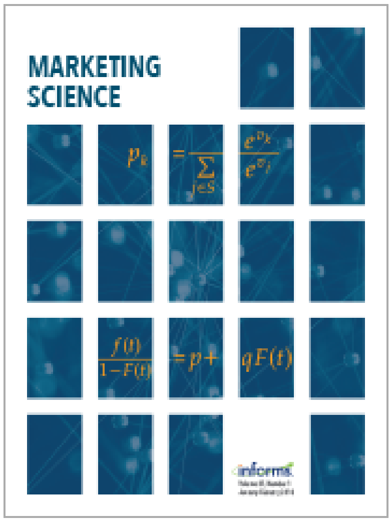

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Implications of Channel Structure for Leasing or Selling Durable Goods

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In spite of the fact that many durable products are sold through dealers, the literature has largely ignored the issue of how product durability affects the interactions between a manufacturer and her dealers. We seek to fill this gap by considering a durable goods manufacturer that uses independent dealers to get her product to consumers. In contrast to much of the literature, we specifically consider the possibility that if the manufacturer sells her product, then the dealers can either sell or lease it to the final consumer. One of our more interesting findings is that, when the level of competition among dealers is high, the manufacturer prefers to use a lease-brokering arrangement in which the dealers earn a margin for brokering leases between the manufacturer and end consumers, instead of selling her product to the dealers. This complements existing results that show that when suppliers of durable goods interact directly with consumers, selling is the dominant strategy for high levels of competitive intensity.

Key words: channel structure; durability; time inconsistency; double marginalization; competition
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1. Introduction

In spite of the fact that intermediaries play an important role in the distribution of many durable products, the issue of product durability has received very little attention in the literature on distribution channels. Conversely, although the durable goods literature has extensively addressed the question of whether products should be sold or leased, little attention has been paid to how intermediaries affect this issue. In channels of distribution for durable products, intermediaries have an additional degree of freedom beyond what they have in channels for nondurables. Specifically, product durability provides intermediaries (dealers) with the potential flexibility to purchase units from a manufacturer and then lease them to consumers while retaining ownership for themselves. Our interest is in understanding how the decisions about selling versus leasing that are made by the manufacturer and by the dealer(s) affect the distribution of ownership of used/off-lease products and, consequently, how channel dynamics are affected by product durability.

The distribution of durable goods through an intermediary can be characterized in terms of three basic forms. In the first, the manufacturer sells a unit to a dealer who in turn sells it to a consumer. In the second, the manufacturer sells a unit to a dealer who leases it to a consumer, retaining ownership for himself.[1] Both of these two forms of distribution are observed in the office equipment industry, where manufacturers typically sell their products, e.g., copiers, printers, etc., to distributors who then either sell or lease to end consumers.

In addition to the two forms of distribution that involve a manufacturer selling her product to a dealer, there is a third form in which the dealer brokers a lease from the manufacturer to the consumer. In this form of distribution, which is common in the automobile industry, the dealer receives a margin that is based on the lease price that he negotiates with the consumer, but the ownership of the leased product is retained by the manufacturer, typically by her captive financial services division, e.g., GMAC, Ford Credit, etc.[2] There are four parameters that determine the lease rate that a consumer pays to lease a new vehicle

[1] Throughout the paper, we adopt the convention of using feminine pronouns to refer to the manufacturer and masculine pronouns for the dealer(s).

[2] Although some leases are sponsored by independent financial services institutions, when this occurs, the ownership of the leased vehicles is transferred outside of the manufacturer-dealer channel. Consequently, the effect of these noncaptive leases on the market price of used vehicles is no different than if the units had been sold to the individual consumers.

for a given length of time: (1) the implicit sales price that he negotiates with a dealer, (2) the *cash back* that is offered by the manufacturer as a direct rebate (which may depend on whether a vehicle is purchased or leased), (3) the annual percentage interest rate, and (4) the residual value that the vehicle is estimated to have at the end of the lease. Of these parameters, the dealer influences only the implicit selling price by negotiating this with the consumer. After the dealer brokers the lease, the manufacturer effectively purchases the vehicle back from the dealer at the implicit selling price that was negotiated with the consumer. As we show in the Technical Appendix (available at http://mktsci.pubs.informs.org), this lease-brokering arrangement is equivalent to one in which the manufacturer sets a wholesale lease rate to which the dealer adds his own margin before leasing the product to a consumer.[3]

It has long been recognized that product durability can have adverse consequences for a firm. When a monopolist sells a durable product, she has an incentive to *skim* the demand curve by producing at a rate that drives down prices over time. Because consumers anticipate this opportunistic behavior, fewer of them are willing to buy at any given price. This issue has been referred to as *time inconsistency* in reference to the fact that a monopolist's ability to sell a durable good at a price above marginal cost is *inconsistent* with her own incentives to produce at a rate that causes the price of the product to decrease. It is well known that by leasing instead of selling her product, the manufacturer can internalize the effects of her future output and eliminate the problem of time inconsistency.

It has also been widely recognized that the use of independent intermediaries—i.e., dealers—can have important implications for a channel of distribution. The externalities that are introduced when each channel member seeks to maximize its own profit lead to higher prices and lower quantities than those that would maximize the combined channel profit. However, product durability introduces another dimension to the relationship between a manufacturer and dealer that needs to be addressed. Specifically, if the manufacturer sells her product to a dealer, the dealer determines not only the number of units to buy but also whether to lease or sell them to an end consumer. On the other hand, if the manufacturer engages in lease brokering with the dealer, then the dealer determines only the quantity to lease to the end consumer.

In this paper, we address the issue of how product durability affects the interactions between a manufacturer and dealer(s). In §2, we review the literatures on product durability and on channel structure. In §3, we develop a model to capture the interaction between the manufacturer of a durable product and a single dealer. In §4, we subsequently consider a setting in which there are multiple dealers and characterize the equilibrium as a function of the intensity of competition among them. In this analysis, we assume that the manufacturer can offer dealer-specific wholesale prices, but in §5 we examine the effect of a requirement that the same price be offered to all dealers. Finally, in §6 we summarize the managerial implications and directions for future research.

2. Relevant Literature

Durable goods have long been studied in the industrial organization literature, where it has been established that durability can interfere with the extraction of rents from consumers. Coase (1972) conjectures that if rational consumers anticipate a durable goods monopolist's incentive to increase product availability over time, then prices will fall down to competitive levels. This line of thought is formalized by Bulow (1982) and Stokey (1981) who propose that, by leasing, a durable goods manufacturer can avoid the time inconsistency problem. Later research identifies conditions under which the Coase conjecture does not apply, resulting in prices that are above marginal costs. Notable among these are the works by Conlisk et al. (1984), who model constant inflow of new consumers; Bond and Samuelson (1984), who incorporate replacement sales; Kahn (1986), who studies increasing marginal production costs; and Bagnoli et al. (1980), who use discrete demand.

Waldman (2003) provides a thorough review of the research on durable goods, but there are several main directions that are worthy of mention here. One of these is product obsolescence. A number of authors, e.g., Levinthal and Purohit (1989), Waldman (1993), Dhebar (1994), and Kornish (2001), examine the incentives for a durable goods manufacturer to make an existing product obsolete by introducing a newer version, and how this can intensify the time inconsistency effect. Another direction that has been pursued by Bulow (1986), Bucovetsky and Chilton (1986), and Desai and Purohit (1999), among others, examines how competition, or threat of competition, can increase the amount of selling that occurs in equilibrium. In another related work, Bhaskaran and Gilbert (2005) show that when the demand for a durable good depends on the availability of complementary goods, selling stimulates demand for complementary products and can benefit the manufacturer of a durable good.

Although most of the research on durable goods ignores the role of intermediaries in a distribution

[3] This description is based on a conversation with Joe Poi, the Director of the Global Risk Management at Ford Motor Credit Company.

channel, there are a few notable exceptions: Purohit (1995) shows that a manufacturer who uses an intermediary would prefer one who sells rather than leases. Two other related works, Purohit and Staelin (1994) and Purohit (1997), examine the effects of alternative channel structures that auto manufacturers use for handling off-lease vehicles that have been leased to rental agencies. More recently, Desai et al. (2004) show that by precommitting to appropriate two-part contracts with dealers, a manufacturer can eliminate time inconsistency, whereas Arya and Mittendorf (2006) extend this by showing that even in the absence of precommitment, the double marginalization that results from decentralization can help mitigate the time inconsistency problem. Our work is distinct from these in several ways: First, in contrast to Purohit and Staelin (1994), Purohit (1997), and Desai et al. (2004), we do not allow the manufacturer to precommit to the future contract terms that she will offer retailer(s). Second, instead of assuming that each intermediary is exogenously defined to be either a leasing or a selling agency, we allow each intermediary (i.e., dealer) to choose whether to lease or sell units that he buys from the manufacturer. Additionally, we allow the manufacturer the option of using a lease-brokering arrangement in which she retains ownership of units for which a dealer brokers the lease. Finally, we allow for competition among dealers and examine how the intensity of interdealer competition influences the lease versus sell decisions of the manufacturer and dealers.

Because our primary interest is to understand the role of intermediaries in the distribution of durable goods, our work is also closely related to the literature in marketing, operations, and economics that deals with the inefficiencies that are associated with use of intermediaries in distribution channels. One of the primary sources of inefficiency is *double marginalization*, which results when each individual channel member adds its own margin to the cost of a product and leads to a final retail price that is higher than the one that would maximize total channel profits. Double marginalization was first recognized by Spengler (1950). Later, Jeuland and Shugan (1983) recognized its effects on nonprice variables such as advertising, shelf-space allocation, etc. A number of others, including McGuire and Staelin (1983), Choi (1991), Ingene and Parry (1995), Iyer (1998), Lee and Staelin (1997), Gupta and Loulou (1998), and Gilbert et al. (2005), have studied various dimensions of double marginalization and how it is related to channel structure. However, these papers tend to focus on single-period models that ignore the effects of product durability and how it might affect the interactions between manufacturers and dealers. Although Anand et al. (2008) consider a multiperiod model that considers how dealer inventory affects channel interactions, they ignore the strategic effects of durability on consumer expectations. By explicitly modeling durability and the resulting choices that are available to a manufacturer and dealer(s), our research bridges the gap between what is known about channel structure for nondurables and what is known about distributing durables directly to consumers.

3. Model Description

Let us begin by considering a manufacturer who distributes a durable product through a single dealer. To represent durability, we adopt the model proposed by Bulow (1982), in which there are two periods and the units produced in period 1 provide two periods of service, whereas those produced in period 2 provide only one. The primary purpose of this assumption is to ensure that continued production of the durable good over time expands its market penetration, rather than simply replaces worn-out units. This notion that continued production expands market penetration is fundamental to the theory of *time inconsistency*. Although the recursive analytical approach that we take does require that there be a finite number of periods, the specific assumption of only two periods simplifies the analysis and facilitates comparisons with most of the existing literature. However, the fundamental trade-offs that we examine should exist and our results should apply, at least qualitatively, whenever continued production expands market penetration and creates the potential for time inconsistency.

We also assume that there is no depreciation of the value provided by the durable good between periods 1 and 2; however, a discount factor of ρ is applied to revenues or cash flows received in period 2. The assumption that there is no depreciation is consistent with that of Bulow (1982) and Bucovetsky and Chilton (1986) and simplifies the presentation of our analysis. Although our model can be easily generalized to allow for depreciation, this would only blur the distinction between durable and nondurable goods.

We adopt the traditional durable goods assumption that no consumer can use more than one unit of the product in a given period. As in Bulow (1982), we assume that consumers' utility for the product is defined by the value of service it provides. In each period, there is a continuum of consumers, with a total mass of a, whose valuations, v, for each period of service from the product are uniformly distributed over $[0, a]$. Given these assumptions, if q units were made available for a single-period lease, the market-clearing lease price would be

$$r(q) = a - q, \tag{1}$$

and all consumers with a valuation above $r(q)$ would lease the product for the period. As is common in the literature on durable products, we assume that the length of all leases is exactly one period. Consequently, in the second (last) period there is no distinction between selling and leasing because both provide exactly one period of use. However, in the first period, selling and leasing are distinct because a consumer who *buys* a product obtains not only the use of the product in the current period but also the right to use it in the next. To determine the market-clearing price that a dealer can obtain from any units that he makes available for sale[4] in the first period, we must consider the additional value that a consumer derives from buying instead of leasing the product. Let q_l and q_s denote the quantities that are made available for lease and for sale in period 1, and let p_1 be the market-clearing price for buying the product. In period 1, consumers correctly anticipate that the market-clearing price in period 2 will be p_2, which we will show is a function of q_l and q_s, and any consumer with valuation $v \geq p_2$ will purchase in period 2 if he has not done so already. By purchasing in period 1, a consumer with valuation v would derive a total utility equal $(1+\rho)v$ from using the product for both periods. However, by postponing the purchase of the product until period 2, this consumer would expect a net utility of $\rho(v - p_2)$. Therefore, a consumer with valuation v will purchase in period 1 only if $(1+\rho)v - p_1 \geq \rho(v - p_2) \geq 0$, and all consumers with valuation $v \geq p_1 - \rho p_2$ will be willing to purchase in the first period. Because the number of consumers with valuation greater than $v = p_1 - \rho p_2$ is $a - p_1 + \rho p_2$, the first-period sale price can be expressed as

$$p_1(q_l, q_s) = (a - q_l - q_s) + \rho p_2. \tag{2}$$

In equilibrium, consumers will be indifferent between leasing and buying in period 1, so the price at which q_l units can be leased, given that q_s units are sold is $r(q_l + q_s) = a - q_l - q_s$, which is identical to the first term in (2). For the consumers who buy the product, this term represents the *implicit lease price* that they pay for the use of it during period 1. The second term represents the additional amount that they must pay for the use of the product in period 2.[5]

The second-period price, p_2, that consumers anticipate depends not only on the first-period quantities, but also on the incentives of the manufacturer and the dealer(s) in period 2. To simplify the analysis, we make the following two assumptions: First, we normalize the marginal costs of both the manufacturer and the dealer to zero. When marginal costs are large relative to the total length of the product's useful life, they can reduce or eliminate the manufacturer's incentive to produce after the first period. This, in turn, can reduce or eliminate the adverse effects of time inconsistency. On the other hand, when marginal costs are not so high as to eliminate time inconsistency, they add considerable complexity to the analysis without altering the qualitative results. The second simplifying assumption that we impose is that the manufacturer cannot simultaneously sell units to the dealer and engage him in lease brokering. Instead, we restrict the manufacturer to either pure selling or pure lease brokering. (If the manufacturer sells to the dealer, we do allow the dealer to use a combination of leasing and selling to end consumers.) Although this restriction precludes the realistic possibility that the manufacturer could use a combination of selling and lease brokering, it is necessary for tractability. Moreover, because the fundamental trade-offs that we analyze continue to be relevant even under this assumption, it allows us to obtain insights about the manufacturer's relative preference between the two forms of interaction without being bogged down by analytical complexity. We discuss the implications of this assumption in more detail in the concluding section.

We assume that the sequence of events is as follows: At the beginning of period 1, the manufacturer decides whether to sell her product to the dealer or to offer a lease-brokering arrangement. In addition, depending on which method of dealer interaction is to be used, the manufacturer announces her margin on each unit of transaction with the dealer. If the manufacturer sells to the dealer, then the dealer responds with the quantities that he will sell and lease to the end consumer, knowing that he will retain ownership of all leased units. On the other hand, under a lease-brokering arrangement, the dealer responds with only the quantity of leases that he will broker, knowing that the manufacturer will retain ownership of all of the units. At the beginning of period 2, the manufacturer determines a per-unit margin, and the dealer responds by determining the quantity to obtain from the manufacturer. Throughout our analysis, we restrict attention to linear wholesale pricing mechanisms in which the manufacturer specifies only a per-unit margin, and we require subgame perfection; i.e., we do not allow the manufacturer to precommit to her future margins. However, because our results are driven by the trade-off between double marginalization and time inconsistency, they should apply under

[4] Without loss of generality, we assume that the dealer's decisions are the quantities that he makes available to consumers and that the market-clearing prices are the market's endogenous response to these quantities.

[5] We assume that the same set of consumers are present in both periods to derive (1) and (2). However, as discussed in Bulow (1982) and Bhaskaran and Gilbert (2005), if there exists a perfect secondhand market through which consumers can buy or sell a durable good without incurring any transaction costs, it is sufficient to assume only that the distribution of the demand is the same in both periods.

more general wholesale pricing structures so long as the manufacturer cannot trivially eliminate both issues by precommitting to appropriate multipart pricing mechanisms.[6]

3.1. Lease Brokering Through a Single Dealer

When the manufacturer uses lease brokering in her interactions with the dealer, the key feature is that the ownership of the durable good is retained by the manufacturer. Let $\widehat{w}_1$ and $\widehat{w}_2$ be the manufacturer's lease margins in the first and second periods, respectively.[7] In each period, the dealer responds to the manufacturer's lease margin by determining the quantity that he will offer to consumers, and his own margin is the difference between the market-clearing lease rate and the manufacturer's margin. Let $\hat{q}_1$ be the quantity that the dealer makes available to consumers in the first period and $\hat{q}_{2T}$ be the total quantity that the dealer makes available in the second period. Denote the difference between these two quantities by $\hat{q}_2 = \hat{q}_{2T} - \hat{q}_1$. This representation is identical to the rental agency model that is analyzed in Purohit (1995); however, for completeness, we summarize those results here.

Let us use lowercase π (uppercase Π) to represent the profit of the dealer (manufacturer). The total profit of the dealer and the manufacturer can be expressed as follows:

$$\pi^L(\widehat{w}_1, \widehat{w}_2, \hat{q}_1, \hat{q}_{2T}) = \hat{q}_1(a - \hat{q}_1 - \widehat{w}_1) + \rho\hat{q}_{2T}(a - \hat{q}_{2T} - \widehat{w}_2), \quad (3)$$

$$\Pi^L(\widehat{w}_1, \widehat{w}_2, \hat{q}_1, \hat{q}_{2T}) = \hat{q}_1\widehat{w}_1 + \rho\hat{q}_{2T}\widehat{w}_2, \quad (4)$$

where the superscript L refers to the manufacturer's decision to use lease brokering. Because π^L is separable in $\hat{q}_1$ and $\hat{q}_{2T}$, it can be seen that the dealer's response is

$$\hat{q}^*(w) = \hat{q}_1^*(\widehat{w}_1) = \hat{q}_{2T}^*(\widehat{w}_2) = \frac{a - \widehat{w}_t}{2} \quad (5)$$

in each period $t \in \{1, 2\}$. Because the demand for service of the product is the same in both periods, the manufacturer should set the same leasing margin in both periods, and it is easy to confirm that her optimal leasing margin is $\widehat{w}_1^* = \widehat{w}_2^* = \widehat{w}^* = a/2$. Substituting into the profit functions (3) and (4), we can find the equilibrium profit of the dealer and manufacturer under lease brokering:

$$\pi^{L*} = \frac{a^2(1+\rho)}{16}, \quad (6)$$

$$\Pi^{L*} = \frac{a^2(1+\rho)}{8}. \quad (7)$$

As in Bulow (1982), this solution completely eliminates time inconsistency. However, because the intermediary introduces double marginalization, the combined profit in the channel is only 75% of what it would be in a vertically integrated channel.

3.2. Manufacturer Selling to a Single Dealer

When the manufacturer sells her product to the dealer, ownership transfers so that the dealer has the option of either selling or leasing it to the consumer in period 1. Recall that in period 2, leasing and selling are indistinguishable because either one provides a single period of use. Let w_t be the wholesale price at which the manufacturer sells the product to the dealer in period $t = 1, 2$. Let q_1 represent the total quantity that the dealer makes available in period 1, and let q_2 be the additional quantity that the dealer makes available in period 2. Note that this notation is distinct from that used in the previous section ($\hat{q}_1, \hat{q}_2, \widehat{w}_1, \widehat{w}_2$) for the lease-brokering arrangement. In period 1, the dealer has the option of selling instead of leasing some or all of the q_1 units to the consumers. Let $q_s(w_1)$ and $q_l(w_1)$ represent the quantities the dealer *sells* and *leases* to consumers when the manufacturer sells to him at a wholesale price of w_1 in period 1, where $q_l(w_1) + q_s(w_1) = q_1(w_1)$.

At the beginning of period 2, the dealer continues to own all of the units that he leased to consumers in period 1. (Recall that this is not the case in the lease-brokering arrangement.) Although the dealer has no obligation to make these units available to the market in period 2, it can be verified that because demand is stable, a dealer will never procure units in period 1 that will not be used in both periods. Thus, the total quantity made available to consumers in period 2 will be $q_l + q_2$. In addition, the q_s units that the dealer sold in period 1 are also available to satisfy consumers' demand for the service of the product. Because the product will be used by the highest-valuation consumers, the price at which the dealer would be able to sell/lease $q_l + q_2$ units of the product in period 2 is

$$p_2(q_1, q_2) = a - q_1 - q_2 = a - q_l - q_s - q_2. \quad (8)$$

Although the market price in period 2 depends only on the *total* number of units available to consumers, $q_1 + q_2$, we will soon see that the equilibrium value of q_2 depends on the extent to which the units made available in period 1 were either *sold* or *leased*.

[6] If we allow for more complex contracts and allow precommitments, then it is relatively easy to identify coordinating contracts, at least within the other assumptions of our model.

[7] As shown in the Technical Appendix (available at http://mktsci.pubs.informs.org), this representation is equivalent to the lease-brokering arrangement that occurs in the automotive industry.

Proceeding with the standard backward induction approach, the profit of the dealer in the second (final) period can be expressed as

$$\pi_2^S(q_l, q_s, q_2, w_2) = (a - q_l - q_s - q_2)(q_l + q_2) - w_2 q_2, \quad (9)$$

where the superscript S reflects the manufacturer's decision to *sell* the product to the dealer. Differentiating (9) twice with respect to q_2, it can be seen that the dealer's profit is concave in q_2. Hence, first-order conditions (FOCs) are sufficient to characterize the dealer's second-period quantity:

$$q_2^*(w_2, q_l, q_s) = \left[\frac{a - w_2 - q_s - 2q_l}{2}\right]^+. \quad (10)$$

When the manufacturer determines her second-period wholesale price, w_2, she anticipates this quantity decision by the dealer. Therefore, the second-period profit function for the manufacturer is

$$\Pi_2^S(w_2, q_l, q_s) = w_2 q_2^*(w_2, q_l, q_s). \quad (11)$$

Because (11) is concave in w_2, we can use FOCs to find the optimal second-period wholesale price:

$$w_2^*(q_l, q_s) = \mathrm{Max}\left\{\frac{a - q_s - 2q_l}{2}, 0\right\} = \left[\frac{a - q_s - 2q_l}{2}\right]^+. \quad (12)$$

From (12), it can be seen that each unit that the dealer either sold or leased in period 1 serves to decrease the wholesale price that the manufacturer offers in period 2. However, units that the dealer leased have twice as much impact as the units that he sold. This can be explained as follows: given that in period 2 the dealer does not withhold any of his first-period leased units (q_l) from the market, then all of the units that he leased or sold drive down the price at which he can sell additional units. However, only the units that he leased generate revenue for him in period 2. Therefore, when the dealer considers buying additional units from the manufacturer in period 2, he worries about the effect that these additional units will have on the revenues that he will earn from the q_l units that he leased, but he cares nothing about the impact on the value of the q_s units that he sold. Consequently, the leased units have a stronger negative effect on the dealer's second-period marginal revenue function than do the sold units. By leasing a larger fraction of his total first-period quantity to consumers, the dealer credibly commits himself to a lower marginal revenue function in period 2, to which the manufacturer responds by offering a lower wholesale price in period 2.

Substituting (12) and (10) back into (9) and (11), the second-period profit of the dealer and manufacturer are the following functions of the first-period decisions:

$$\pi_2^S(q_l, q_s) = \frac{(a - q_s)^2 + 12q_l(a - q_l - q_s)}{16}, \quad (13)$$

$$\Pi_2^S(q_l, q_s) = \frac{(a - q_s - 2q_l)^2}{8}. \quad (14)$$

In the first period, when the dealer determines his leasing and selling quantities, he seeks to maximize his total profit from both periods. If there is a total of $q_1 = q_l + q_s$ units available to consumers, then the market-clearing price for the *leased* units (as well as the implicit lease price for the units that are sold) will be $r(q_1) = a - q_1 = a - q_l - q_s$. From (2) and (8) the market-clearing price for the units that are *sold* will be $p_1(q_l, q_s) = a - q_l - q_s + \rho p_2(q_l + q_s, q_2^*(w_2^*))$, where we have omitted explicit reference to the fact that both q_2^* and w_2^* depend on q_l and q_s. Because of the functional dependence of q_2^* and w_2^* on q_l and q_s, the selling price depends on how the total number of units in period 1 is divided between leasing and selling. The dealer's total profit from both periods is

$$\begin{aligned}\pi^S(w_1, q_l, q_s) = {} & q_l(a - w_1 - q_l - q_s) \\ & + q_s\big(a - w_1 - q_l - q_s + \rho p_2(q_l + q_s, q_2^*(w_2^*))\big) \\ & + \rho \pi_2^S(q_l, q_s),\end{aligned} \quad (15)$$

which he tries to maximize subject to the constraint that $q_l, q_s \geq 0$. The manufacturer's total profit from both periods can be represented as follows:

$$\Pi^S(w_1, q_l, q_s) = w_1(q_s + q_l) + \rho \Pi_2^S(q_l, q_s). \quad (16)$$

To determine the equilibrium that is conditional on the manufacturer selling to the dealer, we must first obtain the dealer's response, $q_s(w_1)$ and $q_l(w_1)$, from the FOCs for (15). Substituting these responses into (16), we can then find the optimal wholesale price at which the manufacturer would sell the product in period 1 from the FOC for (16). By doing this, it is easy to show that when the manufacturer sells her product to a single dealer, the equilibrium is

$$w_1^* = \frac{a(4 + 3\rho)^2}{16(2 + \rho)}, \qquad q_s^* = 0, \qquad q_l^* = \frac{a(4 + \rho)}{8(2 + \rho)}.$$

Substituting these back into (15) and (16), we have the following equilibrium profit for the dealer and the manufacturer, respectively,

$$\pi^{S*} = \frac{a^2(64 + \rho(144 + \rho(92 + 19\rho)))}{256(2 + \rho)^2}, \quad (17)$$

$$\Pi^{S*} = \frac{a^2(4 + 3\rho)^2}{64(2 + \rho)}. \quad (18)$$

Having determined the dealer's optimal policy when the manufacturer sells to him, we now turn our attention to the equilibrium policy of the manufacturer, i.e., whether she should sell to the dealer or engage in a lease-brokering arrangement. The following proposition characterizes that decision.

Proposition 3.1. *When the manufacturer interacts with a single dealer, the equilibrium to the lease brokering-selling game is as follows: rather than using a lease-brokering arrangement, the manufacturer sells her product to the dealer, who in turn leases each unit that he purchases to the end consumer. The total profit of the dealer and manufacturer are $\pi^* = \pi^{S*}$ and $\Pi^* = \Pi^{S*}$, respectively. In the first period, the wholesale price and quantity are w_1^* and $q_1^* = q_l^*$, and in the second period, the wholesale price and quantity will be $w_2^* = w_2^*(q_l^*, 0)$ and $q_2^* = q_2^*(w_2^*, q_l^*, 0)$.*

The above proposition follows immediately from comparing (7) with (18). It is of interest to compare the above results with Bulow's (1982) result that a firm that produces for itself and interacts directly with the market should lease her product. There are two ways in which to make this comparison. The first is to compare the dealer in our model to Bulow's durable goods firm, the difference being that our dealer depends on a strategic supplier. From this perspective, we can conclude that even though the dealer's decision about whether to sell or lease affects the second-period wholesale price offered by the supplier, it is still optimal for him to lease. Thus, endogenizing a strategic supplier to Bulow's model does not alter the result that the firm should lease its product.

Alternatively, we can compare the manufacturer in our model to Bulow's durable goods firm, the difference being that our manufacturer must interact with a downstream intermediary who can either sell or lease the product to consumers if the manufacturer decides to sell. From this perspective, we can conclude that by inserting a strategic intermediary to Bulow's model, the result reverses. The manufacturer of the durable good now sells her product. The reason for the reversal is that the intermediary introduces a trade-off between time inconsistency and double marginalization, both of which are important considerations for the manufacturer. In particular, when the manufacturer sells to the dealer, the equilibrium lease price charged to the consumer is lower than it would be under the lease-brokering arrangement. As a result, the manufacturer's decision to sell the durable good to the dealer results in prices and quantities that are closer to what is optimal for the total supply chain.

It is also of interest to distinguish our results from those of Purohit (1995), who compares a manufacturer who distributes through a rental agency to one who distributes through a (selling) dealer. His analysis of the manufacturer who distributes through a rental agency implicitly assumes that the manufacturer leases the product to the dealer, which is identical to our model of *lease brokering*. However, his analysis of the manufacturer who distributes through a (selling) dealer does not allow the dealer the flexibility to lease to consumers any of the units he purchased from the manufacturer.

To compare the equilibrium from Proposition 3.1 (which we denote by superscript $*$) to the two cases that are analyzed in Purohit (1995), let us use the superscript *SS* to distinguish his result for the situation when the manufacturer sells to a dealer who can only sell the product to the consumer. Recall that his result for the case in which a manufacturer distributes through a rental agency is identical to the situation that we have described as lease brokering. As before, we will use ($\hat{}$) to denote the conditional equilibrium wholesale lease prices/margins and quantities for this case.

Proposition 3.2. *In the equilibrium to the lease brokering-selling game between one manufacturer and one dealer*:

(a) *The first-period wholesale price at which the manufacturer sells to the dealer is higher and the second-period wholesale price is lower than they would be if the dealer were forced to sell to the end consumer. Specifically, $w_1^* > w_1^{SS}$ and $w_2^* < w_2^{SS}$.*

(b) $q_1^* \le q_1^{SS} \le \hat{q}_1$ *and* $\hat{q}_{2T} \le q_{2T}^* \le q_{2T}^{SS}$.

In anticipation that the dealer will lease the product to end consumers, the manufacturer increases the first-period wholesale price. However, because the off-lease units in period 2 deter the dealer from purchasing additional units from the manufacturer, the second-period price is lower than it would have been had the dealer not had the ability to lease. Because of the higher first-period wholesale price, the dealer's first-period quantity is lower than it would have been if she did not have the ability to lease, which is lower still than the quantity under lease brokering. However, the total equilibrium quantity available to consumers in period 2 lies between the quantity that would be available under lease brokering and the quantity that would be available if the dealer did not have the ability to lease.

The equilibrium profit of the dealer, the manufacturer, and the supply chain in the lease brokering-selling game compare as follows to the profit earned in the conditional equilibrium where the manufacturer engages in lease brokering with the dealer and the conditional equilibrium in which the manufacturer sells to a dealer who can only sell to the end consumer:

$$\pi^* \geq \pi^{SS} \geq \pi^L,$$
$$\Pi^{SS} \geq \Pi^* \geq \Pi^L,$$
$$\Pi^{SS} + \pi^{SS} \geq \Pi^* + \pi^* \geq \Pi^L + \pi^L.$$

The retailer benefits from the flexibility of being able to lease units that he purchases from the manufacturer to the consumer. However, the additional profit that the retailer earns from this flexibility is less than the reduction in the manufacturer's profit. Consequently, their combined profit is lower when the retailer has this flexibility than when he must sell the units purchased from the manufacturer.

4. Channel Structure Under Competition

So far, our analysis has focused on how channel structure affects the equilibrium selling, leasing, and pricing decisions of a single manufacturer and dealer. However, in many durable goods markets, the manufacturer relies on multiple intermediaries that may serve overlapping consumer markets. To address this issue, we modify our original model to allow for n competing dealers and define $\theta \in [0,1]$ to be the degree of substitutability between any two dealers. The implicit rental price for a single period of use of a durable good supplied by dealer i can then be defined as

$$r_i(\mathbf{q}) = \left(a - q_i - \theta \sum_{j\neq i} q_j\right), \tag{19}$$

where $\mathbf{q}$ denotes the n-dimensional vector in which the jth element, q_j, is the quantity of products currently in use that was supplied by dealer j.

To simplify presentation, we assume that there is no discounting ($\rho = 1$). Note that time inconsistency, and consequently the distinction between selling and leasing, is greatest when $\rho = 1$ and that it vanishes when $\rho = 0$. At intermediate values of ρ, the trade-off between double marginalization and time inconsistency continues to exist, and our qualitative conclusions remain valid.

4.1. Lease Brokering with Multiple Dealers

Let $\widehat{w}_1$ and $\widehat{w}_2$ be the manufacturer's margin in the lease-brokering arrangement that she offers to all dealers in the first and second periods, respectively. Because of symmetry, it can be shown that the manufacturer could not benefit from offering different leasing margins to different dealers in either period. Let $\hat{q}_{i1}$ be the quantity that dealer i makes available to consumers in period 1 and $\hat{q}_{i2T}$ be the total quantity that dealer i makes available in period 2. We denote the difference between these two quantities by $\hat{q}_{i2} = \hat{q}_{i2T} - \hat{q}_{i1}$. To indicate the n-dimensional vectors of these variables, we will use $\widehat{\mathbf{q}}_1$, $\widehat{\mathbf{q}}_2$, and $\widehat{\mathbf{q}}_{2T}$. This notation is identical to that in §3.1 except that we now have n-dimensional vectors. The optimal decisions of the retailers and the manufacturer can be identified in a recursive fashion. The profit of ith dealer from both periods is

$$\pi_i^L(\widehat{w}_1, \widehat{w}_2, \widehat{\mathbf{q}}_1, \widehat{\mathbf{q}}_{2T}) = \hat{q}_{i1}(r_i(\widehat{\mathbf{q}}_1) - \widehat{w}_1) + \hat{q}_{2T}(r_i(\widehat{\mathbf{q}}_{2T}) - \widehat{w}_2). \tag{20}$$

As in our earlier analysis, each dealer's profit is separable in $\widehat{\mathbf{q}}_1$ and $\widehat{\mathbf{q}}_{2T}$, and the FOCs are

$$\hat{q}_{i1}^*(w_1) = \frac{a - \theta\sum_{j\neq i}\hat{q}_{j1} - \widehat{w}_1}{2},$$
$$\hat{q}_{i2T}^*(w_2) = \frac{a - \theta\sum_{j\neq i}\hat{q}_{j2T} - \widehat{w}_2}{2} \quad i = 1, \ldots, n. \tag{21}$$

The dealers' responses to the manufacturer's leasing margin and to one another's quantities are the same in both periods. By simultaneously solving (21) for all n dealers, the quantity of leases brokered by each dealer $i = 1, \ldots, n$ can be expressed as

$$\hat{q}_{i1}^*(\widehat{w}) = \hat{q}_{i2T}^*(\widehat{w}) = \frac{a - \widehat{w}}{n(2 + (n-1)\theta)}.$$

Consequently, the profit that the manufacturer earns from each dealer i is

$$\Pi_i^L(\widehat{w}) = \widehat{w}_1\hat{q}_{i1}^*(\widehat{w}_1) + \widehat{w}_2\hat{q}_{i2T}^*(\widehat{w}_2).$$

The margin that maximizes the manufacturer's profit from lease brokering is: $\widehat{w}_1^* = \widehat{w}_2^* = \widehat{w}^* = a/2$. Substituting this optimal margin and quantities into the profit functions, we can find the equilibrium profit per dealer of the manufacturer, denoted $\Pi_i^L(n, \theta)$, and of each dealer, denoted $\pi_i^L(n, \theta)$:

$$\Pi_i^L(n, \theta) = \frac{a^2}{4 + 2(n-1)\theta}, \tag{22}$$

$$\pi_i^L(n, \theta) = \frac{a^2}{2(2 + (n-1)\theta)^2}. \tag{23}$$

4.2. Manufacturer Selling to Competing Dealers

Now we consider the case in which the manufacturer sells the product to dealers. In contrast to the lease-brokering arrangement, which is separable in $\widehat{\mathbf{q}}_1$ and $\widehat{\mathbf{q}}_{2T}$, here it is possible that the manufacturer could benefit from offering different wholesale prices (i.e., manufacturer selling margins) to different dealers in the second period, depending on the number of off-lease units held by the individual dealers.[8] In practice, there may be legal requirements that prevent the

[8] As in our original analysis, we require subgame perfection in the sense that the manufacturer cannot precommit to either her second-period margins or the mechanism that she will use to determine these margins.

manufacturer from offering different prices to different dealers, and we consider the implications of such a restriction in §5. For now, however, we assume that the manufacturer can offer dealer-specific wholesale prices. Let w_{i1} and w_{i2} be the prices at which the manufacturer sells the product to dealer i in periods 1 and 2, respectively. In period 1, we denote the quantities that dealer i sells and leases, respectively, as q_{is} and q_{il}; and the total quantity purchased by dealer i in period 1 by $q_{i1} = q_{is} + q_{il}$. In period 2, we denote the total quantity distributed by dealer i by q_{i2T}. As was the case in our previous analysis, this total second-period quantity includes all of the units that dealer i leased in period 1, plus any additional units, denoted q_{i2}, that he purchases from the manufacturer in period 2; i.e., $q_{i2T} = q_{il} + q_{i2}$.

In period 2, the manufacturer announces the wholesale price(s) to all n dealers, and each dealer responds by determining the quantity that he will distribute. Recall that, in equilibrium, a dealer will never withhold in period 2 units that he procured in period 1. The second-period profit of dealer i is

$$\pi_{i2}^{S}(\mathbf{q}_l, \mathbf{q}_s, \mathbf{q}_2, w_{i2}) = r_i(\mathbf{q}_1 + \mathbf{q}_2)(q_{i2} + q_{il}) - w_{i2}q_{i2}. \quad (24)$$

Applying the FOCs to (24) for all n dealers gives us n simultaneous equations, the solution to which yields the second-period response of dealer i:

$$\begin{aligned} &q_{i2}^{*}(\mathbf{q}_l, \mathbf{q}_s, \mathbf{w}_2) \\ &= \Bigg[\Bigg(a(2-\theta) - 2(q_{is} + w_{i2}) \\ &\quad - \theta\Bigg(\sum_{j\neq i}(q_{js} - w_{j2}) - (2-n)w_{i2} + q_{is}(n(1-\theta) - 2 + \theta)\Bigg)\Bigg) \\ &\quad \cdot \big((2-\theta)(2+(n-1)\theta)\big)^{-1} - q_{il}\Bigg]^{+}. \quad (25) \end{aligned}$$

When the manufacturer determines the second-period wholesale prices, she anticipates this response function and how it will affect her own second-period profit, which can be expressed as

$$\Pi_2^{S}(\mathbf{q}_l, \mathbf{q}_s, \mathbf{w}_2) = \sum_j w_{j2} q_{j2}^{*}(\mathbf{q}_l, \mathbf{q}_s, w_{j2}). \quad (26)$$

The second-period, *dealer-specific* wholesale prices, denoted by w_{i2}^{DS}, $i = 1, \dots, n$, can be obtained by simultaneously applying the n FOCs with respect to (26) to obtain

$$w_{i2}^{DS}(\mathbf{q}_l, \mathbf{q}_s) = \left[\frac{a - 2q_{il} - q_{is} - \theta\sum_{j\neq i}(q_{jl} + q_{js})}{2}\right]^{+}. \quad (27)$$

As was the case in our analysis of a single dealer, each unit that was sold or leased in period 1 decreases the wholesale price that the manufacturer offers in period 2, but the effect is twice as strong for leased units as it is for sold units. This is easy to confirm by comparing the corresponding first-order derivatives of (27) with those of (12):

$$\begin{aligned} \frac{dw_{i2}^{DS}(\mathbf{q}_l, \mathbf{q}_s)}{dq_{il}} &= \frac{dw_2^{*}(\mathbf{q}_l, \mathbf{q}_s)}{dq_l} = -1 \\ &= 2\frac{dw_{i2}^{DS}(\mathbf{q}_l, \mathbf{q}_s)}{dq_{is}} = 2\frac{dw_2^{*}(\mathbf{q}_l, \mathbf{q}_s)}{dq_s}. \quad (28) \end{aligned}$$

Let $\pi_{i2}^{DS}(\mathbf{q}_l, \mathbf{q}_s)$ and $\Pi_2^{DS}(\mathbf{q}_l, \mathbf{q}_s)$ be the conditionally optimal second-period profit of dealer i and of the manufacturer for dealer-specific wholesale pricing. By setting $w_{i2}^{*}(\mathbf{q}_l, \mathbf{q}_s) = w_{i2}^{DS}(\mathbf{q}_l, \mathbf{q}_s)$ for $i = 1, \dots, n$ and substituting $w_{i2}^{*}(\mathbf{q}_l, \mathbf{q}_s)$ and (25) into (24) and (26), we have

$$\begin{aligned} &\pi_{i2}^{DS}(\mathbf{q}_l, \mathbf{q}_s) \\ &= \pi_{i2}^{S}(\mathbf{q}_l, \mathbf{q}_s, \mathbf{q}_2^{*}(\mathbf{q}_l, \mathbf{q}_s, \mathbf{w}_2^{DS}(\mathbf{q}_l, \mathbf{q}_s)), w_{i2}^{DS}(\mathbf{q}_l, \mathbf{q}_s)), \quad (29) \end{aligned}$$

$$\Pi_2^{DS}(\mathbf{q}_l, \mathbf{q}_s) = \Pi_2^{S}(\mathbf{q}_l, \mathbf{q}_s, \mathbf{w}_2^{DS}(\mathbf{q}_l, \mathbf{q}_s)). \quad (30)$$

In period 1, consumers can anticipate the second-period market price from the first-period quantities:

$$p_{i2}^{DS}(\mathbf{q}_l, \mathbf{q}_s) = r_i(\mathbf{q}_l + \mathbf{q}_s + \mathbf{q}_2^{*}(\mathbf{q}_l, \mathbf{q}_s, \mathbf{w}_2^{DS}(\mathbf{q}_l, \mathbf{q}_s))).$$

Note that the second-period market price follows from the fact that the total number of units that will be available in period 2 includes all of the units that were either sold or leased in period 1 as well as any additional units that are produced in period 2. By definition, the first-period lease price is the same as the implicit rental price, i.e., $r_i(\mathbf{q}_l + \mathbf{q}_s)$. As in §3.2, the premium that a consumer is willing to pay to buy, instead of lease, the product is equal to the (discounted) market price that is anticipated in period 2, and we must have $p_{is}^{DS}(\mathbf{q}_l, \mathbf{q}_s) = r_i(\mathbf{q}_l + \mathbf{q}_s) + p_{i2}^{DS}(\mathbf{q}_l, \mathbf{q}_s)$ in equilibrium. Thus, the profit of dealer i in period 1 can be represented as

$$\begin{aligned} \pi_{i1}^{DS}(w_1, \mathbf{q}_l, \mathbf{q}_s) &= q_{il} r_i(\mathbf{q}_l + \mathbf{q}_s) + q_{is} p_{is}^{DS}(\mathbf{q}_l, \mathbf{q}_s) \\ &\quad - q_{i1} w_1 + \pi_{i2}^{DS}(\mathbf{q}_l, \mathbf{q}_s), \end{aligned}$$

and each dealer seeks to determine the values of $q_{il}, q_{is} \geq 0$ that maximize his own profit.

By simultaneously solving the FOCs for all n dealers, we can confirm that, for any w_1, there exists a symmetric equilibrium in which $q_{il}(w_1) = q_{jl}(w_1)$ and $q_{is}(w_1) = q_{js}(w_1)$ for all i, j. Note that this implies that, in equilibrium, $w_{i2}^{*} = w_{j2}^{*}$ for all i and j—i.e., even though the manufacturer can offer different margins to different dealers, she does not do so in equilibrium. Let us denote the quantities leased and sold in these symmetric equilibria by $q_{il}^{DS}(w_1)$ and $q_{is}^{DS}(w_1)$, respectively. Depending on the wholesale price, the number of dealers, and the substitutability parameter, the symmetric equilibrium will be either a *hybrid* policy in which there are positive quantities of both leasing and selling, a *pure leasing* policy, or a *pure selling* policy. We can now provide characterizations of the equilibrium dealer response to the manufacturer's first-period margin.

Proposition 4.1. *When the manufacturer can offer dealer-specific wholesale prices (margins) in the second period, then there exists a threshold,* $w^{0SDS}(n, \theta)$, *such that the dealers' optimal response to the manufacturer's first-period wholesale price can be characterized as follows*:

(a) *For* $w_1 < w^{0SDS}(n, \theta)$, *there exists a symmetric equilibrium among the dealers in which each one adopts a hybrid policy, and the quantities for each of the dealers,* $q_{il}^{DS} > 0$ *and* $q_{is}^{DS} > 0$, *satisfy* $d\pi_{i1}^{DS}(w_1, \mathbf{q}_l, \mathbf{q}_s)/dq_{il} = 0$ *and* $d\pi_{i1}^{DS}(w_1, \mathbf{q}_l, \mathbf{q}_s)/dq_{is} = 0$ *for* $i = 1, \ldots, n$.

(b) *For* $w_1 \geq w^{0SDS}(n, \theta)$, *there exists a symmetric equilibrium among the dealers in which each one adopts a pure leasing policy, i.e.,* $q_{is}^{DS} = 0$ *for* $i = 1, \ldots, n$ *and the quantity that dealer i leases,* q_{il}^{DS}, *satisfies* $d\pi_{i1}^{DS}(w_1, \mathbf{q}_l, 0)/dq_{il} = 0$ *for* $i = 1, \ldots, n$.

(c) *Pure selling does not occur in response to any manufacturer wholesale price (margin).*

(d) $w^{0SDS}(n, \theta)$ *is increasing in both* θ *and n.*

The above result highlights the two forces that are influencing the dealers' first-period decisions. The first of these two forces is the one shown by Bucovetsky and Chilton (1986) and Desai and Purohit (1999), in which competitive pressures encourage selling among firms who distribute durable products. By selling, a *dealer* can *lock up* consumers in the first period, reducing the demand available to other dealers. When the intensity of competition is high, a dealer is more concerned with locking up consumers than he is with mitigating time inconsistency. However, the previous results do not consider how the first-period selling and leasing quantities might affect the second-period wholesale price(s) offered by a strategic supplier. By endogenizing these wholesale prices, Proposition 4.1 highlights the second force that may influence the dealers' decisions: by leasing, each dealer can increase the pressure on the manufacturer to offer him a lower wholesale price in the second period. This incentive comes on top of the usual motivation for leasing that involves mitigation of time inconsistency. Consequently, pure selling is never an equilibrium response to any first-period manufacturer wholesale price. Moreover, because higher first-period wholesale prices increase the potential benefit from reducing them in period 2, at sufficiently large values of w_1, the dealers lease all of the units that they purchase from the manufacturer.

Let $\alpha_i^{DS}(w) = q_{il}^{DS}/(q_{il}^{DS} + q_{is}^{DS})$ be the proportion of units that dealer *i* leases in period 1 at a wholesale price of *w* given that the manufacturer can offer dealer-specific wholesale prices in period 2.

Corollary 4.2. *When the manufacturer can offer dealer-specific wholesale prices in the second period, then* $\alpha_i^{DS}(w_1)$ *is increasing in* w_1 *for all n and* θ.

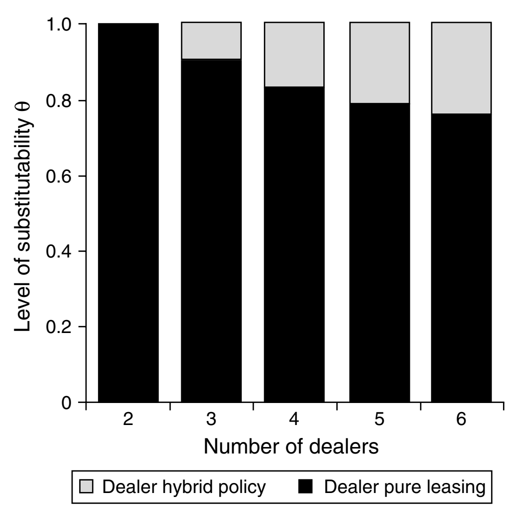
The above corollary further underlines the idea that larger first-period wholesale prices strengthen the incentives of dealers to lease to drive down the second-period wholesale prices that they will be offered. In particular, when the first-period wholesale price increases, there is increased opportunity for dealers to benefit from applying downward pressure on second-period wholesale prices, which they do by increasing the fraction of leasing.

Using the above results, we can numerically identify the equilibrium that is conditional on the manufacturer selling to the dealer at optimal dealer-specific wholesale prices. This is depicted in Figure 1 where we see that as the number of dealers increases they use a hybrid policy at lower and lower levels of substitutability parameter θ, but pure selling never occurs. The latter of these observations is consistent with the results of Bulow (1986), Bucovetsky and Chilton (1986), and Desai and Purohit (1999). However, in contrast to these existing models, we have endogenized the wholesale price at which the competing durable goods firms acquire the product from a common supplier. Because this gives dealers additional motivation for leasing, we now see pure leasing at values of $\theta > 0$, which is not the case in the existing results, which treat the wholesale price as exogenous.

4.3. The Manufacturer's Decision to Sell or Lease Broker

We now address the question of whether the manufacturer will use a lease-brokering arrangement or sell

Figure 1 **Dealer Response to Manufacturer Selling with Optimal Dealer-Specific Wholesale Prices**



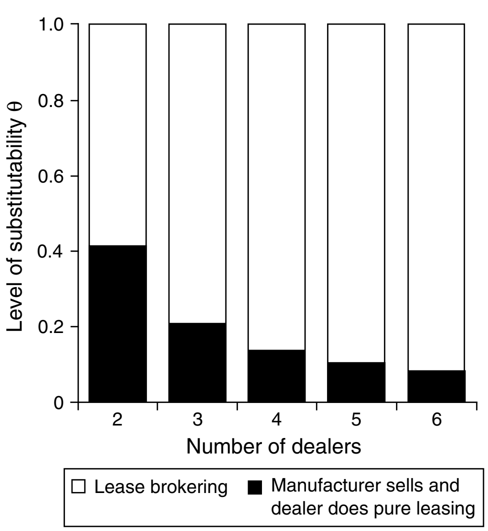
her product to the dealers in equilibrium when she can offer dealer-specific wholesale prices.

PROPOSITION 4.3. *When the manufacturer can offer dealer-specific wholesale prices in the second period, then her equilibrium policy for any number of dealers can be characterized in terms of a threshold, $\theta^L(n)$. For $\theta \le \theta^L(n)$, the manufacturer sells to the dealers and the dealers respond with pure leasing, whereas for $\theta > \theta^L(n)$, the manufacturer prefers to use a lease-brokering arrangement with the dealers.*

The above result generalizes Proposition 3.1, which demonstrates that for a single dealer the manufacturer sells to the dealer and the dealer adopts a pure leasing policy with respect to the consumer. However, as shown in Figure 2, we see that as either θ or n increases, the manufacturer will switch from selling to the dealers to using them to broker her own leases. When competition among the dealers is weak, and the potential adverse effects of double marginalization are the most severe, the manufacturer sells, anticipating that the dealers will lease to the consumer at a lower price than under lease brokering. Although the dealers' off-lease units will put downward pressure on the manufacturer's future margins, she accepts this in return for being able to mitigate double marginalization. However, as dealer competition intensifies, weakening the potential effects of double marginalization, the manufacturer is less willing to accept the downward pressure on her future margins that these off-lease units would create, and her preference shifts to a lease-brokering arrangement.

To understand the effect of strategic intermediaries in a channel of distribution for a durable product, we can compare the equilibria that are depicted in Figure 2 to a hypothetical situation in which the monopolist manufacturer interacts directly with each of the n markets. For that hypothetical situation, it is obvious that it would be optimal for the manufacturer to lease the product to all n markets. On the other hand, as shown in Figure 2, when the manufacturer relies on intermediaries, selling becomes an effective tool for managing double marginalization, particularly when the number of dealers is small, or the level of substitutability is low.

Figure 2 **Equilibrium Under Dealer-Specific Wholesale Prices**



5. The Implications of Uniform Wholesale Pricing

If there are legal requirements, e.g., the Robinson Patman Act, that require the manufacturer to offer the same wholesale price to all dealers, then she will maximize (26) subject to the constraint, $w_{i2} = w_{j2}$ for all i, j. Let w_2^{RP} be the solution to this constrained optimization. It can be identified by substituting w_2 for w_{j2} in (26) and applying FOCs. By doing this, we obtain

$$w_2^{RP}(\mathbf{q}_l, \mathbf{q}_s) = \left[\frac{an-(2+(n-1)\theta)\sum_j q_{jl}-(1+(n-1)\theta)\sum_j q_{js}}{2n}\right]^+. \quad (31)$$

The difference between the functional form of (31) and the second-period dealer-specific wholesale price function (27) is important because of the way in which it alters the incentives for dealers to determine their selling and leasing quantities in the first period. Note that as $\theta \to 0$, the second-period dealer-specific wholesale prices, as shown in (27), converge to (12), the second-period wholesale price for a single dealer. However, such convergence does not occur for the second-period uniform wholesale price in (31) because the uniform wholesale pricing restriction creates an interdependency among dealers even in the absence of marketplace interactions; i.e., $\theta = 0$. It is also of interest to consider how this restriction affects the marginal effects of first-period quantities on the second-period wholesale prices. Differentiating (31) with respect to q_{il} and q_{is}, we have

$$\frac{dw_2^{RP}(\mathbf{q}_l, \mathbf{q}_s)}{dq_{il}} = -\frac{2+(n-1)\theta}{2n} > \frac{dw_2^{DS}(\mathbf{q}_l, \mathbf{q}_s)}{dq_{il}} = -1, \quad (32)$$

$$\frac{dw_2^{RP}(\mathbf{q}_l, \mathbf{q}_s)}{dq_{is}} = -\frac{1+(n-1)\theta}{2n} > \frac{dw_2^{DS}(\mathbf{q}_l, \mathbf{q}_s)}{dq_{is}} = -\frac{1}{2}. \quad (33)$$

The above inequalities reflect the externality that is created when the manufacturer is required to offer the same wholesale price to all dealers. Because each dealer's quantities, q_{il} and q_{is}, have less (negative) effect on the second-period wholesale price, there is less incentive for him to increase these quantities. As the number of dealers increases, the magnitude of the derivatives of w_2^{RP} with respect to q_{il} and q_{is} decreases, both approaching $\theta/2$. Thus, the effects of the externality are strongest when n is large and/or θ is small. Although the units that each dealer leases still have a stronger (more negative) effect on the second-period wholesale price than do units that he sells, this difference also decreases with the number of dealers. Note that $dw_2^{RP}(\mathbf{q}_l, \mathbf{q}_s)/dq_{is} - dw_2^{RP}(\mathbf{q}_l, \mathbf{q}_s)/dq_{il} = 1/2n$.

Let $\pi_{i2}^{RP}(\mathbf{q}_l, \mathbf{q}_s)$ and $\Pi_2^{RP}(\mathbf{q}_l, \mathbf{q}_s)$ be the conditionally optimal second-period profit of dealer i and of the manufacturer when the manufacturer must offer a uniform wholesale price. As we did for dealer-specific pricing, we can obtain these second-period profit functions by setting $w_{i2}^*(\mathbf{q}_l, \mathbf{q}_s) = w_2^{RP}(\mathbf{q}_l, \mathbf{q}_s)$ for $i = 1, \ldots, n$ and substituting $w_{i2}^*(\mathbf{q}_l, \mathbf{q}_s)$ and (25) into (24) and (26):

$$\pi_{i2}^{RP}(\mathbf{q}_l, \mathbf{q}_s) = \pi_{i2}^{S}\big(\mathbf{q}_l, \mathbf{q}_s, \mathbf{q}_2^*\big(\mathbf{q}_l, \mathbf{q}_s, \mathbf{w}_2^{RP}(\mathbf{q}_l, \mathbf{q}_s)\big), w_2^{RP}(\mathbf{q}_l, \mathbf{q}_s)\big), \quad (34)$$

$$\Pi_2^{RP}(\mathbf{q}_l, \mathbf{q}_s) = \Pi_2^{S}\big(\mathbf{q}_l, \mathbf{q}_s, \mathbf{w}_2^{RP}(\mathbf{q}_l, \mathbf{q}_s)\big). \quad (35)$$

In period 1, consumers can anticipate the second-period market price from the first-period quantities:

$$p_{i2}^{RP}(\mathbf{q}_l, \mathbf{q}_s) = r_i\big(\mathbf{q}_l + \mathbf{q}_s + \mathbf{q}_2^*\big(\mathbf{q}_l, \mathbf{q}_s, \mathbf{w}_2^{RP}(\mathbf{q}_l, \mathbf{q}_s)\big)\big),$$

and the total profit of dealer i can be expressed as

$$\pi_{i1}^{RP}(w_1, \mathbf{q}_l, \mathbf{q}_s) = q_{il} r_i(\mathbf{q}_l + \mathbf{q}_s) + q_{is} p_{is}^{RP}(\mathbf{q}_l, \mathbf{q}_s) - (q_{il} + q_{is}) w_1 + \pi_{i2}^{RP}(\mathbf{q}_l, \mathbf{q}_s),$$

where each dealer seeks to determine the values of $q_{il}, q_{is} \geq 0$ that maximize his own profits. Let $\mathbf{q}_l^{RP}(w)$ and $\mathbf{q}_s^{RP}(w)$ be the equilibrium leasing and selling vectors for the n dealers conditional on the first-period wholesale price w that is offered by the manufacturer.

Proposition 5.1. *When the manufacturer is restricted to offering the same wholesale price to all dealers in the second period, then there exist two thresholds, $w^{0SRP}(n, \theta)$ and $w^{0LRP}(n, \theta)$, such that the dealers' optimal response to the manufacturer's first-period wholesale price can be characterized as follows*:

(a) *For $w_1 < \text{Min}\{w^{0LRP}(n, \theta), w^{0SRP}(n, \theta)\}$, there exists a symmetric equilibrium among the dealers in which each dealer adopts a hybrid policy of both leasing and selling, and the quantities satisfy $q_{il}^{RP}(w_1) = q_{il}^{HRP}(w_1)$ and $q_{is}^{RP}(w_1) = q_{is}^{HRP}(w_1)$, where $\mathbf{q}_l^{HRP}(w_1)$ and $\mathbf{q}_s^{HRP}(w_1)$ satisfy $d\pi_{i1}^{RP}(w_1, \mathbf{q}_l^{HRP}, \mathbf{q}_s^{HRP})/dq_{il} = 0$ and $d\pi_{i1}^{RP}(w_1, \mathbf{q}_l^{HRP}, \mathbf{q}_s^{HRP})/dq_{is} = 0$ for $i = 1, \ldots, n$.*

(b) *If $\theta \leq (-1 + \sqrt{1 - 8n + 8n^2})/(2n(n-1))$, then for $w_1 \geq w^{0SRP}(n, \theta)$, there exists a symmetric, pure leasing equilibrium in which $q_{is}^{RP}(w_1) = 0$ and $q_{il}^{RP}(w_1) = [q_{il}^{PLRP}(w_1)]^+$ for $i = 1, \ldots, n$, where $\mathbf{q}_l^{PLRP}(w_1)$ satisfies $d\pi_{i1}^{RP}(w_1, \mathbf{q}_l^{PLRP}, 0)/dq_{il} = 0$ for $i = 1, \ldots, n$.*

(c) *If $\theta \geq (-1 + \sqrt{1 - 8n + 8n^2})/(2n(n-1))$, then for $w_1 \geq w^{0LRP}(n, \theta)$, there exists a symmetric, pure selling equilibrium in which $q_{il}^{RP}(w_1) = 0$ and $q_{is}^{RP}(w_1) = [q_{is}^{PSRP}(w_1)]^+$ for $i = 1, \ldots, n$, where $\mathbf{q}_s^{PSRP}(w_1)$ satisfies $d\pi_{i1}^{RP}(w_1, 0, \mathbf{q}_s^{PSRP})/dq_{is} = 0$ for $i = 1, \ldots, n$.*

Let us define $\alpha_i^{RP}(w) = q_{il}^{RP}(w)/(q_{il}^{RP}(w) + q_{is}^{RP}(w))$ be the proportion of units that dealer i leases when the manufacturer offers wholesale price w in the first period and must offer the same wholesale price to all dealers in the second period. Let $w_1^{MRP}(n, \theta)$ be the largest wholesale price for which a dealer purchases a positive quantity from the manufacturer in period 1.

Corollary 5.2. (a) *Both $q_{is}^{RP}(w_1)$ and $q_{il}^{RP}(w_1)$ are nonincreasing in w_1 for $w_1 \in [0, w_1^{MRP}(n, \theta)]$.*

(b) *For $w_1 \leq \text{Min}\{w^{0LRP}(n, \theta), w^{0SRP}(n, \theta)\}$, the fraction of leasing in the dealer's optimal response, $\alpha_i^{RP}(w_1)$, is nondecreasing in w_1 when $\theta \leq (-1 + \sqrt{1 - 8n + 8n^2})/(2n(n-1))$, and is nonincreasing otherwise. For $w_1 \in [\text{Min}\{w^{0LRP}(n, \theta), w^{0SRP}(n, \theta)\}, w_1^{MRP}(n, \theta)]$: $\alpha_i^*(w_1) = 1$ if and only if $\theta \leq (-1 + \sqrt{1 - 8n + 8n^2})/(2n(n-1))$. Otherwise, $\alpha_i^{RP}(w_1) = 0$.*

When the manufacturer is constrained to offer the same wholesale price to all dealers, higher first-period wholesale prices lead to higher proportions of leasing only when competitive pressures are sufficiently low. This contrasts sharply with the result in Corollary 4.2. Recall that when the manufacturer can offer dealer-specific wholesale prices, higher first-period prices *always* lead to proportionately more leasing and pure selling *never* occurs, regardless of the intensity of competition among the dealers. Here, the externality that is created by the wholesale price constraint weakens the effect that a dealer's lease quantity has on his second-period wholesale price. Consequently, when the intensity of competition is high, the proportion of leasing decreases in the first-period wholesale price, and at sufficiently high values of w_1, we will have a pure selling conditional equilibrium.

We can again numerically identify the equilibrium conditional on the manufacturer selling to the dealer(s) at an optimal uniform wholesale price, and this is depicted in Figure 3. By comparing Figure 3 with Figure 1, it is easy to see that the restriction that prevents the manufacturer from using dealer-specific wholesale pricing not only results in the dealers selling some units (i.e., hybrid) at lower levels of substitutability parameter θ, it also reintroduces pure selling as a conditional equilibrium among the dealers at sufficiently high values of θ. The reason for this, of

Figure 3 Dealer Response to Manufacturer Selling with Optimal Uniform Wholesale Prices

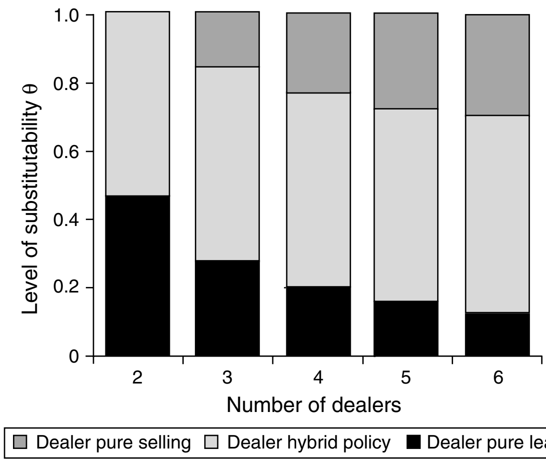
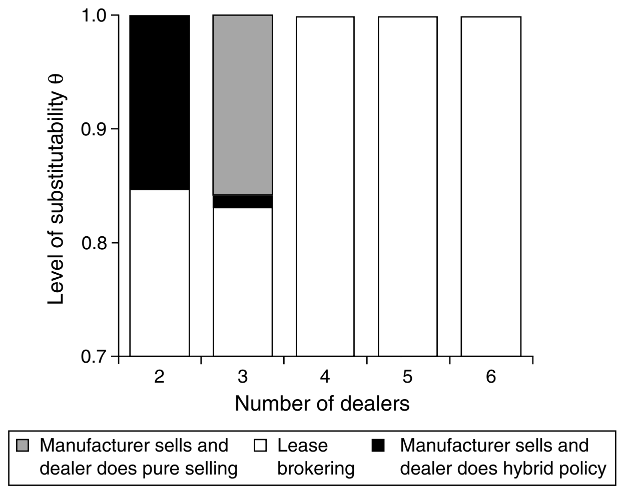


Figure 4 Equilibrium Under Uniform Wholesale Prices



course, is that the constraint on the manufacturer's wholesale prices eliminates a good part of the incentive for dealers to lease. However, even though the wholesale pricing restriction reduces the range of parameters for which the dealers use pure leasing, we can see that pure leasing still occurs for $\theta > 0$. Recall that this contrasts with existing results that ignore the effect of a strategic supplier on wholesale prices.

5.1. The Manufacturer's Decision to Sell or Use Lease Brokering

Let us now consider how a constraint requiring that the manufacturer offer the same wholesale price to all dealers affects her preference between selling to the dealers and using a lease-brokering arrangement. We will see that it alters the equilibrium not only quantitatively, but also qualitatively.

Proposition 5.3. *When the manufacturer is restricted to offering the same wholesale price to all dealers, then her equilibrium policy for any number of dealers can be characterized in terms of a threshold,* $\theta^{LRP}(n)$. *For* $\theta \le \theta^{LRP}(n)$, *the manufacturer uses a lease-brokering arrangement, while for* $\theta > \theta^{LRP}(n)$, *the manufacturer prefers to sell to the dealers who respond with either pure selling or a hybrid of selling and leasing. Further,* $\theta^{LRP}(n) < 1$ *if and only if* $n < 4$.

The above result, which is depicted in Figure 4, demonstrates the effect of the constraint requiring that the manufacturer offer the same wholesale price to all dealers. Recall that this constraint creates an externality that weakens the incentives for dealers to increase their selling and leasing quantities. Under the constraint, the rates at which each dealer's selling and leasing quantities drive down the second-period wholesale price are increasing in θ. For low values of θ, each dealer's incentives to increase his quantities are very weak, especially when n is large, and this erodes the manufacturer's ability to mitigate double marginalization by selling her product to the dealers. Consequently, as seen in Figure 4, the manufacturer's preference for lease brokering expands to include even very low levels of substitutability θ for all values of $n \ge 4$.

When $n < 4$, the effect of the constraint on the wholesale price is more complex. For low values of θ, the constraint severely erodes the manufacturer's ability to use selling to mitigate double marginalization. Rendered impotent to control double marginalization, she can at least control time inconsistency by switching to a lease-brokering arrangement. In contrast, when both θ is large and $n < 4$, the constraint switches the manufacturer's preference in the opposite direction, i.e., from lease brokering to selling. Examining dealers' responses to dealer-specific pricing for the same values of n and θ helps us understand this difference. Under dealer-specific pricing, when $n = 2$ and θ is sufficiently high, both dealers respond to manufacturer selling with pure leasing, just as a single dealer would. (When $n = 3$, the dealers respond with a very high fraction of leasing.) However, with at least two sufficiently substitutable dealers, the potential effects of double marginalization are significantly lower than they are with a single dealer, so the manufacturer is less willing to accept downward pressure on her second-period margins. She consequently prefers the lease-brokering arrangement when there are two or more dealers and θ is sufficiently high. However, under uniform wholesale pricing, the addition of the second dealer would no longer result in a pure leasing response if the manufacturer were to sell her product. Because the wholesale pricing constraint reduces the dealers' incentives to increase their selling and (especially) leasing quantities, the manufacturer faces less downward pressure on her wholesale price if she sells, which improves the relative attractiveness of selling vis-à-vis lease brokering. As long as the number of dealers is not too large, i.e., $n < 4$, the potential adverse effects of double marginalization are sufficiently potent that this is enough to tip the manufacturer's preference from lease brokering to selling.

6. Managerial Implications and Conclusions

The main contribution of this paper is to recognize how the flexibility of dealers to either lease or sell a durable product that they purchase from a manufacturer affects the dynamics of a channel of distribution. When dealers have this flexibility, the manufacturer faces a trade-off between the effects of double marginalization and those of time inconsistency. If the manufacturer uses the dealers to broker her own leases to consumers, then time inconsistency can be eliminated, but the full effects of double marginalization remain. In contrast, if the manufacturer sells her product to the dealers, time inconsistency drives down the retail price and serves as a counter to double marginalization. However, any units that the dealer leases to the end consumer, and subsequently reclaims as off-lease units, also put pressure on the manufacturer's future margins. When the manufacturer interacts with a single dealer, the potential effects of double marginalization are sufficiently large that she benefits more from mitigating them than she is hurt by the decrease in her future margins. Thus, if the durable goods manufacturer in Bulow (1982) were to interact with a single dealer, she would be better off selling instead of leasing to this dealer, even though the dealer would lease to consumers.

When the manufacturer interacts with multiple dealers, the intensity of competition among them plays an important role in determining how they will respond if the manufacturer sells to them. The intensity of competition consequently also drives the manufacturer's preference between selling her product to dealers versus using them to broker her own leases with end consumers. To maintain tractability, we assume that the manufacturer follows an *all-or-nothing* policy on the choice between selling and using a lease-brokering arrangement—an assumption that influences the specific thresholds we have obtained for different equilibrium policies. A more general model that allows the manufacturer flexibility to simultaneously offer lease brokering and purchasing opportunities to dealers would clearly affect the structure of the manufacturer's optimal policy. However, the fundamental trade-offs related to double marginalization and time inconsistency would remain. Therefore, our conclusions about why the manufacturer may shift between strategies are best interpreted in terms of how a change in parameters affects her *relative preferences*. In general, as either the number of dealers or the substitutability among them increases, the potential adverse effects of double marginalization become small relative to those of time inconsistency, and the manufacturer should rely more on lease brokering.

Our results may help explain recent developments in the automobile industry, where, despite increased availability of pricing information through the Internet that has increased interdealer competition (Morton et al. 2001), leasing has increased (Sturgeon 2005, Keel 1998, Waldman 2003) rather than decreased as previous models would have suggested. Our model of lease brokering approximates the way in which cars are leased to consumers in the U.S. market, and the observed increase in these brokered leases is consistent with our finding that as competition among the dealers intensifies, lease brokering becomes more attractive to the manufacturer.

Our analysis also shows that legal restrictions that require the manufacturer to offer a uniform wholesale price to all dealers can significantly alter the leasing and selling equilibrium in the end-product market. Typically, such restrictions are aimed at preventing price discrimination and would be of no consequence unless the intermediaries were asymmetric. However, for a durable product, uniform wholesale pricing affects the equilibrium among even symmetric intermediaries because it creates an externality. By weakening incentives for dealers to increase their quantities, uniform wholesale pricing interferes with the mitigation of double marginalization. However, it also reduces the relative attractiveness of leasing among the dealers, so it reduces the number of off-lease units that would drive down the manufacturer's future margins. Because of these dynamics, when the number of dealers is small, a restriction on the manufacturer's ability to use dealer-specific wholesale prices can reverse her preference between selling to the dealers and using lease brokering.

Although we believe that our model helps to explain how intermediaries can alter the equilibrium selling and leasing strategies of firms that make or distribute durable products, it is not without its limitations. First of all, we have not considered marginal costs of production, distribution, or transactions. These costs may play an important role, and in a separate paper (Bhaskaran and Gilbert 2008) we explore how they will affect a distribution channel consisting of a single manufacturer and a single dealer. Second, our model assumes that the manufacturer is a monopolist. Although this assumption helps us isolate the strategic interactions with dealers, a model that considers competition among manufacturers might provide a richer understanding of when lease brokering will emerge as an equilibrium strategy. We have also assumed a model of complete and perfect information. Although we believe this is not a restrictive assumption for industries like automobiles, where information about sales of vehicles is available from public records, relaxing this assumption will also expand the applicability of the results. Finally, the linear form of the demand function and the way in which we model the interdealer competition as symmetric has implications for the specific thresholds at which different equilibrium structures dominate. Although the existence of these thresholds and the directional effect of competitive intensity on them should apply to more general demand assumptions, it would certainly be of interest to understand whether differences observed in channel behavior across industries can be explained in terms of different demand structures.

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Appendix. Proofs

A. Proof of Proposition 3.1
By applying FOCs to (15) with respect to q_l and q_s, and applying the constraint that q_s, $q_l \geq 0$, it can be shown that for any value of w_1 the dealer will respond by setting $q_s(w)=0$ and setting $q_l(w_1)=a/2-2w_1/(4+3p)$. □

B. Proof of Proposition 3.2
(1) When the dealer engages in pure leasing, the wholesale price of the manufacturer can be obtained as follows:

$$w_1^* = \frac{a(4+3\rho)^2}{16(2+\rho)},$$

$$w_2^* = \frac{a(4+3\rho)}{8(2+\rho)}.$$

For the case in which the dealer sells to the consumers, wholesale price can be found by having $q_l=0$ and solving for the wholesale prices. Doing so, we have that

$$w_1^{SS} = \frac{a(128+184\rho+67\rho^2)}{32(8+5\rho)},$$

$$W_2^{SS} = \frac{a(24+17\rho)}{8(8+5\rho)}.$$

A comparison of the prices show that $w_1^* > w_1^{SS}$ and $w_2^* < w_2^{SS}$.

(2) As before, we can see that

$$q_1^* = \frac{a(4+\rho)}{8(2+\rho)} \qquad q_2^* = \frac{a(4+3\rho)}{16(2+\rho)}$$

$$q_1^{SS} = \frac{a(8+3\rho)}{4(8+5\rho)} \qquad q_2^{SS} = \frac{a(24+17\rho)}{16(8+5\rho)}.$$

A comparison of these quantities with each other show that $q_1^* \leq q_1^{SS} \leq \hat{q}_1$, and $\hat{q}_{2T} \leq q_{2T}^* \leq q_{2T}^{SS}$. □

C. Proof of Proposition 4.1
For a given wholesale price, the equilibrium quantities of a dealer is the solution to the following set of equations (because the dealers are symmetric in first period, the manufacturer will not have any incentive to offer different prices to different dealers):

$$\frac{d\pi_{i1}^S(w_1, \mathbf{q}_l, \mathbf{q}_s)}{dq_{il}} = 0 \quad i=1,\ldots,n, \tag{36}$$

$$\frac{d\pi_{i1}^S(w_1, \mathbf{q}_l, \mathbf{q}_s)}{dq_{is}} = 0 \quad i=1,\ldots,n, \tag{37}$$

$$q_{il}=q_{jl} \quad i=1,\ldots,n;\ j\neq i, \tag{38}$$

$$q_{is}=q_{js} \quad i=1,\ldots,n;\ j\neq i, \tag{39}$$

$$q_{il}\geq 0 \quad i=1,\ldots,n, \tag{40}$$

$$q_{is}\geq 0 \quad i=1,\ldots,n. \tag{41}$$

The solution to the first four equations is

$$q_{il}^*(w_1) = \frac{(2+(n-2)\theta-(n-1)\theta^2)(a(10+3(n-1)\theta-2w_1))}{40+(52n-72)\theta+(45-67n+22n^2)\theta^2+3(n-3)(n-1)^2\theta^3}, \tag{42}$$

$$q_{is}^*(w_1) = \frac{a(n-1)\theta^2(7+3(n-1)\theta)-2w_1(4+(4n-6)\theta+(2-3n+n^2)\theta^2)}{40+(52n-72)\theta+(45-67n+22n^2)\theta^2+3(n-3)(n-1)^2\theta^3}. \tag{43}$$

It can be immediately seen that $q_{il}^*(w_1)$ is always positive, implying that pure selling is never optimal. Also, it can be seen that (43) is positive if and only if $w_1 > w^{0SDS}$, where

$$w^{0SDS} = \frac{a\theta^2(n-1)(7+3\theta(n-1))}{2(2+(n-2)\theta)(2+(n-1)\theta)}.$$

Differentiating it w.r.t. to n and θ, it can be immediately seen that this expression is increasing in both these parameters. □

D. Proof of Corollary 4.2
Differentiating $\alpha_i^{DS}(w_1)$ w.r.t. to w_1, we have that

$$\begin{aligned}\frac{d\alpha_i^{DS}(w_1)}{dw_1} = {}& \big(2a(80+16(9n-14)\theta+(274-350n+96n^2)\theta^2\\ &+(-180+345n-193n^2+28n^3)\theta^3\\ &+(n-1)^2(63-37n+3n^2)\theta^4-3(n-3)(n-1)^3\theta^5)\big)\\ &\cdot\big((-2w_1(6(-8+5n)\theta+(3-4n+n^2)\theta^2)\\ &\quad+a(20+2(-13+8n)\theta+3(3-4n+n^2)\theta^2))^2\big)^{-1}.\end{aligned}$$

The denominator is positive so that the expression has the sign of the numerator. We can see that the numerator is increasing in n. Substituting $n=2$ into this numerator gives us that it is $2a(80+64\theta-42\theta^2-38\theta^3+\theta^4+3\theta^5)>0$. It follows that $d\alpha_i^{DS}(w_1)/dw_1>0$. □

E. Proof of Proposition 5.1
(1) It is easy to confirm that $\pi_{i1}^S(w_1, \mathbf{q}_l, \mathbf{q}_s)$ is jointly concave in q_{il} and q_{is}. The result follows from the definition of $w^{0L}(n,\theta)$, $w^{0S}(n,\theta)$, $q_{il}^{FOC}(w_1)$, and $q_{is}^{FOC}(w_1)$.

(2) From the definitions of $w^{0L}(n,\theta)$ and $w^{0S}(n,\theta)$ we can use the expressions for $q_{il}^{FOC}(w_1)$, and $q_{is}^{FOC}(w_1)$ that are shown in Table 1 to see that

$$w^{0L}(n,\theta) = \frac{a(2-12n-(9+2n(6n-13))\theta-(n-1)\theta^2(6+n(3n-16)-(n-1)(3n-1)\theta))}{6-8n-(11+4n(2n-5)\theta-(n-1)\theta^2(6+n(2n-9)-(n-1)^2)\theta)},$$

$$w^{0S}(n,\theta) = \frac{a(n-1)\theta(3+(3n-1)\theta)}{2+\theta(2n-3+(n-1)^2\theta)}.$$

It can be confirmed that $w^{0L}(n,\theta)$ and $w^{0S}(n,\theta)$ are decreasing and increasing, respectively, in θ and that they intersect at the point $\theta_{th} = (-1+\sqrt{1-8n+8n^2})/(2n(n-1))$. For $\theta \le (-1+\sqrt{1-8n+8n^2})/(2n(n-1))$, we will have $w^{0S}(n,\theta) \le w^{0L}(n,\theta)$, and the result follows from the definition of $q_{il}^{PL}(w_1)$.

(c) For $\theta \ge (-1+\sqrt{1-8n+8n^2})/(2n(n-1))$, we will have $w^{0S}(n,\theta) \ge w^{0L}(n,\theta)$, and the result follows from the definition of $q_{il}^{PS}(w_1)$. □

F. Proof of Corollary 5.2

(1) It is easy to confirm that $q_{il}^{FOC}(w_1)$, $q_{is}^{FOC}(w_1)$, $q_{il}^{PL}(w_1)$, and $q_{is}^{PS}(w_1)$ are all nonincreasing. At the point $w_1 = w^{0S}(n,\theta)$, it can be confirmed that

$$q_{il}^{FOC}(w_1) = q_{il}^{PL}(w_1) = \frac{a(2-\theta-(n-1)n\theta^2)}{4+(-8+6n)\theta+(5-9n+4n^2)\theta^2+(n-1)^3\theta^3}.$$

Similarly, at the point, $w_1 = w^{0L}(n,\theta)$, it can be confirmed that

$$q_{is}^{FOC}(w_1) = q_{is}^{PS}(w_1) = \frac{a(2-\theta-(n-1)n\theta^2)}{6-8n-(11+4n(-5+2n))\theta-(n-1)(6+n(2n-9))\theta^2+n^3\theta^2}.$$

(2) For $w_1 \le \text{Min}\{w^{0L}(n,\theta), w^{0S}(n,\theta)\}$, we have

$$a_i^*(w_1) = \frac{q_{il}^{FOC}(w_1)}{q_{il}^{FOC}(w_1)+q_{is}^{FOC}(w_1)}.$$

Differentiating $\alpha_i^*(w_1)$ with respect to w_1, it can be confirmed that

$$\frac{d\alpha^*(w_1)}{dw_1} = -\frac{a(2+(n-1)\theta)(2-\theta-n(n-1)\theta^2)K(n,\theta)}{((a(6n-1)+(1-4n)w_1)(2+(2n-3)\theta)+J(a,n,\theta))^2},$$

where $J(a,n,\theta) = (n-1)(a(1+n(3n-7)) + ((5-2n)n-1)w_1)\theta^2$ and $K(n,\theta) = (n(12+\theta(12n-19+(n-1)(3n-7)\theta)-2(1-\theta)))$. It can be seen that this expression is negative when $\theta > \theta_{th}$ and negative otherwise. □

G. Proof of Proposition 5.3

First, let us compare the manufacturer's profit under lease brokering with the case in which the dealers engage in pure leasing when she sells to them. Here, when $\theta = 0$, the equilibrium among the dealers will be pure leasing for any $w_1 \ge 0$, since $w^{0S}(n,0) = 0$. Using the results from Table 1 in the Technical Appendix, which can be found at http://mktsci.pubs.informs.org, we can see that for $\theta = 0$, the manufacturer maximizes her profit from selling by setting her wholesale price to $w_1^{PLC}(n,\theta) = w_1^{PL}(n,0) = ((1+6n)^2/(4n(2+10n)))a$. At this price, the manufacturer's profit is $\Pi_1^S(w_1^{PLC}(n,0), \mathbf{q}_l^{PL}(w_1^{PLC}),0) = ((1+6n)^2/(32(1+5n)))a^2 > 0$. Since $w^{HC}(n,0) = 0$, it follows that $\Pi_1^S(w_1^{HC}(n,0), \mathbf{q}_l^{FOC}(w_1^{HC}), \mathbf{q}_s^{FOC}(w_1^{HC})) = 0$. Also note that $\Pi_1^S(w_1^{PLC}(n,\theta), \mathbf{q}_l^{PL}(w_1^{PLC}),0)$ and $\Pi_1^S(w_1^{HC}(n,0), \mathbf{q}_l^{FOC}(w_1^{HC}), \mathbf{q}_s^{FOC}(w_1^{HC}))$ are continuous in w_1^{PLC} and w_1^{HC}, respectively, and w_1^{PLC} and w_1^{HC} are continuous in θ; it follows that there would be a threshold θ_{PL} such that if the manufacturer sells to the dealers, they will lease to the consumers if $\theta < \theta_{PL}$.

In addition, from the proof of Proposition 4.1, we know that for $\theta \in (0, (-1+\sqrt{1-8n+8n^2})/(2n(n-1))$, if the manufacturer sells her product then she can induce either a pure leasing or a hybrid response from the dealers. Because the optimal price at which she can induce the dealers to follow pure leasing policies in the symmetric equilibrium is $w^{PLC}(n,\theta) = \text{Max}\{w^{PL}(n,\theta), w^{0S}(n,\theta)\}$, and $w^{PL}(n,\theta)$ is the unconstrained price that maximizes $\Pi_1^S(w_1, q_l^{PL}(w_1),0)$, we have that $\Pi_1^S(w^{PL}(n,\theta), \mathbf{q}_l^{PL}(w^{PL}),0)$ is an upper bound on the profit that the manufacturer can earn from selling her product to the dealers at a price that induces a pure leasing equilibrium among them. Therefore, the following is a lower bound on the additional profit that she would earn from lease brokering, instead of selling to the dealers:

$$\Pi^L(n,\theta) - \Pi^S(w^{PL}(n,\theta), \mathbf{q}_l^{PL}(w^{PL}),0) = \frac{1+n(2+(n-1)\theta)(6-2\theta+n(18+9n-7)\theta)}{4(2+(n-1)\theta)^2(2-2\theta+n(10+(5n-3)\theta))}a^2,$$

which is positive for $n \ge 2$. It follows that lease brokering always dominates the case in which the dealer does pure leasing when the manufacturer sells to them.

Now we turn our attention to the case in which the dealers engage in hybrid policy or pure selling policy when the manufacturer sells to them. Let $\Pi_D^{SL}(\theta,n)$ be the difference between the manufacturer's profit when she uses lease brokering versus when she sells to the dealers and they use pure selling. Similarly, let $\Pi_D^{HL}(\theta,n)$ be the difference the manufacturer's profit when she uses lease brokering versus when she sells to the dealers and they use a hybrid policy. We have that

$$\alpha^*(\theta,2) = \frac{324+212\theta-259\theta^2-234\theta^3-33\theta^4+6\theta^5}{236+224\theta+23\theta^2-13\theta^3+2\theta^4} > 0,$$

$$\Pi_D^{HL}(\theta,2) = \frac{a^2(60-40\theta-83\theta^2-54\theta^3-3\theta^4)}{2(544+844\theta+360\theta^2-3\theta^3-18\theta^4+\theta^5)}.$$

It follows from above that pure selling is never optimal here, and $\Pi_D^{HL}(\theta,2)$ is positive when θ is sufficiently high. So for $n=2$, lease brokering is optimal if θ is sufficiently low.

We also have that

$$\alpha^*(\theta,3) = \frac{684+1{,}700\theta+287\theta^2-2{,}150\theta^3-1{,}772\theta^4-360\theta^5}{548+1{,}604\theta+1{,}573\theta^2+592\theta^3+84\theta^4},$$

$$\Pi_D^{HL}(\theta,3) = \frac{3a^2(-140-348\theta+65\theta^2+496\theta^3+208\theta^4)}{32(162+659\theta+1{,}002\theta^2+695\theta^3+213\theta^4+23\theta^5)},$$

$$\Pi_D^{SL}(\theta,3) = \frac{a^2(388-276\theta-1{,}127\theta^2+384\theta^3+1{,}096\theta^4-240\theta^6)}{32(1+\theta^2)(288+572\theta+48\theta^2-355\theta^3-60\theta^4+68\theta^5)}.$$

It can be seen that hybrid policy is optimal if θ is sufficiently low; also, hybrid policy from dealers dominate lease brokering if θ is sufficiently high. In addition, $\Pi_D^{SL}(\theta, 3) > 0$. It follows that lease brokering is optimal when θ is low enough.

Now let us look at these profit differences when $n = 4$. We have that

$$\alpha^*(\theta, 4) = \frac{1{,}172+5{,}140\theta+5{,}105\theta^2-5{,}802\theta^3-12{,}123\theta^4-5{,}076\theta^5}{988+4{,}856\theta+8{,}515\theta^2+6{,}285\theta^3+1{,}682\theta^4}.$$

It can be seen that $\alpha^*(\theta, 4) < 0$ when $\theta = \theta^{PS} = 0.765442$. Also,

$$\Pi_D^{HL}(\theta, 4) = \frac{3a^2(-84-368\theta-275\theta^2+426\theta^3+426\theta^4)}{2{,}368+15{,}572\theta+39{,}628\theta^2+48{,}501\theta^3+28{,}386\theta^4+6{,}345\theta^5}.$$

In addition, we also have that $\Pi_D^{HL}(\theta^{PS}, 4) < 0$. Because the denominator is increasing in θ, it follows that lease brokering would dominate the case in which dealer does hybrid policy when manufacturer sells to him. Similarly,

$$\Pi_D^{SL}(\theta, 4) = \frac{3a^2(-84-368\theta-275\theta^2+426\theta^3+426\theta^4)}{2{,}368+15{,}572\theta+39{,}628\theta^2+48{,}501\theta^3+28{,}386\theta^4+6{,}345\theta^5}.$$

Clearly, this is positive if θ is sufficiently low, the threshold of which is given by the point at which the numerator becomes zero as we keep decreasing θ from one to zero. This occurs when $\theta = 0.3101042 < \theta^{PS}$. Because pure selling is optimal only if $\theta > \theta^{PS}$, it follows that lease brokering also dominates the case in which the dealers engage in pure selling when the manufacturer sells to them. We can also show that $\Pi_D^{HL}(\theta, n)$ and $\Pi_D^{SL}(\theta, n)$ are decreasing in n. As a result, lease brokering is optimal when $n \geq 4$. □

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