
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## 1. Introduction

In one of the classic and oft-cited papers (Shugan 2008) in channel management by Barry Alan Pasternack (1985, 2008b), the author analyzed the channel-coordinating pricing strategy for a retailer facing stochastic demand of a "perishable" commodity, when the supplier (or manufacturer) can optionally allow for full or partial credit for unsold goods.[1] Other papers have extended the original model and its implications (Pasternack 2008a).

We begin by discussing some specific characteristics of the model setup. First and foremost, it involves perishable goods, which implies that there is minimal salvage value for the unsold items. Every new period will involve a fresh supply of the good because the value of the excess inventory from the previous period is negligible. Even if there were demand for remaindered stock (as is the case with fashion goods like garments or handbags that are sold at steep markdowns to their original prices in discount stores after their main "season" is over), such demand would usually be generated from a possibly different set of consumers. Consumers who buy fashion merchandise at the height of the fashion season would probably not want to be associated with those goods once they go out of fashion and therefore would not materially affect the demand for the fresh set of goods in the subsequent period. In other words, the implications of the setup can be effectively analyzed in a single-period game (whereas a multiperiod game posits scenarios when the actions in period $t$ have some carryover effect in period $t+1$).[2] The model setup also assumes stochastic demand—if the demand were known with certainty, there would be no need for any returns.

One of the assumptions of the original model—and in much of the literature that looks into issues involved in vertical contracting of this nature—is that there is a single manufacturer (supplier) that *coordinates* the supply chain with an exclusive retailer

[1] Pasternack defines a perishable commodity as one that has "short shelf or demand life" (1985, p. 166), such as newspapers, baked goods, periodicals, and items that come "in fashion" for a limited period of time, such as garments or compact discs. We follow Pasternack in the use of the term "perishable" (i.e., to refer to the class of products that exhibit similar characteristics) rather than in its literal sense.

[2] In §4, we hypothesize a two-period game within a single season, but there too, the environment can be analyzed effectively by invoking a single-period model twice (the second invocation is optional, depending on how the demand shapes up later into the season) because the first subperiod does not (and by design cannot) involve any returns.

for the product.[3] These days, it is more common to find examples where large retailers like Walmart interact with multiple suppliers and, in fact, pit suppliers against one another in a reverse auction environment because such a market setting promotes "price savings and can simplify and support negotiation" (Jap 2003, p. 97). In fact, there can be no coordination between the retailer and a manufacturer if the latter is competing with another manufacturer and the former, thanks to its monopsony power, is expecting to profit from such a competition.

In this article, we explore the competition between two suppliers vying to become the primary supplier for a retailer in a newsvendor setting that harks back to the original Pasternack framework. This single change in the model setting—introducing competition among the suppliers—alters the fundamental dynamics of the Pasternack model. We no longer seek an overall channel-coordinating strategy. Rather, we look for the equilibrium strategy in a competitive setting involving two competing manufacturers vying to be the "preferred supplier" for a retailer that, in turn, is trying to maximize its own expected profit from the trades that ensue. Complications arise in the analysis because it can be reasonably assumed that all three market agents know each other's strategies and have to incorporate them in deciding their own.

In his paper, Pasternack pointed to several examples of manufacturers of perishable goods that offer full credit for unsold items, and based on the analysis therein, suggested that such return policies are "suboptimal" (Pasternack 1985, pp. 166) in nature. It is difficult, however, to comprehend why manufacturers would persist with such suboptimal strategies over time (we tentatively call this the "Pasternack paradox"). For present purposes, we conducted a survey of several industries that deal with perishable products, and this consisted of both a literature survey as well as interviews with industry executives and supply chain professionals with several years of experience in perishable products. These findings are summarized in Table 1. In a range of industries that include, among others, newspapers and magazines, perishable processed foods, and fashion cosmetics, the evidence suggests a widespread acceptance of the seemingly suboptimal practice of allowing full credit for unsold stock.

In light of such empirical evidence, our results suggest an explanation for the Pasternack paradox: notably, it is rarely, if ever, that manufacturers of perishable commodities have the luxury of being the single supplier to a retailer and thus get to coordinate the channel with the retailer. Rather, they are almost always in competition with other suppliers in their bid to be the preferred supplier. In such an environment, offering full credit is indeed the only viable policy, and it is the effect of this competition, rather than inefficient channel coordination, that we observe empirically.[4]

The sellers compete on price and credit terms for unsold stock. The sellers supply an identical product; thus the retailer's decision to favor one supplier over the other is driven purely by profit considerations.[5] The strategies employed by the suppliers must resolve the dilemma between announcing a high price coupled with a generous returns policy on the one hand and a low price but a relatively unattractive returns policy on the other. The pricing and production decisions of the firms are intertwined: a change in one firm's price or quantity has an immediate impact on that of the other. Allowing credit for unsold goods introduces an extra dimension because it pays the retailer to *sell goods from the supplier with the more stringent returns credit terms first*, a fact that may be assumed to be common knowledge among rational agents who would therefore incorporate this knowledge in their best responses.

The problem of vertical contracting and horizontal competition between suppliers is one that has not been fully explored in the literature, all of which either assumes a monopolist manufacturer or supplier. Moreover, the literature assumes that if there is competition between manufacturers, such competition is restricted *downstream*, because retailers in these models do not carry products from competing manufacturers. In contrast, we explore the competition that exists *upstream* between manufacturers of perishable goods when they are competing for preferred status with the *same* retailer. Unlike retailers that team up exclusively with one manufacturer, the reality in much of the retail world today is that of big-box stores like Walmart or Target that will almost always carry items from competing manufacturers. Furthermore, these items then occupy the same set of shelves within the store and are viewed by consumers as substitutes. Our analysis extends the understanding of such upstream competition. Our main structural results can be extended from a duopoly to an oligopoly with more than two suppliers, but for the sake of simplicity, we restrict our analysis to a duopoly.

[3] We use the words "manufacturer" and "supplier" interchangeably.

[4] Given the variety of examples cited in Table 1, it is possible that in some specific cases there might be explanations other than manufacturer competition behind the full-credit policies adopted by the manufacturers.

[5] It is assumed that the retailer, for the purposes of returning any unsold product, can identify the manufacturer of a unit of the product—say, by a barcode.

**Table 1 Summary of Findings of Returns Policies in Different Industries Dealing with Perishable Products**

1. Garnier (maker of the L'Oréal brand of cosmetics) has been known to refund about "one-third of gross sales" in 1998. "Although the return percentage of 30% is high, it is not exceptional" (Kuik et al. 2005).
2. Jim Mason, a supply chain professional with over 18 years of experience delivering optimized results to corporations like Nestle, Sanyo Logistics Corp., LG Electronics, and others in multichannel product distribution, and most recently Vice President, Distribution Operations at Retail Service Associates (interviewed over e-mail): "Major retailers have been known for negotiating full credit on some seasonal items."
3. Director of the supply chain of a large UK-based magazine distributor both within the United Kingdom as well as internationally (interviewed over e-mail): "We work in what is a full sale or return environment across magazines. There are only very limited exceptions where returns are not accepted on very small and specialist business titles where the same copy is purchased from the same retailer each issue. Sale or return works in our industry due to nature of the products, and the high volatility of sale across retailers and by each individual issue of a magazine. Volatility is driven by the fact that each issue of every individual magazine is in itself a very different product—due to the nature of promotions/front cover/editorial content/seasonality/impact of competitor activity and the fact that magazines have a fixed shelf life depending on their frequency—i.e., weekly or monthly. Magazines sales cannot be forecast in a traditional way on a product that stays the same in content throughout the year, and in order to maximize the availability and sales of each individual issue we operate full sale or return for the retailers. To add to this volatility, consumers typically have a repertoire of magazines from which they purchase and a range of retailers they buy from. Again, this adds to the complexity of forecasting and to maintain high availability across a broad range of retailers for each very different and unique issue of magazine, the publisher invests in the risks of full sale or return."
4. Vikesh Wallia, Deputy Director of Bennett, Coleman and Co. (Bennett, Coleman and Co. publishes the *Times of India*, the largest circulating English daily in the world, and *The Economic Times*, India's largest financial daily, three other dailies in local languages, and 31 magazines), who is in charge of distribution for all *Times of India* publications (interviewed over e-mail): "... this is true for magazine and newspaper business all over the world including India and for us too."
5. Kalmbach Publishing Co., which publishes over 70 magazines for different kinds of hobbyists, lists their return policies on http://retailers.kalmbach.com/tss/default.aspx?c=ss&id=36: "U.S. and Canadian retailers are able to receive full credit for unsold magazines for up to six months from cover date."
6. Shantanu Bose, Vice President, Global Sourcing and Operations at School Specialty, an education management company headquartered in Wisconsin (interviewed over e-mail): "In our industry of School and Office supplies, it is typical to return unsold items to manufacturers. In fact many manufacturers who wish to launch their private label products through our catalogs provide us with adequate inventory so as not to miss any sales—and then at the end of the year, they take back unsold inventory for full credit."
7. Keith Fernandez, a principal consultant at LCP Consulting Ltd. (multiple interviews over e-mail): "I work for LCP Consulting and I have worked with the magazine and wholesale business on a number of projects around the supply chain and commercial framework. Most publishers work on 'Sale or Return' where unsold copies are credited through to the retailer. Other industries that where I have seen this is Fashion and Drinks."
8. K. K. Chutani, Senior General Manager, Foods Products Division, Dabur Ltd. (Dabur is the fourth-largest company in India with interests in health care, personal care, and food products; their Réal brand of fruit juices is the number 1 fruit juice brand in India) (multiple interviews over e-mail): "Many fruit juice companies in India do so."
9. A distribution model that is becoming very popular among well-known, fast-moving consumer goods manufacturers like Coca-Cola or Pepsi is the direct store delivery (DSD) model. Here, the manufacturers get directly associated with the retailer for stocking the latter's shelves and creating promotions around local events (like football games) and get paid only for what is sold. The advantage for the manufacturer includes better shelf displays that frequently translate into higher sales (Grocery Manufacturers Association 2008). This has similarities to the vendor managed inventory (VMI) model, where the manufacturer takes care of the inventory and therefore takes back every unsold item.
10. John G. Herndon, integration consultant (interviewed over e-mail): "I have reviewed the sales cycle and distribution channel for several companies. The problem you describe is very pervasive much more than is generally known or acknowledged in the marketplace. Most manufacturers will generally look the other way when their distributors 'deduct' from invoices. Basically, the underlying principle behind this practice is: 'it's cheaper to keep her.'"
11. We finally mention pharmaceuticals, but without direct proof—many interviewees thought that this was common practice for expired drugs but did not have direct experience to corroborate their beliefs.

## 2. Literature Review

We now briefly review the marketing, economics, and operations management literature that model price and quantity interactions in a retailer–supplier newsvendor framework. Table 2 summarizes the various streams in the literature on channel decisions that have points of contact with our work and the crucial modeling assumptions made therein. Coughlan and Wernerfelt (1989), in particular, have remarked that results on channel decisions can often be traced back to the specific assumptions that were made in the modeling, and our aim in Table 2 is to place our research in the context of both the extant literature and their modeling assumptions.

There is a wealth of knowledge in the extant marketing literature on channel structure, so much so that there is at least one established textbook on the subject (Coughlan et al. 2006). Some early research concerned itself with one central question: Should a manufacturer act as its own distributor or use a retailer (e.g., Scherer and Ross 1980, Williamson 1983, Williamson 1998)? Another stream of research looked at single-manufacturer channel models of competition and coordination, with Jeuland and Shugan (1983) arguing that coordination in a marketing channel is the optimal behavior. Their paper formed the foundation of several subsequent studies on the subject, such as Shugan (1985), Moorthy (1987), and Jeuland and Shugan (1988).

Several papers have investigated competition between manufacturers and their channel choices. The seminal article in this area is by McGuire and Staelin (1983), who model two identical manufacturers who must decide whether to integrate into retailing or

**Table 2 Key Literature on Channel Decisions and Related Modeling Assumptions**

<table>
<tr><td colspan="3">On the manufacturer's choice of using a retailer or distributing himself<br>Scherer and Ross (1980), Williamson (1983, 1998)</td></tr>
<tr><td colspan="3">On manufacturer decisions of competition and coordination</td></tr>
<tr><td colspan="2">Single-manufacturer models</td><td>Oligopoly manufacturer models</td></tr>
<tr><td colspan="2">Jeuland and Shugan (1983), Shugan (1985), Moorthy (1987)</td><td>McGuire and Staelin (1983, 1986), Coughlan (1985), Moorthy (1988), Coughlan and Wernerfelt (1989), Gal-Or (1992)</td></tr>
<tr><td colspan="3">On quantity discount and channel coordination<br>Lal and Staelin (1984), Monahan (1984), Weng and Wong (1993), Weng (1995), Taylor and Xiao (2009)</td></tr>
<tr><td colspan="3">On vertical control and use of vertical restraints<br>Rey and Tirole (1986), Gal-Or (1991, 1992), Deneckere et al. (1997)</td></tr>
<tr><td colspan="3">Modeling assumptions: A retailer is exclusive to a manufacturer, manufacturer is in control of supply chain, and downstream competition (if any) between retailers.</td></tr>
<tr><td colspan="3">On uncertain demand and accepting returns</td></tr>
<tr><td colspan="2">On credit for unsold stock</td><td>Other issues with uncertain demand</td></tr>
<tr><td>Why manufacturers might accept returns</td><td>Returns and credit for unsold stock</td><td rowspan="2">Butz (1997), Cachon and Zipkin (1999), Mantrala and Raman (1999), Cachon and Fisher (2000), Dana and Spier (2001), Cachon and Lariviere (2005)</td></tr>
<tr><td>Pellegrini (1986), Marvel and Peck (1995), Kandel (1996), Granot and Yin (2005)</td><td>Pasternack (1985), Padmanabhan and Png (1997, 2004), Tsay (2001), Sarvary and Padmanabhan (2001), Wang (2004), Chen (2007), Lau et al. (2007)</td></tr>
<tr><td colspan="3">Modeling assumptions: Single manufacturer, manufacturer controls supply chain (except Lau et al. 2007), and downstream competition (if any) between retailers.</td></tr>
<tr><td colspan="3">This paper: Retailer controls supply chain, multiple manufacturers compete for same retailer, and upstream competition between manufacturers.</td></tr>
</table>

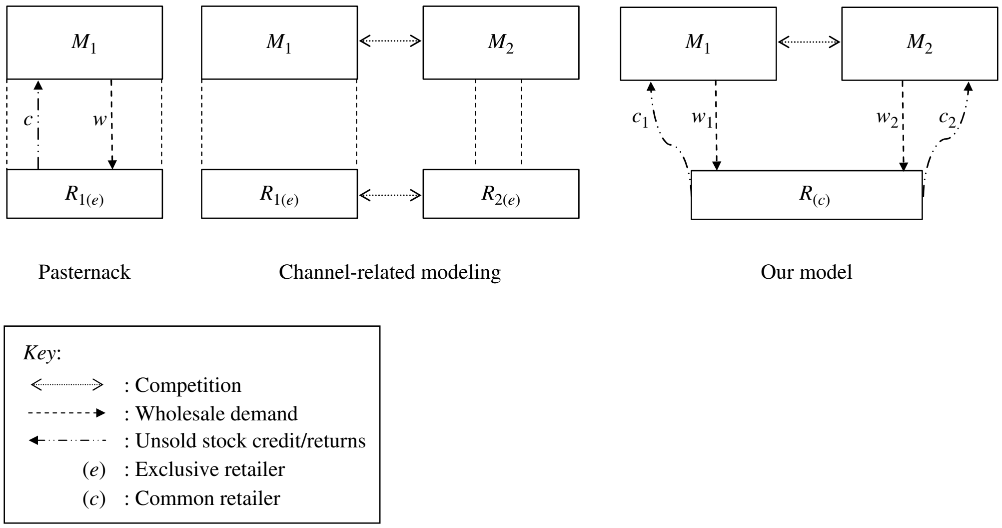
sell their products through an exclusive independent retailer. Several other papers used a similar modeling construct to extend research in this area, including Coughlan (1985), Moorthy (1988), and McGuire and Staelin (1986). Coughlan and Wernerfelt (1989) countered results that tried to explain channel delegation decisions as a profit-maximizing strategy, and they showed that devoid of some crucial assumptions, channel delegation has no effect on manufacturer profits. Gal-Or (1992) investigates the incentive of duopolistic manufacturers to integrate with a downstream agent for distribution purposes. In all these papers, the central assumption is that *retailers do not carry items from competing manufacturers*, and it is the manufacturers that control the supply channel and the decisions therein.

There has been extensive research on the phenomenon of quantity discounts offered by manufacturers to retailers and their effect on channel coordination, including Lal and Staelin (1984), Monahan (1984), Weng and Wong (1993), and Weng (1995).

Padmanabhan and Png (1997) investigated the effect of offering credit on unsold stock on the competition among retailers. For analytical tractability, the competition between the retailers was limited to two firms. The same stylized framework of a single manufacturer with one or two retailers was later carried over in several variants of the model, for example, by Sarvary and Padmanabhan (2001), Wang (2004), and Padmanabhan and Png (2004). A similar setting is also applied by Tsay (2001), who analyzes the phenomenon of "markdown money" handed out by manufacturers to the retailers in order to suppress product returns, and by Taylor and Xiao (2009), who compare the use of rebates (for units sold) vis-à-vis returns (for unsold stock) with an option for the retailer to employ costly forecasting and find the latter strategy to be superior. All these papers emphasize competition (if any) among retailers, with a single upstream manufacturer (or supplier).

Other papers investigating supply chain issues in the face of uncertain demand include Butz (1997), who considers the effect of competing retailers on a monopolist manufacturer's profit and the latter's choices to maximize profit. Cachon and Zipkin (1999) investigate the interactions between a manufacturer and a retailer in setting inventory levels, and Dana and Spier (2001) find that revenue sharing reduces retailer price competition without distorting the retailer's inventory decisions in the video rental industry. Cachon and Lariviere (2005) compare revenue sharing between a manufacturer and a retailer with different types of supply chain contracts, and Cachon and Fisher (2000) investigate how the use of shared information between a single supplier and many identical retailers (through the use of information technology) can help in reducing supply chain costs. Mantrala and Raman (1999) consider the interactions between a manufacturer and a retailer that has multiple stores.

**Figure 1** Comparing Pasternack (1985) and General Channel-Related Modeling Constructs with the Current Model




Our model also has some points of contact with recent work by Chen (2007), who studies optimal mechanism design in a newsvendor setting, and Lau et al. (2007), who study contract design between a dominant retailer and a supplier.

As was pointed out by Coughlan and Wernerfelt (1989), the conceptualization (and consequently the results) of the models employed in the literature rest on certain specific assumptions. In contrast to the existing literature that assumes that the source of market power in the channel lies with the manufacturer (whether it is a monopoly or an oligopoly), we look at situations where the retailer is in charge of the channel, which is often a reality with today's big-box stores such as Walmart or Target. Instead of having exclusive contracts with a single manufacturer, such stores will almost always carry items from competing manufacturers and that occupy the same set of shelves. From a modeling perspective, this translates into having the oligopolistic manufacturers *competing for business with the same retailer*, which has not been modeled in the extant literature.[6] In Figure 1, we present this contrast visually by showing how our model differs from that of Pasternack, as well as the key literature that models strategic interaction in channels.

In the following two sections, we first posit the mechanism of trade and then study the equilibrium that ensues. Our final section concludes with an explanation of our findings and some ideas for further research.

[6] Padmanabhan and Png (1997) mention in their introduction how retailers carry products from more than one manufacturer, but their model considers the effect of two retailers competing for a product from the same manufacturer, effectively ceding control of the channel to the latter. We model the problem in reverse: notably, two manufacturers competing for shelf space of a retailer that is in charge of the channel.

## 3. Equilibrium Returns Policy in a Duopoly

We model the competition between two suppliers that compete for a retailer's business not only on prices but also on the amount of credit issued for every unsold unit. For simplicity, we restrict the main line of the analysis to the case of two retailers although the main equilibrium result (Proposition 1) carries over—as we shall explain later—to the case when there are an arbitrary number of suppliers.

The setting of the game is as follows: there are two suppliers (manufacturers), each with a capacity constraint $k$ and (without loss of generality) marginal costs that are normalized to zero[7] (we note that the assumption of capacity constraints for suppliers dealing with perishable goods with an uncertain market is a realistic one). The wholesale price is denoted by $w_i$ ($i = 1, 2$), and the refund (or credit) for every unit returned by the retailer is denoted by $c_i$ ($i = 1, 2$). Let the quantities supplied by the two suppliers be $Q_i$, $i = 1, 2$, $Q_i \leq k$, and let the retail price be $p$. Retail demand is a nonnegative random variable $D$ with distribution function $F$. We model this interaction between the two suppliers as a sequence of moves $G(w_1, c_1, w_2, c_2)$.

1. The suppliers simultaneously announce a wholesale price and a per-unit credit to the retailer, which can be implemented by opening the bids from the suppliers at the same time, for example.

[7] Our main structural results apply when the suppliers have different costs and capacities, as we explain in the course of the proofs of these results in the appendix.

2. The retailer announces the quantity to be purchased from each supplier.

3. Retail demand is realized.

Suppose the retailer acquires $Q_1$ and $Q_2$ units from suppliers 1 and 2, respectively. Suppose, without loss of generality, that $c_1 > c_2$. Because all units are identically priced at the retail level, *it is optimal for the retailer to sell units sourced from supplier* 2 *before those sourced from supplier* 1—doing so ensures that the retailer maximizes the total credit obtained for unsold units. We assume it is common knowledge that this is the optimal selling strategy for a rational retailer. In particular, the manufacturers know this, and this knowledge of the retailer's optimal selling strategy may be expected to feed back into their equilibrium pricing and credit decisions.

Suppose the combined capacity of the manufacturers is so low that the minimum of the support of the demand distribution is higher than that combined capacity. This situation can exist if the manufacturers and suppliers have shared information technology that can lead to sharing of demand and inventory data, as in Cachon and Fisher (2000). In this case the manufacturers will supply to capacity, there will be no returns, and the wholesale price will equal the retailer's selling price. In the analysis that follows, we assume that the combined capacity is such that there is a positive probability of a return from the retailer to at least one manufacturer. In other words, the combined capacity of the two manufacturers is greater than the minimum possible value of demand, and therefore there is a positive probability that at least one manufacturer would be forced to accept returns.[8]

We begin our analysis by making three immediate inferences about the nature of the equilibrium governing this game.

1. There is no nontrivial pure-strategy equilibrium. If one supplier decides on an arbitrary wholesale price $w^*$ and offers a credit of $c^*$ (in other words, if $(w^*, c^*)$ is a valid pure strategy, with $w^* \geq c^*$ by definition), then the best response by the other supplier is to deviate from that strategy as follows: either offer an infinitesimally lower wholesale price (i.e., the combination $(w^* - \varepsilon, c^*)$) or an infinitesimally better returns credit $((w^*, c^* + \delta))$. Either of these responses would increase the deviating supplier's profit by a strictly positive number because the retailer would then procure as much as possible from that supplier and only procure a residual amount from the other supplier. This shows that there can be no pure-strategy equilibrium with nonzero wholesale prices.

2. The game has one trivial and unsatisfactory pure-strategy equilibrium: $w_1 = c_1 = w_2 = c_2 = 0$, in which case neither supplier makes any profit. If either supplier deviates from this strategy, the best response by the other is to either offer an infinitesimally lower wholesale price or an infinitesimally better returns credit, and doing so would increase the latter's profit by a strictly positive amount because the retailer would then procure as much as possible from the latter and only procure a residual amount from the former supplier. This shows that the strategy is indeed a Nash equilibrium.

3. Because an infinitesimally small change in price or credit can leverage a nontrivial increase in the deviating supplier's expected profit, we have a game in which the payoffs have "complementary discontinuities," the defining criterion for which in informal terms is "that if one agent's payoff drops down in the limit, another agent's must jump up" (Simon 1987, p. 571).[9] It follows from Dasgupta and Maskin (1986) that such a game has a Nash equilibrium in mixed strategies. (Recall that for games in which the strategy spaces are infinite sets—as is the case with the returns game—the existence of even a mixed-strategy Nash equilibrium is not in general guaranteed.) Thus, the only nontrivial equilibrium of the returns game is in mixed strategies. *This is in contrast to the case when there is a single manufacturer, in which case there is a nontrivial full-credit pure-strategy equilibrium* (Tsay 2001).

We proceed to obtain a more detailed characterization of the equilibrium of the returns game. The retailer's problem takes the following form:

$$\begin{aligned}\max_{Q_1,\,Q_2}\ & E\{p\min(D, Q_1+Q_2) - w_1Q_1 \\ & \quad - w_2Q_2 + c_2(Q_2-D)^+ \\ & \quad + c_1[(Q_1+Q_2-D)^+ - (Q_2-D)^+]\} \\ \text{subject to}\ & Q_1 - k \leq 0, \\ & Q_2 - k \leq 0.\end{aligned}$$

This formulation incorporates the retailer's optimal strategy of selling off units from the lower-credit supplier first. Solving the optimization problem (see the appendix for the proof) yields

$$F(Q_1+Q_2) = \frac{p-w_1}{p-c_1}, \tag{1}$$

and

$$F(Q_2) = \frac{w_1-w_2}{c_1-c_2}. \tag{2}$$

[8] Such an assumption is reasonable, because the manufacturers will have a strong incentive to increase capacity in an environment where the added production can be sold with certainty at the highest possible price.

[9] A sufficient condition for complementary discontinuities that can be neatly and formally stated is that the sum of the players' payoffs be upper semicontinuous; this condition is satisfied for our game. Simon's formal definition is cumbersome to state because it involves limits of approximating sequences of strategy spaces.

The optimal solution to the retailer's problem is either a simultaneous solution to Equations (1) and (2), or it is a point on the boundary of the feasible region (which is a rectangle). However, we can give a sharper characterization of the equilibrium on the strength of the following structural result on returns policies, which extends the single-supplier equilibrium derived by Tsay (2001) to the case of oligopolistic competition. All proofs are relegated to the appendix.

Proposition 1. *A full-credit returns policy is the unique mixed-strategy Nash equilibrium of the game when there are two or more suppliers. There is no pure-strategy equilibrium. Specifically, either manufacturer would choose a wholesale price between the retail price* $p$ *and* 0 (*or the higher of the marginal costs with asymmetric suppliers*) *randomly and offer a full credit for every unsold unit of the product. The results hold true even with asymmetric suppliers.*

This proposition is particularly interesting when we examine it in light of a single-manufacturer–single-retailer channel. In the case of a single supplier there is no channel-coordinating full-credit returns policy (Pasternack 1985). According to Pasternack, the manufacturers were pursuing suboptimal strategies in offering full credit for all unsold goods. The partial returns policies suggested by Pasternack, however, are not equilibrium contracts; they are credible only when one party owns the entire manufacturer–retailer supply chain. Moreover, manufacturers often compete to be the retailer's preferred supplier. In that case, offering full credit for unsold goods is the sole equilibrium strategy.

In light of this full-credit policy, one possibility for the retailer might be to simply order as large an amount as possible from both retailers. Although our model abstracts away the implications of such an outcome, a retailer in real life would be dissuaded from such an action because of the associated costs—e.g., the inventory-carrying cost and the opportunity cost for the shelf space apportioned to the possibly excess inventory. For example, the book retailer Barnes and Noble has consignment contracts with publishers for many of its books, but it does not order unlimited quantities because displaying a book in-store uses up scarce real estate.[10]

Proposition 2 explores the practical implication of our analysis from the retailer's point of view, because it is the retailer that has to decide which supplier to source from, given two competing bids. The utility of Proposition 2 may be seen from the following reasoning: when acquiring individual units of the perishable commodity from the two manufacturers, it is possible that after acquiring the first few units from, say, Supplier 1, it becomes optimal for the retailer to obtain the next few units from Supplier 2, at which point it again becomes optimal to acquire the subsequent few units from Supplier 1, and so on.[11] Proposition 2 proves that such intermediate "turning points" do not exist, and in fact the only turning point for the retailer to evaluate is when one manufacturer has supplied to capacity.

Proposition 2. *The only possible equilibrium outcome is the following: one supplier supplies up to capacity and the other supplier supplies the residual amount—if any—demanded by the retailer. Because the manufacturers offer full credit to the retailer for any unsold stock, the retailer simply orders first from the manufacturer with the lower wholesale price and follows up by ordering the residual* (*if any*) *from the other manufacturer.*

The profit for selling one unit of the good for either manufacturer is the difference between his wholesale price and his marginal cost. Because at least some units of the good are sold by the retailer (note that the full credit is extended only for unsold stock), the manufacturers make positive profit and therefore have the incentive to participate in the game.

Proposition 2 formalizes the notion that when multiple suppliers compete to win business from a single retailer, in equilibrium they differentiate themselves in the contractual terms they offer, and the retailer is able to identify a "preferred" supplier from which the quantity obtained is maximized. It is worth noting that it is possible for the suppliers to make offers that are not easy to discriminate between. For instance, the competing offers $w_1 = 6$, $c_1 = 3$ and $w_2 = 7$, $c_2 = 3.5$ are not straightforward to evaluate, and there is no obvious reason why such offers cannot be part of a mixed-strategy Nash equilibrium. Proposition 1, however, ensures that if the suppliers use the equilibrium strategy, offers like those in the example above will never be made and the retailer will be able to discriminate between the competing offers instantly. The significance of this point is that discriminating between $w_1 = 6$, $c_1 = 3$ and $w_2 = 7$, $c_2 = 3.5$ *requires precise distributional information* in order for the retailer to determine the preferred supplier, whereas discriminating between the equilibrium strategies does not require the retailer to go through with any sort of complicated computations involving the demand distribution. In practice, the proposition states that if we assume the players to be rational, competing suppliers need not bother with complicated offers of partial credit (or try

[10] We thank the area editor for alerting us to this possibility and suggesting this discussion.

[11] The word "few" can mean as little as one unit. In fact, in the absence of the results of Proposition 2, the retailer should evaluate the two competing bids by carrying out a marginal analysis after acquiring each additional unit of the merchandise.

to offset higher wholesale prices with more generous buyback credit, and vice versa), and they should simply concentrate on giving the best possible wholesale price to the retailer (and a corresponding full credit for all unsold stock).

Taken together, Propositions 1 and 2 have significant implications. First, Proposition 1 establishes that if manufacturers of perishable commodities are competing to be the preferred supplier to a retailer, the only equilibrium is one where unsold goods are credited in full. In contrast to Pasternack (1985), which would require the knowledge of the exact functional form of the distribution to find out the optimal returns strategy, Proposition 1 establishes that such a calculation would not be required at all, because any response other than full credit is not a Nash equilibrium (it is necessary to know the demand distribution function to determine the optimal wholesale pricing strategy). Proposition 2 then simplifies the evaluation of two competing offers from the rival suppliers for a retailer: the preferred supplier is the one that has the lower wholesale price (and a credit for unsold items equal to that wholesale price, by Proposition 1), and the optimal strategy of the retailer would be to source as many units as possible from that supplier. The residual demand, if any, after reaching the capacity of the preferred supplier would be sourced from the second supplier.[12]

## 4. Equilibrium Price-Only Policy in a Duopoly

It is interesting to compare the equilibrium of the returns-policy game with that of the corresponding price-only game, where the suppliers offer no credit for unsold goods ($c_i = 0$). With this change in contractual form, the equilibrium outcomes are qualitatively different. The price-only model may also be motivated by a two-period horizon.

Consider a situation facing the retailer where the item has a random demand with a high coefficient of variation, which makes the retailer wary about the quantity to order. To reduce risk, the retailer decides to break up his forecast of demand for the season into two parts: an early-season estimate at time zero followed by a more informed estimate after the selling season is underway. As a result, the retailer informs the suppliers that it will place an initial (conservative) order, possibly followed by a second order, depending on the demand. It is reasonable to model the early-season demand distribution estimated by the retailer to be such that either manufacturer alone can supply the quantity demanded. We can also model this part of the game as one that is governed by a price-only contract, because the order is conservative and the retailer is confident of selling all of it at least over the entire season. Thus the initial supply may be a price-only equilibrium along the lines of the analysis in this section. The second order, based on the revised estimate of demand, will be a full-credit mixed-strategy equilibrium as analyzed in the previous section.

In this situation the demand estimate is stochastically increasing from preseason to in-season. When demand is stochastically increasing from period to period, it is well known that in the space of "order-up-to" policies without large initial inventories (see Çetinkaya and Parlar 1998), the optimal multiperiod problem reduces to solving each period myopically as a single-period problem.[13] This observation justifies the optimality of our invocation of a single-period model twice to address this two-period extension.

The sequence of moves in the price-only contract is as follows:

1. The suppliers simultaneously announce a wholesale price to the retailer.
2. The retailer announces the quantity to be purchased from each supplier.
3. Retail demand is realized.

The retailer's problem is to compute the quantity to be ordered from each supplier so as to maximize expected profit:

$$\max_{Q_1,\,Q_2} \; E[p\min(D, Q_1+Q_2) - w_1 Q_1 - w_1 Q_1]$$
$$\text{subject to } \; Q_1 \le k, \quad Q_2 \le k.$$

Faced with two suppliers charging wholesale prices $w_1$ and $w_2$ (where $w_1 < w_2$ without loss of generality), a straightforward marginal analysis shows that the retailer's optimal purchasing strategy is the following:

1. If $F^{-1}((p-w_1)/p) \le k$, purchase $F^{-1}((p-w_1)/p)$ from supplier 1 (the low-cost supplier) and nothing from supplier 2.
2. Otherwise, purchase $k$ units from supplier 1 and the "residual quantity" of $\min\{k, \max\{F^{-1}((p-w_2)/p) - k, 0\}\}$ units from supplier 2.

The equilibrium of the game is summarized by Proposition 3.

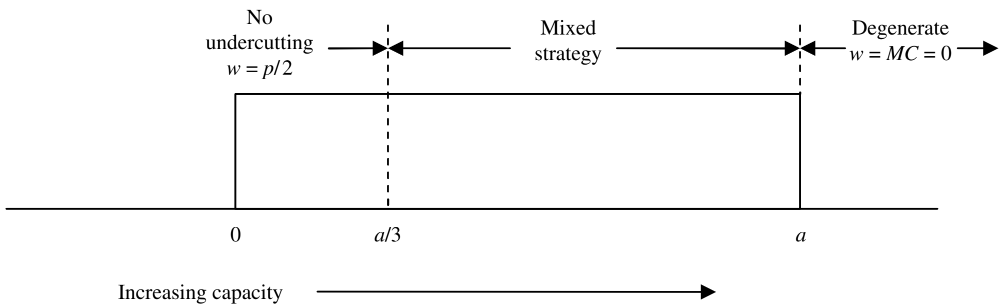
Proposition 3. (a) *When the capacity of each supplier is smaller than a certain threshold value, there is a pure-strategy equilibrium.*

(b) *When the capacity crosses this threshold, there is a mixed-strategy equilibrium.*

[12] We emphasize that our setting solves a single-period game. If the retailer sources the goods from the manufacturers over multiple periods, it is possible that the contracts therein would encourage some measure of price stability. However, such considerations are outside the purview of the current model.

[13] In our case, the initial inventory at the start of the first period is the small initial order, which is by design smaller than a subsequent order, if it materializes. This fact justifies the myopic optimality of our two-period game.

**Figure 2 The Region for Pure and Mixed Strategies in the Game Without Returns Credit**




(c) *When each supplier alone can supply all the quantity demanded, there is no equilibrium.*

We illustrate the nature of the equilibrium in the case when demand is uniformly distributed over $[0, a]$ for any positive number $a$. For the higher-priced supplier charging a price $w_h$, the quantity supplied is $a((p - w_h)/p) - k$. Define $a/p = b$, so that the profit of the supplier at that price where he loses with certainty is $(a - bw_h - k)w_h$. From the reasoning in the proof of Proposition 3, we have $kw_l = (a - bw_h - k)w_h$. Because the supplier tries to maximize the profit he will make at $w_h$, we maximize the expression on the right-hand side of the equation with respect to $w_h$ to get $w_h^* = ((a - k)/2b) = ((a - k)/2a)p$, and hence $w_l^* = (1/ak)((a-k)/2)^2 p$. Equating the two expressions shows that if the capacity $k$ of the suppliers is less than or equal to $a/3$, there is a pure-strategy equilibrium; there is no incentive for either supplier to undercut prices, and each behaves like a monopolist, charging the price $\arg\max_{w_h}[((p - w_h)/p)aw_h] = p/2$ and selling to capacity. When the capacity exceeds $a/3$, the suppliers indulge in a mixed-strategy equilibrium. One can verify that the equilibrium distribution of prices between $(w_h, w_l)$ is characterized by distribution function $\psi(w) = (kw - \pi)/((2k - a)w + bw^2)$, where $\pi = kw_l^* = (p/4a)(a - k)^2$. The corresponding probability density function is $\xi(w) = (\pi - kw)\{2(k + bw) - a\}/\{w(a - 2k - bw)\}^2$. The demarcation between pure- and mixed-strategy equilibria as a function of capacity is depicted in Figure 2, where $MC$ denotes the marginal cost.

## 5. Concluding Remarks

Manufacturers of perishable goods have been widely known to allow full credit for unsold items. The analysis by Pasternack (1985) showed that such a policy is suboptimal if a single manufacturer of the product were coordinating the supply chain with a retailer, which leads us to the Pasternack paradox: Why would such suboptimal policies persist over time? This article tries to provide an alternate explanation to the practice and suggests that such a returns policy might indeed be optimal; in fact, it is the only possible Nash equilibrium.

In contrast to the modeling assumptions in the extant literature on supply chain coordination and/or competition, we analyze a situation where the retailer does not sell products from one manufacturer exclusively. With the ubiquity of big-box stores, we find retailers that almost overwhelmingly stock items from rival manufacturers. In this context, we study the strategic interaction of two capacity-constrained suppliers supplying a single product to a retailer facing random consumer demand. We investigate the equilibrium outcomes in the framework of a single-period time horizon for two different types of trade: a price-only policy and a price and returns policy. In the case of returns policies there is no nontrivial pure-strategy equilibrium, and we show that a full-credit returns policy is the unique mixed-strategy equilibrium. In contrast, the same game with price-only contracting has a pure-strategy equilibrium when the supplier capacities are below a threshold value and a mixed-strategy equilibrium when the supplier capacities cross this threshold, but they are still so limited that no single supplier can supply all the quantity demanded with certainty.

The specific goal of this article limits the scope of the areas for further research, but some intriguing questions do arise. One idea is to explore the characteristics of the game where the retailer, either to placate the anxieties of the supplier or in a tacit realization of the latter's market power, guarantees a minimum order quantity (this may be returned later for credit if a corresponding consumer demand is not realized) to be ordered from one of the suppliers. A second interesting research question would be to invert the original question and explore the possibility of a collusion between the suppliers in industries that are characterized by few players and price opacities (e.g., pharmaceuticals). However, such considerations are beyond the scope of the present article.

### Appendix. Proof of the Optimal Solution to the Retailer's Procurement Problem

Denote the capacity constraints as $g_1(Q_1, Q_2) = 0$ and $g_2(Q_1, Q_2) = 0$. Note that nonnegativity constraints for

$Q_1$ and $Q_2$ are redundant. Denote the retailer's profit expression as $\Phi(Q_1, Q_2)$. Expanding this expression (while noting that $g_i(\cdot) \le 0$), and expressing the maximization problem as a minimization of the negative of the expression (for compatibility with the standard formulation; see Bazaraa et al. 1983), we get

$$\begin{aligned}\Phi(Q_1, Q_2) &\\ &= -p\left[\int_0^{Q_1+Q_2} xf(x)dx + \int_{Q_1+Q_2}^{\infty} (Q_1+Q_2) f(x)dx\right]\\ &\quad + (c_1-c_2)\int_0^{Q_2} (Q_2-x) f(x)dx\\ &\quad - c_1\int_0^{Q_1+Q_2} (Q_1+Q_2-x) f(x)dx + w_1Q_1 + w_2Q_2.\end{aligned}$$

The Karush–Kuhn–Tucker (KKT) necessary conditions take the following form (see Bazaraa et al. 1983, p. 137, Theorem 4.2.10):

$$\frac{\partial\Phi}{\partial Q_1} = 0 \;\Rightarrow\; (p-c_1)F(Q_1+Q_2) = p - w_1$$

$$\Rightarrow\; F(Q_1+Q_2) = \frac{p-w_1}{p-c_1}, \tag{3}$$

$$\frac{\partial\Phi}{\partial Q_2} = 0 \;\Rightarrow\; (w_2-p) + (p-c_1)F(Q_1+Q_2)$$

$$+ (c_1-c_2)F(Q_2) = 0, \tag{4}$$

$$\nabla g_1 = [1 \quad 0]^T, \tag{5}$$

$$\nabla g_2 = [0 \quad 1]^T. \tag{6}$$

Conditions (5) and (6) imply that the gradient vectors of the inequality constraint functions are linearly independent, and this meets the constraint qualification for conditions (3) and (4) to be necessary conditions for a solution to the problem (Bazaraa et al. 1983); (3) and (4) together imply

$$F(Q_2) = \frac{w_1-w_2}{c_1-c_2}. \quad \square \tag{7}$$

Remark. We note that the analysis above does not change if we replace $k$ in one capacity constraint by $k_1$ and $k$ in the other by $k_2$. This follows from the observation that the gradient vectors corresponding to the capacity constraints remain the same (see (5) and (6) above). Furthermore, it is immediate that the retailer's maximization problem incorporates only the suppliers' wholesale price and credit and is therefore independent of the suppliers' costs.

**Proofs of Propositions**

Proof of Proposition 1. The strategy of the proof is to show that there does not exist an equilibrium partial credit returns policy. However, because this is a game with complementary discontinuities (assuming finite capacities), it follows from Simon (1987) and Dasgupta and Maskin (1986) that a mixed-strategy equilibrium does exist. Therefore, the equilibrium returns policy is full credit. We further note that although the proof does exploit the assumption that the suppliers have identical costs, it does not assume that their capacities are identical. We explain the slight modification of the proof that is needed to account for different supplier costs in Remark 1 at the end of the proof.

We begin by noting that the strategy space of each player is a triangular region of the $w$-$c$ plane bounded by the lines $w \le c$, $c = 0$, and $w = p$. There are three classes of distributions on the plane: discrete, absolutely continuous with respect to plane Lebesgue measure, and continuous singular. We take up these cases one by one.

It is easy to see that there cannot be a joint distribution whose support is a discrete set of points on the plane. Assume that there is such an equilibrium distribution; call it $H$. Suppose $(w_1, c_1)$ in the support carries probability mass $q (0 < q < 1)$. If one supplier (say, supplier 1) chooses its $w_1$ and $c_1$ randomly via $H$, we claim that the other supplier (supplier 2) would do better to choose its $w_2$ and $c_2$ randomly from a distribution $G$ (to be constructed) rather than $H$. We construct $G$ as follows from $H$: replace $(w_1, c_1)$ by $(w_1 + \varepsilon, c_1)$ and let everything else remain unchanged. It is clear that with $\varepsilon$ sufficiently small, the expected profit of supplier 2 is greater with $(w, c)$ chosen randomly from $G$ rather than $H$. Hence, $H$ cannot be an equilibrium distribution.

Next, suppose there is an equilibrium distribution $H$ supported on a curve $T$ in the interior of the feasible region of the $w-c$ plane. Suppose the strategy of supplier 1 is to draw $(w, c)$ randomly according to $H$. Consider the expected profit $\Pi(t)$ of supplier 2 when he draws a point $t$ in the $w-c$ plane. Then if the best response of supplier 2 to supplier 1 is to draw $(w, c)$ randomly on the curve $T$ according to $H$, it follows that $\Pi(t_1) = \Pi(t_2)\ \forall\, t_1 \in T, t_2 \in T$ and $\Pi(t_1) < \Pi(t_2)\ \forall\, t_1 \notin T, t_2 \in T$. Let the value of $\Pi(t)$ at every point $t \in T$ be $\Pi_0$. Let $\varepsilon > 0$ be given. Let $V = \{(w, c): \Pi(t) = \Pi_0 - \varepsilon\}$. As long as $\varepsilon$ is sufficiently small, the set $V$ is a simple closed curve in the plane. It is clear that $V$ completely encloses $T$; therefore, there are two points $v_1$ and $v_2$ on $V$ such that the straight line joining them intersects $T$, say, at the point $v_0$. However, $v_0$ is a convex combination of $v_1$ and $v_2$, and the expected profit from playing $v_0$ is (using the linearity of the expectation operator)

$$\begin{aligned}E_H[qz_1 + (1-q)z_2] &= qE_H[z_1] + (1-q)E_H[z_2]\\ &= q(\Pi_0 - \varepsilon) + (1-q)(\Pi_0 - \varepsilon)\\ &= \Pi_0 - \varepsilon.\end{aligned}$$

However, the expected profit from playing $v_0$ is $\Pi_0$ because $v_0 \in T$ (a contradiction). Therefore, there is no equilibrium distribution supported on a curve in the plane. The same argument applies when $H$ is absolutely continuous and supported on a connected subset of the feasible region of the plane; the only difference is that the curve $T$ is replaced by a plane figure enclosing positive Lebesgue measure. Distributions supported on disconnected subsets can be decomposed into their connected components and each component subjected to the foregoing argument.

Finally, it remains to treat distributions supported entirely along a linear segment of the boundaries of the feasible triangle. It is easily seen that neither the line $w = p$ nor the line $c = 0$ or any subset thereof can be the support of an equilibrium distribution: if one supplier fixes $w = p$, the other supplier has an incentive to price infinitesimally below $p$, whereas if one supplier fixes $c = 0$, the other supplier has an incentive to offer an infinitesimally higher credit. That leaves the line $w = c$ or a subset of it as the only candidate for the support of an equilibrium distribution. Note that when $c = w$, neither supplier has an incentive to deviate from this strategy, because a credit higher than the wholesale price is not possible, whereas offering a credit lower than the wholesale price is strictly dominated by a strategy of offering a credit equal to the wholesale price. □

Remark 1. Suppose suppliers 1 and 2 have costs $c_H$ and $c_L$, respectively, where $c_H > c_L$. Suppose that there is such a mixed-strategy equilibrium in *discrete distributions*; let the equilibrium be the ordered pair of distributions $(H, L)$. If one supplier (say, supplier 2) chooses $w_1$ and $c_1$ randomly via $L$, we claim that the other supplier (supplier 1) would do better to choose its $w_2$ and $c_2$ randomly from a distribution $G$ different from $H$. Suppose $(w_1, c_1)$ in the support of $H$ carries probability mass $q (0 < q < 1)$. We construct $G$ from $H$ as follows: replace $(w_1, c_1)$ by $(w_1 + \varepsilon, c_1)$ and let everything else remain unchanged. It is clear that with $\varepsilon$ sufficiently small, the expected profit of supplier 2 is greater with $(w, c)$ chosen randomly from $G$ rather than $H$. Hence, $(H, L)$ cannot be a mixed-strategy equilibrium in discrete distributions. If the distributions are absolutely continuous, the only modification needed in the original proof is that the joint strategy space in the $w - c$ plane changes slightly: because the supplier with the lower cost will never need to price below $c_H$, the strategy space becomes the triangular region bounded by the lines $w \le c$, $c = c_H$, and $w = p$. With this modification implemented, the proof goes through unchanged.

Remark 2. We note that Proposition 1 applies even when there are *more than two suppliers*; we simply apply the argument of the proof to any pair of them to extract the necessary condition for an equilibrium (namely, that the returns policy must be full credit).

Proof of Proposition 2. We examine the necessary conditions for a turning point to support an equilibrium in light of Proposition 1, which states that $w_1 = c_1$, $w_2 = c_2$. Substituting into (1) and (2), we get $F(Q_2) = 1$ and $F(Q_1 + Q_2) = 1$. Therefore, $Q_2$ equals the maximum value of demand (call it $U$) that can be realized. This in turn implies that $Q_1 = 0$. This suggests two feasible cases:

(a) $F(\cdot)$ has a finite support $[0, U]$.
(b) $F(\cdot)$ has an infinite support.

However, case (b) can be ruled out because it implies $Q_2 = \infty$, which is not feasible for capacity-constrained suppliers. If (a) holds, then the optimal strategy is to select only the one supplier who happens to be the "better" supplier from the retailer's point of view. However, this outcome is a special case of Proposition 2 wherein the residual amount supplied by the less-preferred supplier is zero.

If there are no turning points, then the objective function is a monotone nondecreasing or a monotone nonincreasing function of $(Q_1, Q_2)$. This implies that the retailer's optimal solution, and the equilibrium point, lies on the boundary of the feasible region of the retailer's optimization problem. It is easy to see that the only feasible boundary points for an equilibrium are on one of the two line segments $Q_1 = k$ and $Q_2 = k$; this proves the proposition. □

Remark. If the supplier capacities were $k_1$ and $k_2$, the feasible boundary points would lie on one of the two line segments $Q_1 = k_1$ and $Q_2 = k_2$.

Proof of Proposition 3. If a mixed-strategy equilibrium exists, let the support of that strategy be $(w_l, w_h)$. If $w_l = w_h$, the support of the distribution collapses, and we have a pure strategy instead. Note that if a supplier were to announce $w_l$ as the price, he would be the lower-priced supplier with probability one and therefore supply to capacity and make a profit of $kw_l$ with certainty. If he were to announce $w_h$ as the price he would be the higher-priced supplier with certainty, supply the residual demand, and make a profit of $[F^{-1}((p - w_h)/p) - k]w_h$. By the definition of a mixed-strategy equilibrium, the expected profit at every point in the support of the equilibrium distribution is the same. Hence, the expected profit at the lowest price and at the highest price of the support are equal, yielding $kw_l = [F^{-1}((p - w_h)/p) - k]w_h$. Given a retail price $p$ (the choice of which is unique for an expected profit-maximizing retailer for a large class of distributions; see Lariviere and Porteus 2001, Paul 2006), we have that $w_l = [F^{-1}((p - w_h)/p) - k]w_h/k$. Define $w_h^*$ to be the value of $w_h$ that maximizes $[F^{-1}((p - w_h)/p) - k]w_h$. The equality above then yields the corresponding $w_l^*$. If $F^{-1}((p - w_h^*)/p) < k$, then the equality above has no solution in nonzero prices and we get the degenerate equilibrium $w_h^* = w_l^* = 0$. Otherwise, if $w_h^* \le w_l^*$, the equilibrium is one with pure strategy and if $w_h^* > w_l^*$, the equilibrium involves mixed strategy. It follows that if $F^{-1}((p - w_h^*)/p) \ge 2k$, there is a pure-strategy equilibrium and if $k \le F^{-1}((p - w_h^*)/p) < 2k$, there is a mixed-strategy equilibrium. □

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