Production, Manufacturing and Logistics

Clicks versus Bricks: The role of durability in marketing channel strategy of durable goods manufacturers

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ABSTRACT

We develop a two-period dual-channel model for a durable goods manufacturer to investigate how product durability and the channel structure create strategic issues that are significantly different from those in managing a dual channel for nondurables. The manufacturer can sell directly by its own e-channel and indirectly via an independent reseller. Our game-theoretic model nests Arya et al. (2007) as a special case when product durability reduces to zero and thus generalizes it to the durable goods setting. The equilibrium solutions indicate that, when the product is durable, both parties' profitability strongly depends on product durability and direct selling cost. In particular, we find that, compared to encroaching the reseller's market by direct selling online, it is optimal for the manufacturer to open an inactive e-channel that serves only as an information medium. Moreover, we find that, contrary to Arya et al.'s (2007) results, if product durability is moderate, for any direct selling cost, manufacturer's encroachment is always detrimental to the reseller, and thus its bright side disappears. We test our model's theoretical predictions of the effects of product durability on manufacturer's and reseller's profitability with data from the U.S. x86 computer server market, and find strong empirical support-profitability of both parties is higher when product durability is sufficiently low or sufficiently high, and lower when durability is intermediate.

1. Introduction

Many durable goods manufacturers, including Lenovo, HP, Epson and IKEA, have adopted dual channels to market their products (Epson, 2016; Hewlett-Packard; IKEA, 2016; Lenovo, 2016). Durable goods pose a number of questions that are quite different from those in nondurable goods marketing (Desai & Purohit, 1998;1999). For example, when facing encroachment from an upstream agent (manufacturer), a downstream agent (reseller) of durable goods is in a more difficult position than the reseller of nondurable goods because with durable goods, the reseller is not only essentially competing with the new products from the manufacturer today but also dealing with the used units tomorrow. On the other hand, if consumers are able to anticipate the manufac-

turer's incentive to increase product availability and lower prices, a time-inconsistency problem[1] arises under which the manufacturer's sequence of direct selling may not maximize both parties' overall profitability[2]. In practice, in some durable goods industries (e.g., the home furniture industry), 66% of manufacturers report Internet channel conflict[3] as the largest obstacle to their online sales (Lee et al., 2003). Indeed, finding the best way to utilize the e-channel in conjunction with the reseller channel continues to be a challenge for many durable goods manufacturers. For exam-

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[1] The time inconsistency problem refers to a situation in which rational consumers, anticipating that the monopolist has an incentive to increase product availability and lower its price over time, postpone purchases until the price falls to a competitive level. This issue is formalized in Stokey (1981) and Bulow (1982).

[2] Such issues are aptly addressed in a comprehensive review of several questions involved in durable goods marketing in Waldman (1993).

[3] Lee, Lee, and Larsen (2003) use this term to describe a conflict that occurs when Internet and traditional bricks-and-mortar channels compete against each other when selling to the same markets.

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ple, in the personal computer market, to avoid alienating its resellers, HP chooses to sell direct only to its 1,000 largest accounts and leave the large accounts to the resellers. Unfortunately, the reverse seems to be happening—HP's resellers are clashing with HP over direct sales—"We are now nervous about engaging with certain HP people; they have taken business direct even though the deal was registered and approached some of our longest standing customers," said Repton boss Greg Carlow (MicroScope, 2009). In contrast, Gateway closed all its manufacturer-owned retail stores in 2004 and now distributes its products through its direct Internet channel and independent retailers such as Best Buy and Costco (Yoo & Lee, 2011). Particularly, among the durable goods manufacturers that adopt dual channels to consumers, the marketing strategies chosen by them are quite different from one another. For example, Epson, HP, IKEA, and Lenovo sell their products in both channels, 3M, NEC, and Whirlpool, in contrast, accept no orders online but simply use the Internet as a medium for product information provision and reseller links. There is scant literature, however, addressing product durability and its impact on players' optimal strategies in a dual-channel supply chain[4].

In this paper, we develop a two-period game-theoretic model to investigate how product durability and the channel structure create strategic issues that are significantly different from those in managing a dual channel for nondurables. Specifically, we intend to answer the following questions: Under what conditions is it optimal for a durable goods manufacturer to open an e-channel? How does the addition of an e-channel affect manufacturer's and reseller's performance? What is the implication of product durability in the manufacturer's choice of e-channel addition and in channel members' performance? Our model accounts for the strategic effects of product durability, channel structure, and direct selling cost, and is able to capture several characteristics salient in many of today's durable goods markets. Further, our model reduces to Arya, Mittendorf and Sappington (2007) when product durability goes to zero, thus it nests Arya et al. as a special case and generalizes it to the durable goods setting. Therefore, our model can account for the strategic effects of product durability, channel structure, and direct selling cost, and is able to capture several characteristics salient in many of today's durable goods markets.

Our model provides new insights about marketing durables in dual-channel supply chains. The equilibrium solutions indicate that, when the product is durable, both parties' profitability strongly depends on product durability and direct selling cost. In particular, we find that, under certain conditions, compared to encroaching the reseller's market by direct selling online, it is optimal for the manufacturer to open an inactive e-channel that serves only as an information medium. Further, contrary to Arya, Mittendorf and Sappington (2007) results, our model shows that, if product durability is moderate, for any direct selling cost, manufacturer encroachment is always detrimental to the reseller, meaning its bright side disappears. These results imply that durable goods manufacturers should be more cautious when adding an e-channel. Our findings are consistent with the industry practice that many durable goods manufacturers are using the Internet only as a medium for providing product information and links to resellers but not accepting orders online. Some studies (e.g., Gilbert & Bacheldor, 2000; King, 2000; Webb, 2002) explain this practice may stem from manufacturers' reluctance to upset their resellers. We instead find this choice as the manufacturers' wish to use the Internet as a strategic channel for control because they can obtain
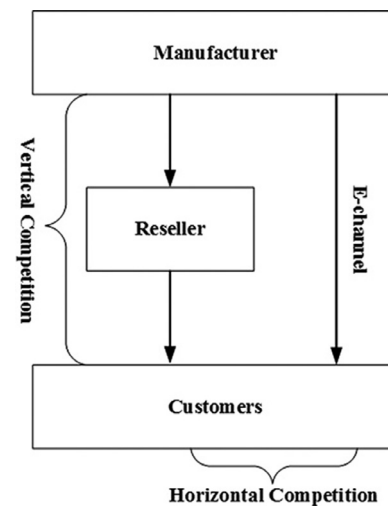
Fig. 1. Vertical and horizontal competition in dual-channel supply chain.

higher profits from using a sham e-channel than accepting orders online.

Our model contributes to the literature in several important ways. First, we address an aspect mostly ignored by extant research in the dual-channel area: the fact that many manufacturers accept no orders online despite their potential flexibility and capability to sell products through an e-channel. Hence, unlike prior studies, which take the structure of the distribution system as a given and often assume that products are sold through both channels, we endogenize channel choice and allow the manufacturer to choose whether or not to sell units through the e-channel. Second, we examine an issue that is minimally covered in the existing literature, the role of product durability in a dual-channel supply chain. As shown by our model, both manufacturer's and reseller's profitability depends critically on product durability, and the equilibrium results and conclusions can be quite different when product durability is factored in. Third, although the question of whether manufacturer encroachment results in "Internet channel conflict" or brings Pareto gains to both parties has been well studied in dual-channel supply chains for nondurables, cost concerns aside, little is known about how product durability and channel structure can affect these results. In this paper, we analyze the importance of such factors in shaping both parties' policies and determining their profits. Fourth, we go a step further to test our model's empirical validity. Our model predicts that both parties are likely to be beneficial if product durability is either sufficiently small or sufficiently large.

The remainder of the paper is organized as follows. Section 2 reviews the related literature and explains our contributions in more detail. Section 3 describes the key elements of our basic model and introduces notations. Section 4 outlines two models—the single-channel and the dual-channel model—and reports our main findings. Section 5 concludes the paper.

2. Relevant literature

Because the manufacturer is both a supplier to and a competitor of the reseller, a dual-channel supply chain contains two main types of channel competition: vertical competition and horizontal competition (see Fig. 1).

Vertical competition induces a double marginalization problem: all channel members independently seek to maximize their own profits, the manufacturer charges more than marginal cost, and the intermediary cuts supply, which leads to lower sales quantities and profits than in a vertically integrated channel (Spengler, 1950).

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[4] Although Xiong, Yan, Fernandes, Xiong, and Guo (2012) examine the reseller's strategic choices of leasing and selling in a dual-channel supply chain, they assume that the product does not deteriorate over time, and thus they have ignored the issue created by product durability.

Many coordination policy remedies have been proposed to eliminate the double marginalization problem (e.g., Cachon & Lariviere, 2005; Cai, 2010; Caldieraro & Coughlan, 2007; Chick, Mamani & Simchi-Levi, 2008; Chung, Talluri & Narasimhan, 2014). Xiao and Shi (2016) study the channel priority strategy in a dual channel supply chain where potential supply shortage is possible. They find that channel coordination may reduce the retailer's complaint of supply shortage. Chen, Liang, Yao, and Sun (2017) analyse the vertical competition when quality decision is incorporated in dual-channel supply chain in addition to the well studied price decision. They show that the introduction of a new channel can improve quality. Zhao, Hou, Guo, and Wei (2017) extend the single manufacturer single retailer supply chain structure to a supply chain consisting two manufacturers and one retailer, and investigate the impacts of consumer channel loyalty, complementarity and market power structures on the pricing decisions. Saha, Sarmah, and Modak (2017) extend the levels of supply chain and explore the channel structures of three-echelon supply chain. They find that introduction of dual channel is not always profitable for the channel members. Most of existing research studies the price competition assuming that the manufacturer and retailer set the retail prices simultaneously. Matsui (2017) studies the timing problem in dual channel supply chain and find that the manufacturer should post the direct price before or upon setting the wholesale price for the retailer. Zhang, He, and Shi (2017) study when a retailer decides to move to dual channel rather than a manufacturer, what is the channel structure choice. Results show that retailer's channel choice depends on customers' acceptance rate for the online channel.

Horizontal competition research in dual-channel supply chains has two different tracks. The first emphasizes that manufacturer encroachment establishes the manufacturer as both a supplier to and a direct competitor of its reseller partners, which potentially exerts competitive pressure on the reseller by increasing the manufacturer's negotiation power and decreasing the loyalty of retail customers. It thus results in Internet channel conflict, which has been the subject of several studies. For example, Webb (2002) and Lee et al. (2003) propose practical guidelines for Internet channel conflict management. Liu and Zhang (2006) explore whether a retailer can benefit from personalized pricing and how upstream personalized pricing or entry into a direct distribution channel affects the allocation of channel profit. They conclude that a retailer is worse off because of its own or upstream personalized pricing. Cattani, Gilland, Heese, and Swaminathan (2006) liken a manufacturer who adds a direct channel to the parable of boiling frog: if the costs and average convenience of the Internet channel become more favorable over time, then the manufacturer will be in a position to use the direct channel to undercut the prices in the traditional channel and so "boil" the traditional retailer. Webb and Lambe (2007) focus on the conflict internal to the supplier firm among the groups and individuals responsible for managing the various channels. The second research stream, in contrast, argues that both the manufacturer and the incumbent reseller benefit from manufacturer encroachment; that is, manufacturer encroachment can lead to Pareto gains. Chiang, Chhajed, and Hess (2003) construct a price-setting game between a manufacturer and its independent retailer, and demonstrate a Pareto zone in which both the manufacturer and the retailer can be better off after the manufacturer enters the direct channel. Chun, Rhee, Park, and Kim (2011) extend these findings by showing that, under certain circumstances, both manufacturers and retailers are better off in a dual distribution channel. Tsay and Agrawal (2004) demonstrate that the addition of a direct channel alongside a reseller channel is not necessarily detrimental to the reseller. Xiong et al. (2012) then address the strategies of selling and leasing in a dual-channel supply chain and find that both the dealer and the supply chain may

benefit from the manufacturer's encroachment. Luo, Li, and Cheng (2016) investigate the free ride effect in the dual-channel supply chain where pre-sales services are provided by the retailer and find that free ride effect has both positive and negative impact. When the manufacturing cost and customer demand are fuzzy, Soleimani (2016) develops two models using game theoretical approach and fuzzy set theory to optimize the pricing decision.

Our work is distinct from this extant literature in two important aspects: First, the above papers, like much of the extant literature, ignore product durability and pay little attention to its impact on players' optimal strategies. We attempt to help fill this void by addressing the issue of product durability and analyzing how it creates strategic issues that are significantly different from those in managing a dual-channel for nondurables. Second, as mentioned earlier, most studies in the dual-channel area assume both the structure of the distribution system and the sale of products through both channels, thereby ignoring a manufacturer's flexibility in whether or not to sell through the e-channel. Our dual-channel model, in contrast, endogenizes the channel decision and allows the manufacturer to choose whether to sell through its own direct channel.

In particular, our work is closely related to Arya, Mittendorf and Sappington (2007) and Xiong et al. (2012), but different from them in important ways. We generalize Arya, Mittendorf and Sappington (2007) to the durable goods setting and nest it as a special case. We differ from Xiong et al. (2012) in two important aspects. First, they assume that the product is perfectly durable and does not deteriorate over time, and thus they have ignored the issue of how product durability affects the interactions between a manufacturer and its dealers. In contrast, we assume that the product will deteriorate over time and investigate how this parameter create strategic issues that are significantly different from those in managing a dual channel for nondurables. Second, they focus on the effects of encroachment on the dealer's strategic choice of leasing and selling, which we find is very uncommon in practice——few resellers we contacted directly and searched in the PC magazine and other related publications adopt a mix of selling and leasing to consumers. We instead focus on a much more common channel issue facing manufacturers of durable goods in terms of e-channel choice, product durability and its impact on channel performance.

Our work is also related to the literature on durable goods, which argues that durability can interfere with the extraction of rents from consumers. Coase (1972) conjectures that rational consumers, anticipating a monopolist's incentive to increase product availability and lower its price over time, postpone their purchases until the price falls to the competitive level. They label this likelihood the "time-inconsistency problem". According to Bulow (1986), this problem can be avoided if the durable goods manufacturer adopts "planned obsolescence" to kill off the market for old copies and force customers to make repeat purchases. An incentive to practice such planned obsolescence arises if a monopolist markets its output by selling rather than leasing Waldman (1993). While, Chen, Esteban, and Shum (2013) conclude that the size of the used good stock decreases, such as when products become less durable, when the number of firms decreases, or when firms can commit to future production levels, increase the profitability of opening the secondary market[5].

Different from the previous research, this paper strives to understand how product durability creates strategic issues, specifically, the impact of product durability on manufacturer's channel decision, manufacturer's, reseller's and supply chain performance.

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[5] For a thorough review of the literature on durable goods, see Waldman (2003).

3. Model development

In this section, we introduce our notation and lay out our assumptions regarding the product, the manufacturer, the reseller, and the consumers. Assuming a two-period model in which a manufacturer markets a durable product through two channels—a reseller channel and her[6] own e-channel, we adopt the Arya, Mittendorf and Sappington (2007) assumptions about the sequence of the game between the manufacturer and the reseller, that is, the manufacturer decides whether to operate a direct channel and then announces the wholesale price to the reseller, who then responds by determining the optimal units of selling. The manufacturer then chooses the units to be sold through the e-channel.

3.1. Product

To capture the durability of a product, we use a two-period model[7] in which the products produced in Period 1 provide two periods of service: they are "new" when marketed in Period 1 and then classified as "used" in Period 2. Products produced in Period 2, in contrast, provide only one period of service. Hence, in our model, only new products are available in Period 1, but both new and used products (i.e., those marketed in Period 1) are available in Period 2. We also assume that the manufacturer and the reseller always sell new products in both periods; that is, used products are traded between consumers on the secondary market[8]. The market clearance price will be achieved in the equilibrium.

To model the differentiation between new and used units, we designate the durability of the products produced in Period 1 using a factor γ $(0 \leq \gamma \leq 1)$. If $\gamma = 1$, the product is perfectly durable and shows no deterioration over time, meaning that in Period 2, used units are identical to new units. If $\gamma = 0$, the product is nondurable and deteriorates fully after one period of use.

3.2. Manufacturer's problem

The manufacturer's problem is to set a wholesale price (w_i) and choose units to sell through the e-channel (q_{iM}) that will maximize her profits. Here, $i = 1, 2$ denotes Period 1 or 2. As in Arya, Mittendorf and Sappington (2007), we normalize her marginal cost of production to zero and assume that her marginal cost of selling on the e-channel is $C_d = c \geq 0$. This models the reseller's cost advantage in the sales process.

3.3. Reseller's problem

If the manufacturer sets her wholesale price, the reseller must choose the quantities that he intends to sell to maximize his profit. To ensure that the reseller has an advantage in the distribution channel and recalling that the manufacturer's unit direct selling cost is $C_d = c \geq 0$, we, similar to Arya et al. (2007), assume that the reseller's unit marketing cost is $C_R = 0$. This is because when selling to consumers directly, the manufacturer incurs packaging and delivery cost, while there is no such cost for retailer who has established the physical channel. Therefore, when modeling the unit selling cost, it is reasonable to assume that the reseller's unit marketing cost is zero.

3.4. Consumers

The size of the consumer population is assumed not to change over time and is normalized to 1. To enable a focus on product durability and dual-channel characteristics, we assume that consumers value the product for the flow of services that it provides over time. We also assume that no consumer can use more than one unit of the product in any period (Purohit & Staelin, 1994). We use the parameter θ to represent a consumer's valuation of the service provided by a durable per period, which is distributed uniformly in the interval [0, 1]. Consumer type θ has a valuation of θ for a new product. Recalling that the durability of the product γ represents how well a unit sold in Period 1 holds up in Period 2 (when it is classified as "used"), then consumer type θ has a valuation of $\gamma\theta$ for a used product. However, the consumers do not distinguish the products sold by different channels. Following Purohit and Staelin (1994), we do not model how consumer choose from different channels, but rather focus on the quantities sold by reseller and e-channel directly, which leads to the reverse demand function in the first period.

Denote q_{iM} and q_{iR}, respectively, as the quantity sold by the manufacturer and the reseller in period i, and let l_{ik} be the price of the services provided by product k in period i, where $k = n, u$ refers to, respectively, new products and used products. Following the same procedure of Agrawal, Ferguson, Toktay, and Thomas (2012); Desai and Purohit (1998), we derive the inverse demand functions from the consumer utility functions for Period 2. The one-period prices for a new and a used product in Period 2 are given, respectively, by

$$l_{2n} = 1 - \gamma(q_{1R} + q_{1M}) - q_{2R} - q_{2M}$$
$$l_{2u} = \gamma(1 - q_{1R} - q_{2R} - q_{1M} - q_{2M}) \quad (1)$$

Because only new products are available in Period 1, by applying the same procedure of Purohit and Staelin (1994), we can have the one-period price for a new product in Period 1 as follows:

$$l_{1n} = 1 - q_{1R} - q_{1M} \quad (2)$$

The durable produced in Period 1 can provide a stream of services for both periods; hence, its selling price is the sum of the one-period price for a new product in Period 1 and the one-period price for a used product in Period 2; that is, $p_{1n} = l_{1n} + \rho l_{2u}$, where ρ is a discount factor denoting the cash flows received in Period 2. To simplify, we assume a zero discount rate and a discount factor $\rho = 1$[9]. Since a durable produced in Period 2 provides only one period of service, its selling price is $p_{2n} = l_{2n}$.

4. Model analysis

In this section, we consider both parties' optimal strategies and analyze how they are affected by durability. That is, we look first at a single-channel model in which no e-channel is open and then consider a dual-channel model in which the manufacturer opens her own e-channel and sells products through both it and a reseller channel. It should be noted that in the dual-channel supply chain, the manufacturer has the flexibility to sell or not sell her products through the e-channel.

4.1. Model S—a single-channel model

We begin our analysis by first considering a single-channel model that serves as a useful benchmark for the subsequent model, which allows horizontal competition in a dual channel supply chain. From Eqs. (1) and (2), we derive the following

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[6] In reporting our computations, for purposes of differentiation, we use the feminine pronoun to refer to the manufacturer and the masculine pronoun to refer to the reseller.

[7] This assumption is consistent with previous literature (e.g., Desai & Purohit, 1998; 1999). A two-period model not only allows us to study dynamic issues while retaining tractability but simplifies the presentation of our analysis.

[8] For example, with the development of the internet and information technology, electronic peer-to-peer (P2P) markets become popular, and consumers can buy and sell used products among themselves in electronic peer-to-peer (P2P) used goods markets (e.g., eBay.com, Amazon.com).

[9] Although allowing the discount factor $0 < \rho < 1$ increases the complexity of the analysis, all our results remain unaffected.

single-channel inverse demand functions:

$$p_{1n} = l_{1n} + l_{2u} = 1 - q_{1R} + \gamma (1 - q_{1R} - q_{2R}) \tag{3}$$

$$p_{2n} = l_{2n} = 1 - \gamma q_{1R} - q_{2R} \tag{4}$$

We perform the ensuing analysis using backward induction, that is, we first determine both parties' optimal policies in Period 2 and then solve their problems in Period 1. This backward induction is necessary because consumers' expectations are rational, meaning that a subgame perfect Nash equilibrium can be determined.

4.1.1. Second-period analysis

In this analysis, we use lowercase π_i^j (uppercase Π_i^j) to represent the reseller's (manufacturer's) profit in period i under model j, where $j = s, d$ refers to the single-channel model and the dual-channel model, respectively. The reseller maximizes his profits over both periods by choosing optimal quantities of q_{1R} and q_{2R}. Then, under the single-channel model, the reseller profit in Period 2 is $\max_{q_{2R}} \pi_2^s(q_{2R}, w_2) = p_{2n} q_{2R} - w_2 q_{2R}$. Plugging (3) into the reseller's profit and solving the first-order condition yields q_{2R}^{s*}, so that the choice of q_{2R}^{s*} is

$$q_{2R}^{s*} = \frac{1 - \gamma q_{1R} - w_2}{2} \tag{5}$$

Working backwards, plugging (4) into $\Pi_2^s(q_{1R}, w_2)$ and solving the first-order condition yields w_2^{s*}:

$$w_2^{s*} = \frac{1 - \gamma q_{1R}}{2} \tag{6}$$

4.1.2. First-period analysis

Given the optimal solution for the second-period problem, we now look at both parties' first-period policies. In Period 1, the reseller's objective is to maximize his profits in both periods, $\max_{q_{1R}} \pi^s(q_{1R}, w_1) = \pi_1^s(q_{1R}, w_1) + \pi_2^{s*}(q_{1R}, w_1)$, while the manufacturer's problem is to choose a wholesale price w_1^{s*} that maximizes her profits in both periods, $\max_{w_1} \Pi^s(q_{1R}, w_1) = \Pi_1^s(q_{1R}, w_1) + \Pi_2^{s*}(q_{1R}, w_2)$. Maximizing the reseller's profit yields q_{1R}^{s*}, which, when substituted into the manufacturer's profit, yields w_1^{s*}. Substituting the ensuing q_{1R}^{s*} and w_1^{s*} into the quantities in (4) and the wholesale price in (5) provides the equilibrium outcome under the single-channel model, which is presented in Lemma 1 in Appendix A.

It is of particular interest to compare the result in Lemma 1 with that of the No-Encroachment Setting in Arya, Mittendorf and Sappington (2007), in which a manufacturer distributes a non-durable through both an e-channel and a reseller channel. Their outcome is identical to our result for the fully deteriorated product, $\gamma = 0$. Therefore, our model nests theirs as a special case.

To analyze the role played by product durability and the effects of endogenizing the reseller, it is of interest to compare the results in Model S with that of Desai and Purohit (1998)'s Pure Selling Model, in which the manufacturer sells durables to consumers directly. Using superscript b to represent the results from the Pure Selling Model in Desai and Purohit (1998) and representing the total profit in the pure selling model and the single-channel model by Π_T^{b*} and Π_T^{s*}, respectively, we can compare the two outcomes and summarize the findings in the following proposition:

Proposition 1. *(a) The optimal total profit of Π_T^{b*} (Π_T^{s*}) is convex in γ^b (γ^s) and achieve minimum in medium durability of γ^b (γ^s).*

(b) The presence of the reseller induces a double marginalization problem, $q_{1R}^{s*} + q_{2R}^{s*} < q_{1M}^{b*} + q_{2M}^{b*}$, $\Pi_T^{s*} < \Pi_T^{b*}$, which induces the minimum point of the optimal total profit to move leftward in the durability domain, $\gamma^s < \gamma^b$.

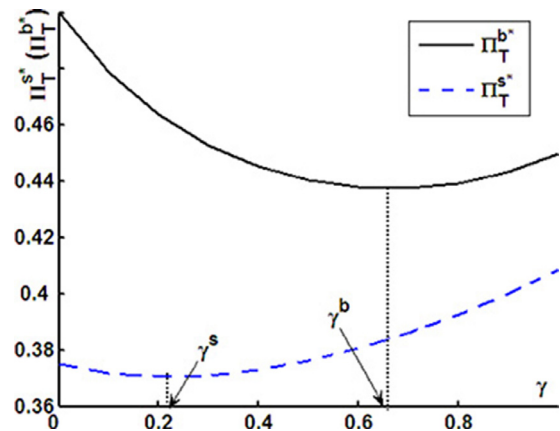**Proof.** See Appendix B. □

Fig. 2. Optimal profits in the single-channel and pure selling models.

Durability, particularly, plays an interesting and intuitively likely role in the manufacturer's choice of the optimal quantity: Not only is there cannibalization of new products by used ones in Period 2, but as durability increases, used and new products become closer substitutes and the cannibalization effect intensifies, causing the manufacturer to derive less revenue from new products in Period 2. Conversely, as durability increases, the consumer's valuation of a used product ($\gamma \theta$) increases and the price of the used product increases, which causes the manufacturer to derive more revenue from new products in Period 1.

Proposition 1(a) also shows that as long as durability is smaller than the threshold (i.e., γ^b and γ^s), the former component dominates, that is, the difference between used and new products is sufficient and the cannibalization effect becomes less significant, so that the manufacturer obtains more revenue from new products in Period 2. The manufacturer should therefore sell fewer units in Period 1 and adopt higher prices for new products in Period 2. However, if $1 > \gamma > \gamma^b(\gamma^s)$, the latter component dominates, that is, the difference between used and new products is not sufficient and the cannibalization effect intensifies, so that the manufacturer obtains more revenue from new products in Period 1. The manufacturer thus needs to earn more revenue from new products in Period 1 by choosing a smaller quantity of new units in Period 2.

We then consider the effects of endogenizing a reseller, whose presence induces $q_{1R}^{s*} + q_{2R}^{s*} < q_{1M}^{b*} + q_{2M}^{b*}$, $\Pi_T^{s*} < \Pi_T^{b*}$, the well-documented double marginalization effect. We find that endogenizing a reseller also leads to a leftward move in the minimum point of the optimal total profit, that is, $\gamma^s < \gamma^b$ (see Fig. 2). This observation can be explained as follows: the difference between $q_{1R}^{s*} - q_{1M}^{b*}$ and $q_{2R}^{s*} - q_{2M}^{b*}$ is increasing with durability, which means that the manufacturer faces a more severe double marginalization problem in Period 1 than in Period 2 (see Fig. 3). In other words, the relative amount of $q_{1M}^{b*} - q_{1R}^{s*}$ is larger than $q_{2M}^{b*} - q_{2R}^{s*}$, meaning that in Model S, as compared with q_{1M}^{b*} (q_{2M}^{b*}) in the pure selling model, the manufacturer has a smaller (larger) zone in which to obtain more revenue from new products in Period 2 (1). In other words, the minimum point of the optimal total profit has moved left, that is, $\gamma^s < \gamma^b$.

4.2. Model D-Dual-channel model

The timing in Model D is as follows. Before the game starts, the manufacturer has opened her own e-channel and decided to operate a direct channel. Then the manufacturer and the reseller play the following game. The manufacturer announces the wholesale price (w_i) to the reseller, who then responds by determining the optimal units of selling (q_{iR}). The manufacturer then chooses the
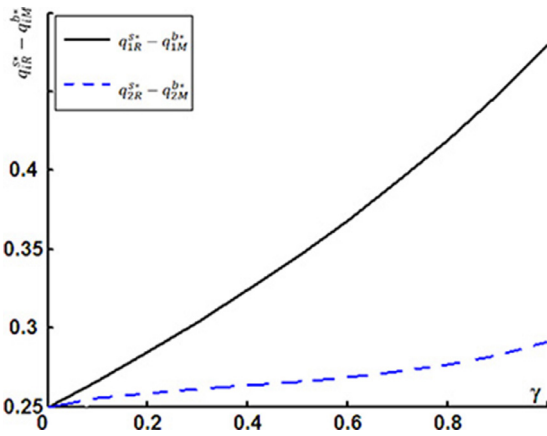
Fig. 3. $q_{1R}^{s*} - q_{1M}^{b*}$ and $q_{2R}^{s*} - q_{2M}^{b*}$.

Fig. 4. Strategy choices in Model D.

units to be sold through the e-channel (q_{iM}). Note that, although the manufacturer always opens an e-channel, she has the potential flexibility to sell products through an e-channel or adopt the e-channel only to provide product information and accept no orders online. From Eq. (1) and (2), we can derive the inverse demand functions in the dual-channel model as follows:

$$p_{1n} = l_{1n} + l_{2u} = 1 - q_{1R} - q_{1M} + \gamma (1 - q_{1R} - q_{2R} - q_{1M} - q_{2M}) \tag{7}$$

$$p_{2n} = l_{2n} = 1 - \gamma (q_{1R} + q_{1M}) - q_{2R} - q_{2M} \tag{8}$$

4.2.1. Second-period analysis

In the dual-channel model, the manufacturer's problem is

$$\max_{q_{2M}} \Pi_2^d (q_{2M}, q_{2R}, w_2) = w_2 q_{2R} + p_{2n} q_{2M} - c q_{2M} \tag{9}$$

Performing the optimization in (7) yields q_{2M}^{d*}. The reseller, anticipating the manufacturer's response, q_{2M}^{d*}, optimizes his profits by choosing the optimal quantity to sell (q_{2R}^{d*}) in Period 2. That is, he maximizes

$$\max_{q_{2R}} \pi_2^d (q_{2M}, q_{2R}, w_2) = p_{2n} q_{2R} - w_2 q_{2R} \tag{10}$$

We can then substitute q_{2M}^{d*} and q_{2R}^{d*} into (9) and maximize this expression to find the optimal wholesale price w_2^{d*}.

4.2.2. First-period analysis

The manufacturer (the reseller) optimizes her (his) profits over both periods by choosing q_{1M}^{d*}/w_1^{d*} (q_{2R}^{d*}) in Period 1, yielding the following profits, respectively:

$$\max_{q_{1M}} \Pi^d (w_1, q_{1R}, q_{1M}) = w_1 q_{1R} + p_{1n} q_{1M} - c q_{1M}$$
$$+ \Pi_2^{d*} (w_1, q_{1R}, q_{1M}) \tag{11}$$

$$\max_{q_{1R}} \pi^d (w_1, q_{1R}, q_{1M}) = p_{1n} q_{1R} - w_1 q_{1R} + \pi_2^{d*} (w_1, q_{1R}, q_{1M}) \tag{12}$$

As before, using backward induction, we first solve the manufacturer's maximization problem with respect to q_{1M}^{d*}. The reseller then maximizes his profits by choosing the optimal q_{1R}^{d*}, and given q_{1M}^{d*} and q_{1R}^{d*}, the manufacturer determines her first-period wholesale price (w_1^{d*}). These results are tabulated in Lemma 2 in Appendix A.

Lemma 2 indicates that, in the dual channel supply chain, the manufacturer can maximize her profit in two ways: opening an inactive e-channel and/or encroaching the reseller's market by selling
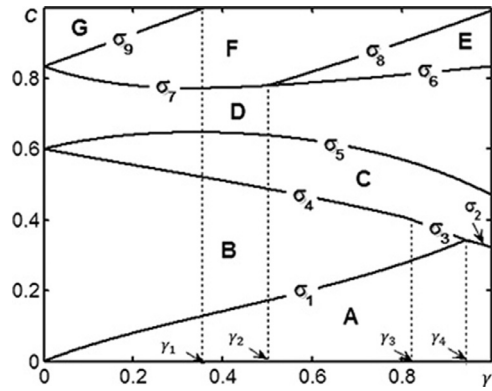
the products through the e-channel. And we find that this strategic choice is affected by both the relative direct sales cost c and product durability γ (see Fig. 4)[10]. We summarize our findings in the following proposition, which can be obtained from Lemma 2.

Proposition 2. *(a) when $\gamma > \gamma_2$, $\sigma_6 < c < \sigma_8$; $0 < \gamma < \gamma_3$, $\sigma_4 < c < \sigma_5$ and $\gamma_3 < \gamma < 1$, $\sigma_3 < c < \sigma_5$, the manufacturer starts encroaching into the reseller's market and sells the products through the e-channel only in Period 1.*

(b) $0 < \gamma < \gamma_3$, $\sigma_1 < c < \sigma_4$ and $\gamma_3 < \gamma < \gamma_4$, $\sigma_1 < c < \sigma_3$, the manufacturer is encroaching further and sells the products through the e-channel in both periods.

(c) $0 < \gamma < \gamma_4$, $0 < c < \sigma_1$ and $\gamma_4 < \gamma < 1$, $0 < c < \sigma_2$, the reseller starts withdrawing from the retail channel in Period 2.

The above proposition shows that, in the dual-channel supply chain, the manufacturer's strategic choice of encroaching her reseller's market is affected by both product durability γ and the direct selling cost c. As Xiong et al. (2012) show, the manufacturer begins to encroach into the market in Period 1 at a higher direct selling cost, and encroaches into the market in both periods at a lower direct selling cost. On the other hand, the product durability can have an important impact on the manufacturer's strategic choice as well. Take E and F in Fig. 4 for an example. With a fixed direct selling cost c, comparing the strategic choices of E and F based on the durability change, we can find that, the manufacturer is more likely to encroach the reseller's market in period 1 with a higher durability, because, as durability increases, the consumer's valuation of a used product ($\gamma\theta$) increases and the price of the used product increases, which induces the manufacturer to derive more revenue from new products in Period 1.

The general conclusion of previous research in this area (e.g., Arya, Mittendorf & Sappington, 2007; Xiong et al., 2012) is that the manufacturer is better off by encroaching the reseller's market and selling online. Yet it is not entirely clear whether this conclusion will hold if the manufacturer has the flexibility to open an inactive e-channel. In particular, we formulate the following proposition:

Proposition 3. *When $0 < \gamma < \gamma_2$, $\sigma_5 < c < \sigma_7$; $\gamma_2 \leq \gamma$, $\sigma_5 < c < \sigma_6$; $0 < \gamma < \gamma_1$, $\sigma_7 < c < \sigma_9$; $\gamma_1 \leq \gamma < \gamma_2$, $\sigma_7 < c < 1$; $\gamma_2 \leq \gamma$, $\sigma_8 < c < 1$ and $0 < \gamma < \gamma_1$, $\sigma_9 < c < 1$, compared to encroaching the reseller's market by direct selling online, it is optimal for the manufacturer to open an inactive e-channel, that is, opening an e-channel but not selling products through it, in other words, using the e-channel as a sham leads to higher profits than a direct selling strategy.*

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[10] Note that Arya, Mittendorf and Sappington (2007) outcome is identical to our result for the fully deteriorated product, $\gamma = 0$. Therefore, our model nests theirs as a special case.

Proof. See Appendix B. □

This observation is partly similar to that of Chiang et al. (2003), who conclude that "it is sometimes optimal for an independent manufacturer to open a direct channel although no direct sales occur" (P.12). We further find, however, that durability plays an important role as well. Before explaining Proposition 3, we briefly examine the manufacturer's profits, which come from two sources: selling products through the e-channel and product wholesaling. Note that opening an inactive e-channel means that the reseller faces the potential threat of direct selling, which leads to the reseller to lower his price and increase the number of sales units. Proposition 3 can thus be interpreted as follows: when the inactive e-channel is a strong threat (i.e., $0 < \gamma < \gamma_2$, $\sigma_5 < c < \sigma_7$ and $\gamma_2 \leq \gamma$, $\sigma_5 < c < \sigma_6$), the manufacturer benefits from adding an inactive e-channel because it can mitigate the double marginalization problem with her reseller. When $\gamma_2 \leq \gamma$, $\sigma_8 < c < 1$, direct selling becomes more costly, the manufacturer has no choice to open an inactive e-channel. When $0 < \gamma < \gamma_1$, $\sigma_7 < c < \sigma_9$ and $\gamma_1 \leq \gamma < \gamma_2$, $\sigma_7 < c < 1$, the durability is small (i.e., $\gamma \leq \gamma_2$) and the manufacturer derives little revenue from direct selling[11]. She thus chooses to add an inactive e-channel because she can benefit from it by mitigating the double marginalization problem. When $0 < \gamma < \gamma_1$, $\sigma_9 < c < 1$, the durability is so small and the threat of an inactive e-channel is so weak that the manufacturer opens an inactive e-channel though it can be easily overcome by her reseller.

Proposition 3 shows that under certain conditions, opening an inactive e-channel may lead to higher profits than a direct selling strategy. This finding may be consistent with the attitude reflected in the dual-channel program of 3M, NEC, and Whirlpool, which accept no orders online and simply use the Internet as a medium for product information provision and reseller links. As suggested by our model, this choice may stem from a wish to use the Internet as a strategic channel for control, that is, using a sham e-channel brings in higher profits than accepting orders online. And we also note that Gilbert and Bacheldor (2000); King (2000) and Webb (2002) report that they do so for not to upset their resellers. In our view, however, this explanation is insufficient because none of these manufacturers has made a public commitment to give up the choice of direct selling through e-channel and provide product information only. And more importantly, instead of the path of self-sacrifice, they can easily find many other measures to avoid the "Internet channel conflict" and achieve win-win results. For example, Ethan Allen Interiors Inc. shares its online profits with its licensees. Equipment distributor W.W. Grainger Inc. awards commissions to area sales representatives when a customer purchases from Grainger.com (Goldman, 1999). Bobbi Brown, however, transfers all her online orders to Neiman Marcus (Garner, 1999).

4.3. Comparison of the two models

We are now in a position to address the question posed at the beginning of this paper: How does the addition of an e-channel affect both parties' performance? We answer this question first from the manufacturer's point of view, and we have the following proposition.

Proposition 4. *When* $\gamma < \gamma_1$, $\sigma_9 < c < 1$, *the manufacturer's profit in the dual-channel model equals that in the single-channel model; otherwise, the manufacturer's profit in the dual-channel model is higher than that in the single-channel model.*

Proof. See Appendix B. □

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[11] Recall that, as durability decreases, the consumer's valuation of a used product decreases, which causes the manufacturer to derive less revenue from new products in Period 1.
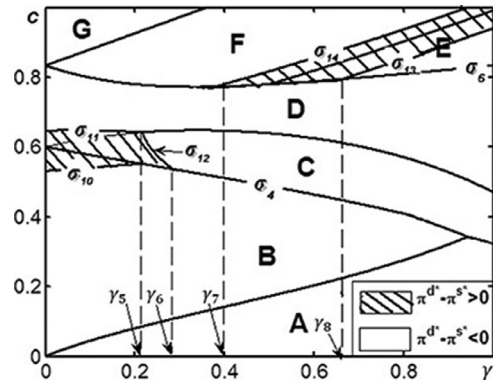

Fig. 5. $\pi^{d*} - \pi^{d*}$.

Proposition 4 suggests that, in contrast to the conventional wisdom that the manufacturer is always better off by encroaching the reseller's market (Arya, Mittendorf & Sappington 2007; Tsay & Agrawal, 2004; Xiong et al., 2012), the manufacturer does not always benefit from adding an e-channel.

Proposition 4 shows that the manufacturer motivates the reseller to lower his price and increase sales units by opening the e-channel. The effectiveness of this strategy, however, depends on the viability of the threat to sell directly, which, in turn, depends on the reseller's cost advantage and product durability. When the direct cost is below σ_9, the manufacturer benefits from adding the e-channel because two factors provide her with greater profits in the dual-channel model. The reasons behind it are as follows: First, it is usually assumed that the manufacturer is the Stackelberg leader, that is, she takes into account the profit-maximizing actions of the reseller and simultaneously sets the wholesale price. Second, she benefits from direct selling because it not only provides revenue to her directly but can also mitigate the double marginalization problem between both parties. For the product durability, when the manufacturer's distribution disadvantage exceeds a certain threshold, specifically $\sigma_9 < c < 1$, and the product durability is so small (i.e., $\gamma < \gamma_1$) that the manufacturer's profit in the dual-channel model equals that in the single-channel model. The intuition underlying this is as follows: When $\sigma_9 < c < 1$, the manufacturer's distribution disadvantage is so pronounced that the harm of the manufacturer's encroachment to the reseller would seem to be small. On the other hand, when $\sigma_9 < c < 1$, we find that, if the product durability is below a certain threshold, (i.e., $\gamma < \gamma_1$), the revenue in Period 1 of the manufacturer's encroachment is too small to accept no orders online. Thus, when $\gamma < \gamma_1$, $\sigma_9 < c < 1$, the manufacturer's profit in the dual-channel model equals that in the single-channel model. But when $\gamma > \gamma_1$, the manufacturer will encroach the reseller's market by directly selling, because as durability increases, the consumer's valuation of a used product ($\gamma\theta$) increases, which induces the manufacturer to derive more revenue from new products in Period 1.

As regards the variations in the reseller's profitability, i.e., how addition of the e-channel affects the reseller's performance — based on Lemmas 1 and 2, we provide the following response (see, Fig. 5):

Proposition 5. *When* $0 < \gamma < \gamma_5$, $\sigma_{10} < c < \sigma_{11}$, $\gamma_5 \leq \gamma < \gamma_6$, $\sigma_4 < c < \sigma_{12}$, $\gamma_7 \leq \gamma < \gamma_8$, $\sigma_6 < c < \sigma_{14}$ *and* $\gamma_8 \leq \gamma < 1$, $\sigma_{13} < c < \sigma_{14}$, *the reseller benefits from the encroachment; otherwise, the reseller's profit in the dual-channel model is lower than that in the single-channel model, especially when* $\gamma_6 < \gamma < \gamma_7$, *in which case, for any direct selling cost (c), the reseller is always worse off in the dual-channel model.*
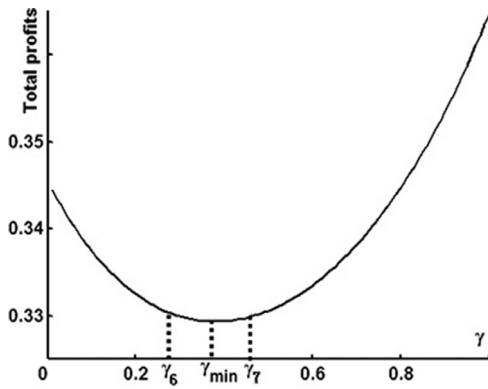
Proof. See Appendix B. □

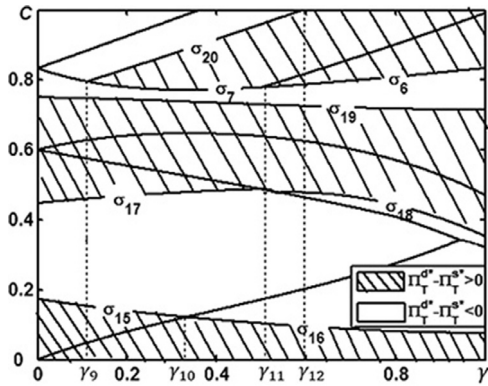**Fig. 6.** Total profits of the dual-channel supply chain ($c = 0.33$).

Fig. 7. $\Pi_T^{d*} - \Pi_T^{s*}$.

These observations—particularly that when $\gamma_6 < \gamma < \gamma_7$, the reseller is always worse off in the dual-channel model regardless of the direct selling cost (c)—are obviously somewhat at odds with Arya, Mittendorf and Sappington (2007) showing that the retailer can benefit from encroachment due to the reduction of wholesale price. To explain this finding, we must briefly consider the role of durability in the total profits of a supply chain. Recall that the optimal total profits of the single-channel model and the pure selling model, Π_T^{s*} (Π_T^{b*}), are the lowest for medium durability of γ^s (γ^b) and that the double marginalization problem induces the minimum point of the optimal total profit to move leftward, we can interpret Proposition 5 as follows: As in the single-channel and pure selling models, the total profit of the dual-channel supply chain is still convex in durability γ (see Fig. 6).[12] When $\gamma_6 < \gamma < \gamma_7$, the total profit of the dual-channel supply chain is so small that the manufacturer, acting as the Stackelberg leader, is reluctant to transfer the profit to the reseller. As a result, the bright side of encroachment disappears, which is contrary with the finding of Arya, Mittendorf and Sappington (2007).

As regards the variation in the supply chain profit—that is, the effects of encroachment on the supply chain profit—based on Lemmas 1 and 2, we offer the following proposition (see Fig. 7):

Proposition 6. *When* $0 < \gamma < \gamma_{10}$, $0 < c < \gamma_{15}$, $\gamma_{10} \leq \gamma < 1$, $0 < c < \sigma_{16}$, $0 \leq \gamma < \gamma_{11}, \sigma_{17}^d < c < \sigma_{19}^d$, $\gamma_{11} \leq \gamma < 1, \sigma_{18}^d < c < \sigma_{19}^d$, $\gamma_9 \leq \gamma < \gamma_{11}$, $\sigma_7 < c < \sigma_{20}$, $\gamma_{11} \leq \gamma < \gamma_{12}$, $\sigma_6 < c < \sigma_{20}$ *and* $\gamma_{12} \leq \gamma < 1$, $\sigma_6 < c < 1$, *the supply chain profit in the dual-channel model is higher than that in the single-channel model; otherwise, the opposite is true.*

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[12] We depict the total profit of the dual-channel supply chain for a numerical example.

Proposition 6 shows that encroachment can enhance the supply chain profit even when the manufacturer opens an inactive e-channel. The intuition behind this is that, in the encroachment setting, the manufacturer always provides lower wholesale prices to her reseller that leads to limited losses from double marginalization. Moreover, we can easily find that durability has an impact on the supply chain profit as well. For example, when $\gamma_9 \leq \gamma < \gamma_{11}$, $\sigma_7 < c < \sigma_{20}$, total profit in the dual-channel model is higher than that in the single-channel model. This can be explained as follows: notice that the manufacturer starts encroaching into the reseller's market in Period 1 and, as durability increases, the price of the used product increases and the manufacturer derives more revenue from new products in Period 1. That is, as durability increases, the manufacturer is more likely to operate the online selling and starting to encroach the reseller's market, i.e., the threat of an e-channel becomes stronger. As durability increases, to avoid the manufacturer's encroachment, the reseller sells more units in his retail channel. For the manufacturer, anticipating that the reseller will sell more products through the retail channel, decreases the wholesale price and opens an inactive e-channel. The manufacturer thus benefits from the reduction of losses from double marginalization and her reseller can benefit from the lower wholesale prices.

5. Empirical analysis

As pointed out earlier, our model tries to investigate how product durability creates strategic issues that are significantly different from those in managing a dual channel for nondurables. Although, in our model, as in Desai and Purohit (1998,1999), the manufacturer does not determine the durability endogenously, it does have an important impact on all players' profitability and determine their optimal strategies. In particular, we find that as long as the product durability varies, both parties are likely to be beneficial if the durability is either sufficiently small or sufficiently large (see Propositions 1, 5 and 6. In other words, the profits of the manufacturer, the reseller, and the supply chain are convex in product durability.

Do these predictions hold empirically? To test these theoretical predictions, we need data on wholesale margin, retail margin and product durability. We use data from the U.S. x86 computer server market for 2002–2004. Wholesaler's, retailer's and channel margins are obtained from Chu and Chintagunta (2009), and product durability data are from Chu and Chintagunta (2011).

The original data in Chu and Chintagunta (2009) are provided by Gartner® and have information on quarterly server unit sales, wholesale prices, retail prices, manufacturer names, brands, and warranty duration (in months) of computer servers at the manufacturer brand-model level (e.g., HP ProLiant DL100 servers). The x86 servers are mainly produced by HP, IBM and Dell, and sold through five distribution channels - direct fax/phone/Web, direct sales force, indirect fax/phone/Web, local dealer, and value-added resellers (VARs). Chu and Chintagunta (2009) use structural modeling to infer manufacturer marginal costs and retail marginal costs (for indirect channels), and compute wholesaler's, retailer's and total channel margins.

The quarterly product durability data for 2002–2004 in Chu and Chintagunta (2011) are originally obtained from Technology Business Research Inc (TBRI). TBRI conducts a quarterly survey of corporate information technology buying behavior and customer satisfaction of x86 servers, covering various dimensions of server quality. The evaluation questions are administered on a seven-point Likert scale, where 1 is "worst or totally dissatisfied" and 7 is "excellent or totally satisfied." Dell has the highest mean score of 6.21 (SD = .07) on product durability, though it is only slightly higher

Table 1
Regression of manufacturer (wholesale), reseller (retail) and channel profit.[a]

	Manufacturer profit (wholesale)			Reseller profit[b] (retail)			Channel profit[b] (wholesale + retail)		
	est.	se	t	est.	se	t	est.	se	t
HP	46.941	13.399	3.503	14.760	4.882	3.023	57.349	16.870	3.399
IBM	46.793	13.395	3.493	14.766	4.882	3.025	57.272	16.867	3.395
Dell	46.897	13.399	3.500						
1Q2002	−0.032	0.018	−1.751	−0.001	0.007	−0.072	0.006	0.026	0.241
2Q2002	-0.072	0.017	−4.204	0.000	0.007	0.027	−0.024	0.024	−1.004
3Q2002	0.050	0.017	2.982	0.009	0.007	1.343	0.098	0.023	4.274
4Q2002	0.084	0.017	5.049	0.012	0.007	1.762	0.151	0.023	6.708
1Q2003	-0.038	0.017	−2.176	0.002	0.007	0.290	0.000	0.024	0.015
2Q2003	0.040	0.024	1.699	−0.007	0.010	−0.755	0.027	0.034	0.803
3Q2003	0.027	0.021	1.308	−0.008	0.009	-0.902	0.043	0.031	1.365
4Q2003	0.049	0.020	2.402	−0.001	0.009	−0.134	0.039	0.031	1.265
1Q2004	0.014	0.018	0.771	0.000	0.008	0.019	0.027	0.028	0.949
2Q2004	−0.008	0.016	−0.515	0.008	0.006	1.240	0.064	0.022	2.912
3Q2004	0.023	0.016	1.397	0.002	0.007	0.355	0.083	0.023	3.634
Warranty duration	−0.004	0.000	−12.133	0.000	0.000	−2.548	−0.004	0.000	−8.103
Durability	−14.608	4.359	−3.351	−4.803	1.591	−3.019	−18.296	5.497	−3.328
Durability^2	1.144	0.355	3.225	0.394	0.130	3.038	1.469	0.448	3.281
Brand fixed effects	yes			yes			yes		
N	1163			425			425		
R^2	0.311			0.101			0.394		

[a] Manufacturer profit = (wholesale price - manufacturer marginal cost)/wholesale price. Reseller profit = (retail price − retail marginal cost)/retail price. Channel profit = (retail price − manufacturer marginal cost)/retail price
[b] Retail and channel profits only apply to indirect channels where Dell did not have presence in this period.

than HP (Mean = 6.18, SD = .09), and IBM's score is the lowest but still above 6.0 (SD = .07).

We regress manufacturer's profit $\Pi_{R,t}$, retailer's profit $\pi_{R,t}$ and channel profit $\pi_{C,t}$ on product durability as follows:

$$\Pi_{M,t} = \alpha_0 + \alpha_1 \gamma_{M,t} + \alpha_2 \gamma_{M,t}^2 + \alpha_3 X_{M,t} + \varepsilon_t$$
$$\pi_{R,t} = \beta_0 + \beta_1 \gamma_{M,t} + \beta_2 \gamma_{M,t}^2 + \beta_3 X_{M,t} + e_t$$
$$\Pi_{C,t} = \lambda_0 + \lambda_1 \gamma_{M,t} + \lambda_2 \gamma_{M,t}^2 + \lambda_3 X_{M,t} + \xi_t$$

Where $X_{M,t}$ is a list of control variables, including manufacturer warranty duration, manufacturer fixed effects, brand fixed effects, and quarter fixed effects. The results are in Table 1. As predicted by our theory, there exists a convex relationship between manufacturer profitability and product durability, between reseller's profitability and product durability, and between channel profitability and product durability. For all three regressions, the linear coefficient of durability is negative and highly significant, and the quadratic coefficient of durability is positive and highly significant, providing strong empirical support for our theory. This also adds face validity to our theoretical model.

The empirical results also generate some managerial insights which are aligned with our theoretical results. First, product durability is significantly related to the companies' profitability. For durable product manufacturers, durability is an important decision. Second, when the durability is relatively small, increasing the durability is not always good. But when it exceeds a threshold, increasing durability can increase profits. This reminds manufacturers' that they need to consider their products' current durability and find the threshold so that the decision of increasing durability could really benefit.

6. Conclusions

Even though many durable goods manufacturers have adopted dual-channel supply chains to market their products, there is scant literature addressing product durability and its impact on players' optimal strategies in a dual-channel supply chain. We thus generalize Arya, Mittendorf and Sappington (2007)'s model to the area of marketing durables in dual-channel supply chains. Specifically, by analyzing a two-period dual-channel supply chain, we investigate how product durability and the channel structure create strategic issues that are significantly different from those involved in the management of a dual-channel for nondurables.

To generate managerial insights into the issues of product durability and the channel structure, we characterize the optimal strategies of both parties and derive a number of propositions and conclusions. One important result of our analysis is that the manufacturer may be worse off selling online; that is, under certain conditions, it is optimal for the manufacturer to open an inactive e-channel and not accept orders online. This finding is consistent with the practice reflected in the dual-channel programs of 3M, NEC, and Whirlpool, which accept no orders online but simply use the Internet as a medium for product information provision and reseller links.

Another important result of our analysis is that we are able to generalize the results in the literature on dual-channel supply chains, in particular, Arya, Mittendorf and Sappington (2007), who show that the retailer can benefit from encroachment even when it admits no synergies and facilitates neither product differentiation nor price discrimination. In this paper, we show that this argument depends greatly on both product durability and direct selling cost. In fact, our analysis of a two-period dual-channel supply chain with different product durability demonstrates that, contrary to Arya, Mittendorf and Sappington (2007)'s results, if product durability is moderate, for any direct selling cost, manufacturer encroachment is always detrimental to the reseller and its bright side disappears.

We acknowledge a few limitations of our model. First, given our focus on durability, we abstract away other factors, including strategic choice of leasing and selling, which can potentially play an important role in a dual-channel supply chain with durables. Second, some of our assumptions, such as the monopoly manufacturer, complete information, and zero production costs, could be relaxed in future research. Third, we view the reseller as a

brick-and-mortar reseller, an assumption that, although common in the literature of E-commerce (Arya, Mittendorf & Sappington, 2007; Cai, 2010; Chen, Zhang, & Sun, 2012; Tsay & Agrawal, 2004; Xiong et al., 2012), does not reflect the actuality that many resellers have ventured into the online world. Finally, we assume that consumers show no preference between the e-channel and the reseller channel, whereas in reality, consumers may exhibit different preferences over different distribution channels, as is found in Chu, Chintagunta, and Vilcassim (2007). This latter in fact opens a potentially interesting avenue of research: incorporation into the model's demand functions of consumer preferences for services provided by durables in different distributions.

Acknowledgments

Supplementary material

Supplementary material associated with this article can be found, in the online version, at 10.1016/j.ejor.2017.08.039

References

Agrawal, V. V., Ferguson, M., Toktay, L. B., & Thomas, V. M. (2012). Is leasing greener than selling? *Management Science, 58*(3), 523–533. doi:10.1287/mnsc.1110.1428.

Arya, A., Mittendorf, B., & Sappington, D. E. M. (2007). The bright side of supplier encroachment. *Marketing Science, 26*(5), 651–659. doi:10.1287/mksc.1070.0280.

Bulow, J. (1986). An economic theory of planned obsolescence. *The Quarterly Journal of Economics, 101*(4), 729–749. doi:10.2307/1884176.

Bulow, J. I. (1982). Durable-goods monopolists. *Journal of Political Economy, 90*(2), 314–332. doi:10.2307/1830295.

Cachon, G. P., & Lariviere, M. A. (2005). Supply chain coordination with revenue-sharing contracts: Strengths and limitations. *Management Science, 51*(1), 30–44. doi:10.1287/mnsc.1040.0215.

Cai, G. G. (2010). Channel selection and coordination in dual-channel supply chains. *Journal of Retailing, 86*(1), 22–36. http://dx.doi.org/10.1016/j.jretai.2009.11.002.

Caldieraro, F., & Coughlan, A. T. (2007). Spiffed-up channels: The role of spiffs in hierarchical selling organizations. *Marketing Science, 26*(1), 31–51. doi:10.1287/mksc.1060.0204.

Cattani, K., Gilland, W., Heese, H. S., & Swaminathan, J. (2006). Boiling frogs: Pricing strategies for a manufacturer adding a direct channel that competes with the traditional channel. *Production and Operations Management, 15*(1), 40–56.

Chen, J., Esteban, S., & Shum, M. (2013). When do secondary markets harm firms? *American Economic Review, 103*(7), 2911–2934. doi:10.1257/aer.103.7.2911.

Chen, J., Liang, L., Yao, D.-Q., & Sun, S. (2017). Price and quality decisions in dual-channel supply chains. *European Journal of Operational Research, 259*(3), 935–948. doi:10.1016/j.ejor.2016.11.016.

Chen, J., Zhang, H., & Sun, Y. (2012). Implementing coordination contracts in a manufacturer stackelberg dual-channel supply chain. *Omega, 40*(5), 571–583. http://dx.doi.org/10.1016/j.omega.2011.11.005.

Chiang, W.-y. K., Chhajed, D., & Hess, J. D. (2003). Direct marketing, indirect profits: A strategic analysis of dual-channel supply-chain design. *Management Science, 49*(1), 1–20. doi:10.1287/mnsc.49.1.1.12749.

Chick, S. E., Mamani, H., & Simchi-Levi, D. (2008). Supply chain coordination and influenza vaccination. *Operations Research, 56*(6), 1493–1506. doi:10.1287/opre.1080.0527.

Chu, J., & Chintagunta, P. K. (2009). Quantifying the economic value of warranties in the u.s. server market. *Marketing Science, 28*(1), 99–121. doi:10.1287/mksc.1080.0380.

Chu, J., & Chintagunta, P. K. (2011). An empirical test of warranty theories in the u.s. computer server and automobile markets. *Journal of Marketing, 75*(2), 75–92. doi:10.1509/jmkg.75.2.75.

Chu, J., Chintagunta, P. K., & Vilcassim, N. J. (2007). Assessing the economic value of distribution channels: An application to the personal computer industry. *Journal of Marketing Research, 44*(1), 29–41. doi:10.1509/jmkr.44.1.29.

Chun, S.-H., Rhee, B.-D., Park, S. Y., & Kim, J.-C. (2011). Emerging dual channel system and manufacturer's direct retail channel strategy. *International Review of Economics & Finance, 20*(4), 812–825. http://dx.doi.org/10.1016/j.iref.2011.02.006.

Chung, W., Talluri, S., & Narasimhan, R. (2014). Quantity flexibility contract in the presence of discount incentive. *Decision Sciences, 45*(1), 49–79. doi:10.1111/deci.12058.

Coase, R. (1972). Durability and monopoly. *Journal of Law and Economics, 15*(1), 143–149.

Desai, P., & Purohit, D. (1998). Leasing and selling: Optimal marketing strategies for a durable goods firm. *Management Science, 44*(11-part-2), S19–S34. doi:10.1287/mnsc.44.11.S19.

Desai, P. S., & Purohit, D. (1999). Competition in durable goods markets: The strategic consequences of leasing and selling. *Marketing Science, 18*(1), 42–58. doi:10.1287/mksc.18.1.42.

Epson (2016). http://www.printerinks.com/4/2p-n-011/inkjet-and-toner-cartridges/epson/.

Garner, R. (1999). Mad as hell. *Sales & Marketing Management, June*(1), 55.

Gilbert, A., & Bacheldor, B. (2000). The big squeeze. *Information Week, 779*(March 27), 46–56.

Goldman, A. (1999). *Battle for web customers pits reretail against manufacturers. Los Angles Times, August 8*.

Hewlett-Packard. Hp store uk. http://store.hp.com/ukstore/.

IKEA (2016). Ikea welcome. http://www.ikea.com/gb/en/.

King, J. (2000). manufacturer ease online channel war. *Computer World, 33*(May 17), 20–24.

Lee, Y., Lee, Z., & Larsen, K. R. T. (2003). Coping with internet channel conflict. *Communications of the ACM, 46*(7), 137–142. doi:10.1145/792704.792712.

Lenovo (2016). Lenovo online strore. http://www.lenovo.com/uk/en/.

Liu, Y., & Zhang, Z. J. (2006). The benefits of personalized pricing in a channel. *Marketing Science, 25*(1), 97–105. doi:10.1287/mksc.1050.0120.

Luo, M., Li, G., & Cheng, T. (2016). Free riding and coordination in a dual-channel supply chain in e-commerce. *International Journal of Shipping and Transport Logistics, 8*(3), 223–249. doi:10.1504/IJSTL.2016.076253.

Matsui, K. (2017). When should a manufacturer set its direct price and wholesale price in dual-channel supply chains? *European Journal of Operational Research, 258*(2), 501–511. doi:10.1016/j.ejor.2016.08.048.

MicroScope (2009). Resellers clash with hp over direct sales. http://www.computerweekly.com/microscope/news/2240152990/Resellers-clash-with-HP-over-direct-sales.

Purohit, D., & Staelin, R. (1994). Rentals, sales, and buybacks: Managing secondary distribution channels. *Journal of Marketing Research, 31*(3), 325–338. http://www.jstor.org/stable/3152220.

Saha, S., Sarmah, S., & Modak, N. (2017). Single versus dual-channel: A strategic analysis in perspective of retailer'sprofitability under three-level dual-channel supply chain. *Asia Pacific Management Review*. doi:10.1016/j.apmrv.2017.03.001.

Soleimani, F. (2016). Optimal pricing decisions in a fuzzy dual-channel supply chain. *Soft Computing, 20*(2), 689–696. doi:10.1007/s00500-014-1532-1.

Spengler, J. J. (1950). Vertical integration and antitrust policy. *Journal of Political Economy, 58*(4), 347–352. http://www.jstor.org/stable/1828887.

Stokey, N. L. (1981). Rational expectations and durable goods pricing. *The Bell Journal of Economics, 12*(1), 112–128. http://www.jstor.org/stable/3003511.

Tsay, A. A., & Agrawal, N. (2004). Channel conflict and coordination in the e-commerce age. *Production and Operations Management, 13*(1), 93–110. doi:10.1111/j.1937-5956.2004.tb00147.x.

Waldman, M. (1993). A new perspective on planned obsolescence. *The Quarterly Journal of Economics, 108*(1), 273–283. http://www.jstor.org/stable/2118504.

Waldman, M. (2003). Durable goods theory for real world markets. *Journal of Economic Perspectives, 17*(1), 131–154. doi:10.1257/089533003321164985.

Webb, K. L. (2002). Managing channels of distribution in the age of electronic commerce. *Industrial Marketing Management, 31*(2), 95–102. http://dx.doi.org/10.1016/S0019-8501(01)00181-X. Internet-Based Business-to-Business Marketing.

Webb, K. L., & Lambe, C. J. (2007). Internal multi-channel conflict: An exploratory investigation and conceptual framework. *Industrial Marketing Management, 36*(1), 29–43. http://dx.doi.org/10.1016/j.indmarman.2006.06.013. Multi-Channel Strategy in {B2B} Markets.

Xiao, T., & Shi, J. J. (2016). Pricing and supply priority in a dual-channel supply chain. *European Journal of Operational Research, 254*(3), 813–823. http://dx.doi.org/10.1016/j.ejor.2016.04.018.

Xiong, Y., Yan, W., Fernandes, K., Xiong, Z.-K., & Guo, N. (2012). "bicks vs. clicks": The impact of manufacturer encroachment with a dealer leasing and selling of durable goods. *European Journal of Operational Research, 217*(1), 75–83. http://dx.doi.org/10.1016/j.ejor.2011.08.012.

Yoo, W. S., & Lee, E. (2011). Internet channel entry: A strategic analysis of mixed channel structures. *Marketing Science, 30*(1), 29–41. doi:10.1287/mksc.1100.0586.

Zhang, P., He, Y., & Shi, C. V. (2017). Retailer's channel structure choice: Online channel, offline channel, or dual channels? *International Journal of Production Economics, 191*, 37–50. doi:10.1016/j.ijpe.2017.05.013.

Zhao, J., Hou, X., Guo, Y., & Wei, J. (2017). Pricing policies for complementary products in a dual-channel supply chain. *Applied Mathematical Modelling, 49*, 437–451. doi:10.1016/j.apm.2017.04.023.