Optimal Digital Content Distribution Strategy in the Presence of the Consumer-to-Consumer Channel

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ABSTRACT: Although the online business-to-consumer (B2C) channel is the primary selling channel for digital content (e.g., videos, images, and music), modern digital technology has made possible the legal dissemination of such content over the consumer-to-consumer (C2C) channel through personal computing devices, such as PCs, mobile phones, and portable media players. This paper investigates the optimal channel structure and the corresponding pricing and service strategies for digital content distribution in order to understand the business value of introducing the C2C channel alongside the prevailing B2C channel. We identify conditions under which it is more profitable to use both B2C and C2C channels simultaneously (i.e., the dual-channel distribution). In such cases, the seller performs price discrimination among consumers but provides them with a higher level of service. Our analysis further characterizes the benefits of service provision. We show that service provision can increase the dual-channel pricing flexibility, reduce the seller's B2C channel dependence, and allow the seller to tolerate higher C2C channel redistribution costs. Finally, in examining the effect of a competitively determined B2C channel price on optimal channel strategy, we find that the seller prefers a dual-channel distribution under higher B2C channel prices.

All authors contributed equally to this paper.

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IN A RECENT INTERVIEW, Douglas Merrill, former Google chief information officer (CIO) and now president of EMI digital business division, said, "I think the industry as a whole has got some really interesting experiments in what the future world is. . . . We don't know yet what the real business model is going to be. We have to do more experiments, try more things to see what works" [17]. At a time when the music industry is in flux, Merrill's move from Google to EMI aims to help the company form a digital business strategy to compete on the Internet. It is yet to be seen what innovation is needed in a realm where all music companies have had limited success. It is clear, however, that integration of technology innovation into the firm's digital business strategy is being taken seriously.

The Web has created unprecedented opportunities to distribute digital content (or information goods) such as music, videos, e-books, and software. Anyone who owns the product can become an effective marketer in the distribution chain due to easy reproduction and redistribution. On the other hand, this capability can easily be outweighed by increasing online infringement. In contrast to conventional methods such as tight law enforcement, and technology protection that increases the costs to pirates, of copyright violation, an alternative solution invites consumers to a broader participation in the distribution chain so they can be hosts for legitimate business as easily as for copyright infringement [10]. This new approach rewards consumers who share the digital content with others. Because unlimited copies of the digital content can be created and distributed, the reward could be large enough to cover the original purchase price. The reward provides an economic incentive for consumers to purchase and distribute digital files legitimately. As new technological tools can meet both business and consumer needs that were impossible before, allowing consumers' active participation in the distribution chain is now recognized as an innovative digital business strategy for distributing information goods [24].

Several business initiatives with regard to the digital content distribution have been proposed in various technological environments. For instance, Brilliant Digital Entertainment subsidiary Altnet formed an alliance with KaZaa to kick off a peer-to-peer (P2P) marketing campaign [10]. KaZaa users who search for content see results displaying Altnet files with a gold icon, indicating that the files are available for lawful download and use. Users who share the searched files with others can accumulate Gold Points to redeem rewards. More recently, a novel platform was proposed in the mobile commerce environment for the free trade of digital content where ordinary users are allowed to market and resell copies of digital content to neighbors in their wireless devices vicinity [5, 12]. Transactions among users can first be performed in an offline P2P manner without the immediate assistance of any central entity. Later when users are connected to the Internet, sales are recorded and parties involved in the transactions are credited to their own accounts accordingly. Resellers share part of the proceeds with the original copyright owner as both incentive rewards for their marketing efforts and compensations for their contribution of personal resources for the offline transaction. Such a process has been shown to be technically feasible [15].

The underlying technology that makes the decentralized distribution architecture work is digital rights management (DRM) [9]. DRM is an umbrella term including any digital protection system on any type of digital media. Common types of DRM include encrypted codes on DVDs and CDs, digital watermarking, and product activation. DRM aims at protecting ownership and copyright of digital content by restricting what actions an authorized recipient may take with respect to that content. For example, Apple's iPod uses its own DRM system called "FairPlay," which encrypts songs and limits the playback of music purchased on iTunes, thereby protecting musicians' copyrights [3]. While music labels continue their battle against illegal downloading in the courts, they have increasingly shifted their focus toward promoting legitimate online distribution. Embracing and leveraging DRM technology is essential to this effort. So far, a healthy number of DRM-codec platforms have been approved for use by mobile operators to explore this mobile music market opportunity [31].

Two other factors also contribute to the development of this new form of paid-content, consumer-to-consumer (C2C) channel distribution. First, increasingly popular social interactions among taste-sharing user groups can easily transform fans into effective marketers in the Internet environment. This model exploits social interactions to promote digital product distribution and consumption. Second, newly available information technologies (IT) such as micropayments provide trading platforms to support distributed information processing and market transactions among consumers. This secured trading environment makes it technically feasible for the copyright owner to effectively track sales and monitor user accounts. Both social networks and new trading platforms help create the most cost-effective model for legitimate C2C distribution.

Yet although the concept is intuitively appealing and technically feasible, its underlying business model is neither well defined nor widely adopted. Today, the dominant trading platform for digital products is based on the online business-to-consumer (B2C) model. There are over 500 legitimate online music services in over 40 countries. iTunes, the leader in online downloads, has sold over 2 billion tracks since its launch in April 2003 and more than 1 billion in 2006 alone [9]. The recent innovation of the incentive-based C2C channel distribution represents a new business strategy addressing the emerging new form of digital content delivery. Along with the huge potential, growing pains can occur when established business models are confronted with emerging technological advances. Businesses must carefully assess the potential benefits and involved trade-offs when integrating the new C2C channel distribution into their existing B2C channel strategy. This paper aims to address these fundamental issues in the dual-channel design and distribution.

We have developed economic models to study the business potential of adopting a dual-channel distribution for a digital product with heterogeneous consumers whose willingness to pay depends on both their inherent valuation of the product and the associated service provision provided by the product seller/creator. Under various market scenarios, we identify conditions under which it is more profitable to use both B2C and C2C channels simultaneously. We find that when the dual-channel distribution is optimal, the seller will always set a higher B2C channel price and offer a higher level of service in comparison to the optimal single-channel distribution strategy. Our further analysis also indicates that service provision increases the dual-channel pricing flexibility, reduces the seller's B2C channel dependence, and allows the seller to tolerate a higher C2C channel redistribution cost. We also explore a likely scenario where the digital product has a competitively determined price in the B2C channel. We find that the higher the B2C channel price, the less the seller's B2C channel dependence in adopting an optimal dual-channel strategy.

Literature Review

Two streams of literature are particularly relevant to our study—dual-channel strategies in the supply chain and economics models for digital content distribution.

A large body of work on the supply-chain structures over the Internet has focused on the dual-channel distribution models, which typically consist of a manufacturer-owned direct sales channel and an intermediated retail channel. Channel conflict and coordination have been widely studied in the literature, often with a focus on pricing [29]. Under various scenarios, dual-channel design has been shown to have important strategic implications in firms' optimal distribution strategy [18].

Besides pricing, service has been viewed as a nonprice attribute that positively affects demand [14, 28, 30]. Strategic consumers who either have heterogeneous valuation [8] or heterogeneous preference toward channel selection [4] have also been considered in modeling channel competition. However, most works in this area assume the dual-channel distribution structure of selling physical products in a B2C environment. Few insights are available for managing the sales of digital products in an environment that can be characterized by extensive C2C interaction.

With the increasingly sophisticated Internet delivery channel and the ever-increasing digitalization of products and services, economics of digital goods have received substantial research attention in recent years [19, 23, 25]. Due to the popularity of P2P technologies and free content shared and exchanged in the network, piracy is often considered as a significant threat on the copyright owners' profitability [6, 16]. Some studies assume that pirate copies are low-quality alternatives to original products. It is shown that, under some conditions, unauthorized reproduction can help the copyright owner price discriminate different classes of consumers [26]. Alternatively, piracy can be viewed as an opportunity for consumers to try out the product before making a legitimate purchase. Therefore, sampling can be a potential piracy-mitigating strategy [7]. Much research effort in this area shows the potential of using economic rather than purely technical solutions to fight piracy.

In addition to piracy, free riding [27] is another widely observed phenomenon. Various incentive mechanisms and payment schemes have been proposed to encourage users to share files in P2P networks [11]. One way to ensure participants are compensated is cascading payments, where royalties and commissions are determined by the flow of distribution through the system [1]. Another solution, dynamic referral strategy, provides payment to users who distribute content to others depending on the sufficient diffusion of digital media in the P2P network [13]. However, none of these proposed methods have yet been successfully implemented.

Recent work also shows that in the competitive interaction between the centralized client-server structure and the decentralized P2P networks, the coexistence of a P2P network with a competing centralized architecture can be mutually beneficial [2]. The same study suggests that the impact of P2P networks needs to be carefully considered when pricing digital legal downloads in the B2C market. Prior work, while interesting, does not consider an integrated model that can be supported by a platform structure taking advantage of both the centralized (e.g., iTunes) and decentralized (e.g., C2C) distribution strategies. This paper aims to provide a first step toward understanding the consumer-oriented dual-channel distribution of digital content.

A Dual-Channel Model with C2C Distribution

In this section, we present two general models. The benchmark model has a digital product seller (or copyright owner) operating an online B2C channel that sells directly to customers. We compare this single-channel model with a dual-channel model in which the seller allows consumers who have already purchased the product from the online B2C channel to legally resell to other consumers (i.e., using both the B2C direct channel and the C2C indirect channel simultaneously).

First, let us focus on the single-channel model. Consider a seller who sells a digital product to a market with heterogeneous consumers through the online B2C direct channel. We characterize each consumer by a parameter, $\nu \in [0, a]$, representing his or her basic valuation for the digital product. Following a conventional treatment (e.g., [21, 22, 27]), we assume that the basic valuation is uniformly distributed with the population density normalized to one, which, without further loss of generality, captures heterogeneity in necessities, preferences, tastes, and purchasing power, and so on, for the digital product. We further assume that a consumer's willingness to pay also depends on a product-specific service, denoted by s, that is provided by the seller. The service can be understood as a nonprice attribute associated with the product offering, such as product quality, after sales supports, software updates, warranties, and so on. The service can also be viewed as terms and conditions that are defined by the access control technologies in terms of usage, transfer, or storage of the digital product. For example, enhancing the quality of graphical user interface (GUI) or incorporating additional features of a given computer software can typically increase consumers' willingness to pay for the product. Similarly, a song with unlimited playbacks is more valuable than the same song with a limited number of playbacks, and a video file that can be played in most commonly used digital media devices is more attractive than the same video file that can only be played on some restricted codec platforms. Therefore, we define the reservation price for the consumer whose basic valuation is ν as $U(\nu, s) = \nu + fs$, where f is a positive constant that measures the service effect.

Let p denote the price charged by the seller. Assume that each consumer, who demands at most one unit, will buy the product if the resulting surplus is nonnegative. Then, the valuation of the consumer who is indifferent about buying from the B2C channel is defined as $\hat{v}$:

$$\hat{v} = p - fs. \tag{1}$$

Because all customers whose valuation satisfies $v \in [\hat{v}, a]$ will buy the product, the total number of buyers will be $a - \hat{v}$, that is,

$$D(p, s) = a - p + fs. \tag{2}$$

Obviously, the market demand is affected negatively by market price p, but positively by the seller's service effort s.

Alternatively, the seller can consider a dual-channel model consisting of both a B2C direct channel and a C2C indirect channel. Suppose the original seller charges a royalty fee, denoted by R, to the reseller for successfully redistributing the digital product to a customer through the C2C channel. Let d be the cost incurred by the resellers to redistribute the product to a customer.[1] The redistribution cost d reflects the sellers' time and the effort spent in the redistribution processes, which include identifying potential customers, interacting with them, differentiating among them, and redistributing the product to them through the C2C technology.

To account for the rich interactive patterns and unique C2C distribution nature in the C2C network, assume that the C2C channel pricing decision is delegated to the consumer resellers, who may charge a high/low price to high-/low-valuation consumers.[2] Therefore, unlike that in the B2C channel, the price in the C2C channel is not a decision variable for the original seller. The C2C channel prices will be negotiated between the resellers and the buyers such that the resellers have a nonnegative surplus for making a sale and the buyers have a higher surplus to buy from the resellers (rather than to buy from the B2C channel with price p). Thus, given the B2C price p, the royalty fee R, and the redistribution cost d, all possible prices in the C2C channel fall on the interval $[R + d, p]$. This implies that no sales will occur in the C2C channel if $R + d > p$. When $R + d \leq p$, the marginal consumer who is offered the lowest possible price $R + d$ is indifferent to buying from the C2C channel or nothing at all. The marginal consumer's valuation $\tilde{v}$ is expressed as

$$\tilde{v} = R + d - fs. \tag{3}$$

When there is an opportunity to buy the product in the C2C channel, there is a channel cannibalization effect on the B2C channel. To model this effect, we define θ, $0 < \theta \leq 1$, as the proportion of innovators (or loyal consumers) who always buy from the B2C channel and become the early adopters of the product provided that the price p does not exceed their reservation prices. If the innovators cannot afford to buy from the B2C channel (p is higher than their reservation prices), they would buy from the C2C channel so long as the offered price in the C2C channel is lower than or equal to their reservation prices. Accordingly, those innovators whose valuation satisfies $v \in [\hat{v}, a]$ (Segment 1 in Figure 1) will buy from the online B2C channel, while those

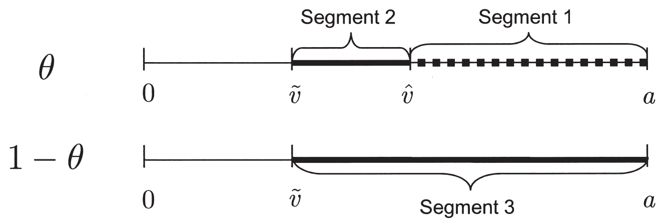

Figure 1. Market Segmentation

with $\nu \in [\tilde{\nu}, \hat{\nu}]$ (Segment 2 in Figure 1) will buy from the C2C channel at an affordable price. All other customers whose valuation satisfies $\nu \in [\tilde{\nu}, a]$ (Segment 3 in Figure 1) will buy from the C2C channel with a higher consumer surplus.

As a result, the total number of customers in Segments 1, 2, and 3, respectively, can be spelled out as $\theta(a - p + fs)$, $\theta(p - R - d)$, and $(1 - \theta)(a - R - d + fs)$. In summary, the total demand in the B2C channel (Segment 1) is given by

$$D_B(p, s) = \theta(a - p + fs), \tag{4}$$

while the total demand in the C2C channel (Segments 2 and 3) is specified as

$$D_C(p, R, s) = (1 - \theta)(a - p + fs) + p - R - d. \tag{5}$$

It is straightforward to verify that Equation (5) reflects the empirically most likely scenario where the demand in the C2C channel increases in the B2C channel price p and the service level s, but decreases in the royalty fee R. Note that the parameter a can be interpreted as the potential market size. When price and service are offered such that all consumers make their purchase, we say the market has full coverage. Otherwise, the market has partial coverage.

To capture the diminishing returns on service expenditure, following a common assumption in the literature (e.g., [14, 28]), let the service cost incurred by the seller be a quadratic function of the service effort, $s^2/2$. When only the B2C channel strategy is adopted, the seller sets the price and the service level that maximize its total profit given by

$$\Pi_1(p,s) = p(a - p + fs) - \frac{s^2}{2}. \tag{6}$$

On the other hand, when the dual-channel strategy is adopted, the seller maximizes the following profit by determining the B2C channel price, the service level, and the royalty fee:

$$\Pi_2(p,s,R) = p\theta(a - p + fs) + R\big((1-\theta)(a - p + fs) + p - R - d\big) - \frac{s^2}{2}. \tag{7}$$

Table 1 summarizes the optimal decisions and the corresponding optimal channel profits with different channel strategies under different market conditions.[3]

Table 1. Optimal Channel Pricing and Service Strategies and Channel Profits

Channel structure	Condition	Optimal market coverage	Corresponding decisions	Profits
Single channel	$f \le 1$	Partial coverage	$\begin{cases} p_1^s = \dfrac{a}{2-f^2} \\ s_1 = \dfrac{fa}{2-f^2} \end{cases}$	$\dfrac{a^2}{2\left(2-f^2\right)}$
	$f > 1$	Full coverage	$\begin{cases} p_1^s = af^2 \\ s_1 = af \end{cases}$	$\dfrac{a^2 f^2}{2}$
Dual channel	$f \le \sqrt{\dfrac{(2-\theta)(a+d)}{2a}}$	Partial coverage	$\begin{cases} p_2^s = \dfrac{a(3-\theta)-d-df^2(1-\theta)}{4-2f^2-\theta} \\ R^s = \dfrac{a(2-\theta)-2d+df^2\theta}{4-2f^2-\theta} \\ s_2 = \dfrac{f\left(2(a-d)+d\theta\right)}{4-2f^2-\theta} \end{cases}$	$\dfrac{2(a-d)^2+d\theta\left(2a-df^2\right)}{2\left(4-\theta-2f^2\right)}$
	$f > \sqrt{\dfrac{(2-\theta)(a+d)}{2a}}$	Full coverage	$\begin{cases} p^s = \dfrac{(a-d)+2af^2}{2} \\ R^s = af^2-d \\ s_2 = af \end{cases}$	$\dfrac{(a+d)^2\theta+2a\left(af^2-2d\right)}{4}$

When the single-channel strategy is adopted, it is more profitable for the seller to provide full market coverage if $f > 1$. When the dual-channel strategy is adopted, the profit-maximizing seller will provide full market coverage if

$$f > \sqrt{\frac{(2-\theta)(a+d)}{2a}}.$$

Accordingly, depending on the parametric values observed, there are four market scenarios as illustrated in Figure 2:

SD-Partial: Partial coverage with both single- and dual-channel strategies;
D-Full: Partial coverage with single-channel strategy and full coverage with dual-channel strategy;
S-Full: Partial coverage with dual-channel strategy and full coverage with single-channel strategy;
SD-Full: Full coverage with both single- and dual-channel strategies.

Optimal Channel Strategy

By direct comparison of the dual-channel and single-channel profits in Table 1, we can identify the optimal channel structure and the corresponding pricing and service strategies under the different market scenarios.

Proposition 1: (a) In an SD-Partial market, it is optimal for the seller to adopt the dual-channel strategy when the proportion of innovators $\theta > \theta_1$, *where*

$$\theta_1 = \frac{2d\left(2-f^2\right)(2a-d)}{\left(a-df^2\right)^2 + 2d\left(2a-df^2\right)}. \tag{8}$$

(b) In a D-Full market, it is optimal for the seller to adopt the dual-channel strategy when the proportion of innovators $\theta > \theta_2$, *where*

$$\theta_2 = \frac{2a\left(\left(2-f^2\right)\left(2d-af^2\right)+a\right)}{(a+d)^2\left(2-f^2\right)}. \tag{9}$$

(c) In an S-Full market, it is always optimal to adopt the single-channel strategy.

(d) In an SD-Full market, it is optimal for the seller to adopt the dual-channel strategy when the proportion of innovators $\theta > \theta_3$, *where*

$$\theta_3 = \frac{4ad}{(a+d)^2}. \tag{10}$$

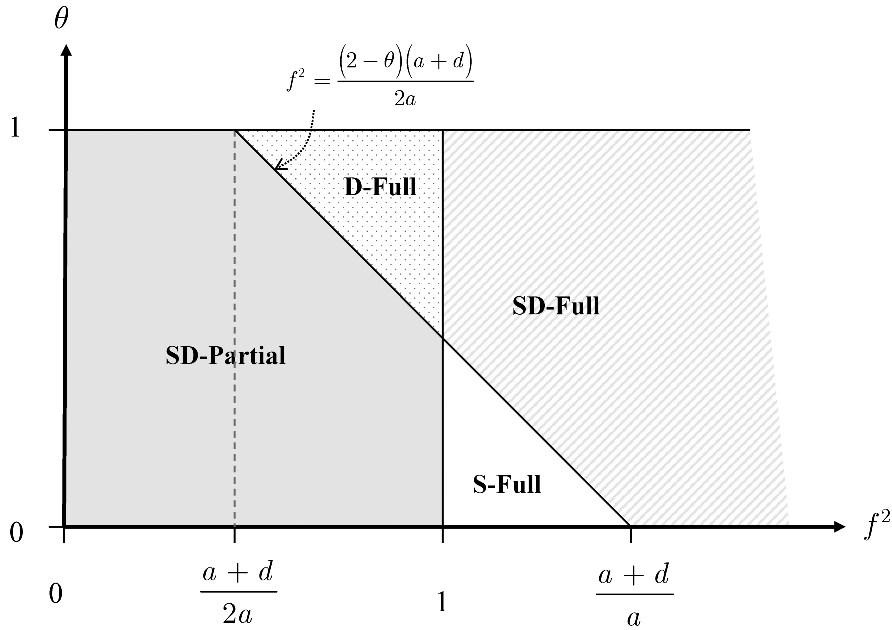

Figure 2. Optimal Market Coverage with Different Channel Strategy

Proofs for the propositions are in the Appendix. Figure 3 shows a graphical representation of this proposition.

Obviously, the proportion of innovators θ must be high enough to validate the dual-channel distribution. Further sensitivity analysis for θ with respect to other parameters shows that when $f^2 \leq 1$, the threshold levels θ_1 and θ_2 decrease in the market size a and the responsiveness of market demand to service f^2, but increase in the C2C channel redistribution cost d. In a different way, the threshold level θ_3 is independent of service-related market parameters when $f^2 > 1$. This is evident from Table 1 that the seller charges the same level of services $s_1 = s_2 = af$ regardless of selling through single channel or dual channel.

In order to further understand the effect of channel structure on pricing and service strategies, we compare the optimal prices and services in the single channel with those in the dual channel. The results are summarized in the following proposition:

> *Proposition 2: (a) Under the optimal dual-channel strategy, the seller sets a higher price in the B2C channel and a lower royalty fee in the C2C channel than the price in the single channel, that is,* $p_2^s > p_1^s > R^s$.
>
> *(b) Under the optimal dual-channel strategy, the seller always sets a higher service level than that in the single channel, that is,* $s_2 > s_1$.

An intuitive explanation for the above results holds that in the dual-channel distribution, a profit-maximizing seller sets prices and service more efficiently to achieve

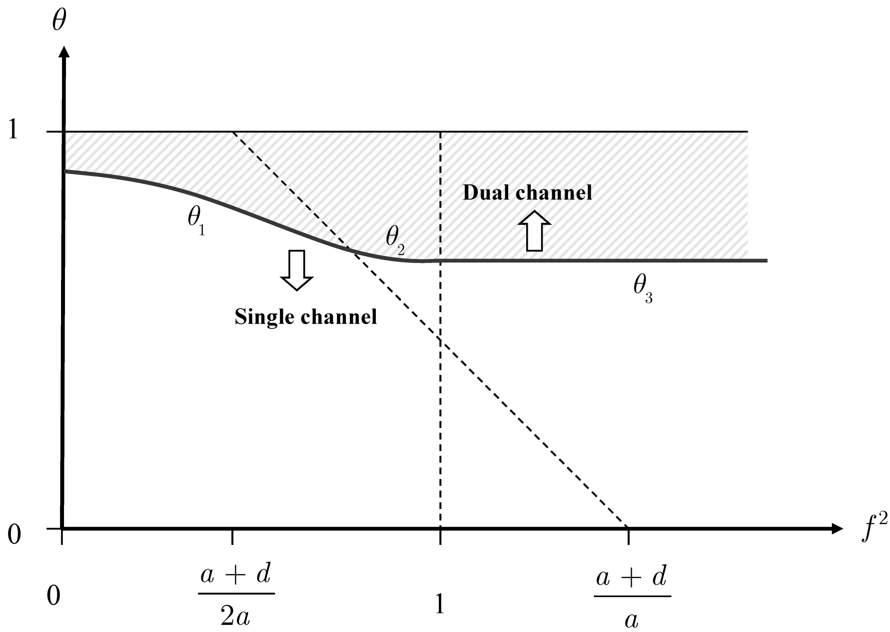

Figure 3. Optimal Channel Choices

the second-degree price discrimination. The coordination between the B2C and C2C channels allows the seller to charge a higher price and offer a higher service in the dual-channel B2C market than their single-channel counterparts.

Effect of Redistribution Cost on Optimal Channel Strategy

We have identified the threshold values for adopting the dual-channel strategy under different market scenarios in Proposition 1. Figure 4 illustrates the effect of the C2C channel redistribution cost d on the three threshold values expressed in Equations (8)–(10).

It indicates a positive correlation between the least redistribution cost d in the C2C channel and the least portion of innovators for adopting the dual-channel strategy. The intuition is that, when the redistribution cost is relatively low, the seller can rely on resellers to generate more profit in the C2C market to compensate for his or her loss in the B2C market. Therefore, the seller can afford a low portion of innovators to purchase through the B2C channel. In contrast, when the redistribution cost is relatively high, the seller is more interested in securing sales in the B2C channel, thus requiring a higher portion of innovative consumers. Moreover, the indifference threshold is more sensitive to the redistribution cost in an SD-Partial market than in other markets. This implies that reducing the consumer redistribution cost can more easily promote adoption of the dual-channel distribution in a partially covered market under both the optimal single- and dual-channel strategies.

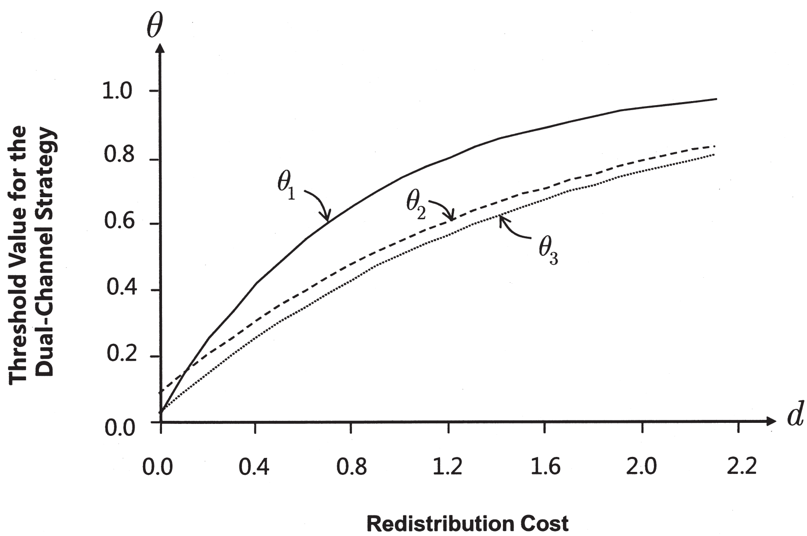

Figure 4. The Effect of *d* on the Threshold Values for the Dual-Channel Strategy

Impact of Proportion of Innovators on Channel Profitability

Now we investigate the impact of the proportion of innovators on the relative benefit of the dual-channel strategy in comparison with the single-channel counterpart under different market scenarios. Using the corresponding single-channel profit as the benchmark, Figure 5 illustrates the percentage gain or loss in profit when adopting the dual-channel distribution with respect to the change of the proportion of innovators θ for a given set of parametric values ($a = 6$, $d = 0.4$, $f = 0.1$ (SD-Partial), 0.9 (D-Full), and 1.3 (SD-Full)).

The strictly increasing curves in the figure show that, although the dual-channel strategy yields more profit than the single-channel strategy as the proportion of innovators increases under all three market scenarios, the slope of the increase is slightly different. When the responsiveness of service relative to price (i.e., parameter f) is high, the profit increase is less significant than other cases. The primary reason, as we believe, is that both dual-channel and single-channel operations result in an SD-Full market in which the maximum market demand is achieved and there is no room for further improvement in profitability. The managerial insight, however, is that dual-channel design still brings additional benefit in a fully covered market by price differentiation and finer market segmentation. In contrast, the most significant benefit can be achieved when the responsiveness of service relative to price is medium. In other words, when neither price nor service effect dominates each other, it is more beneficial to adopt the dual-channel rather than the single-channel distribution strategy.

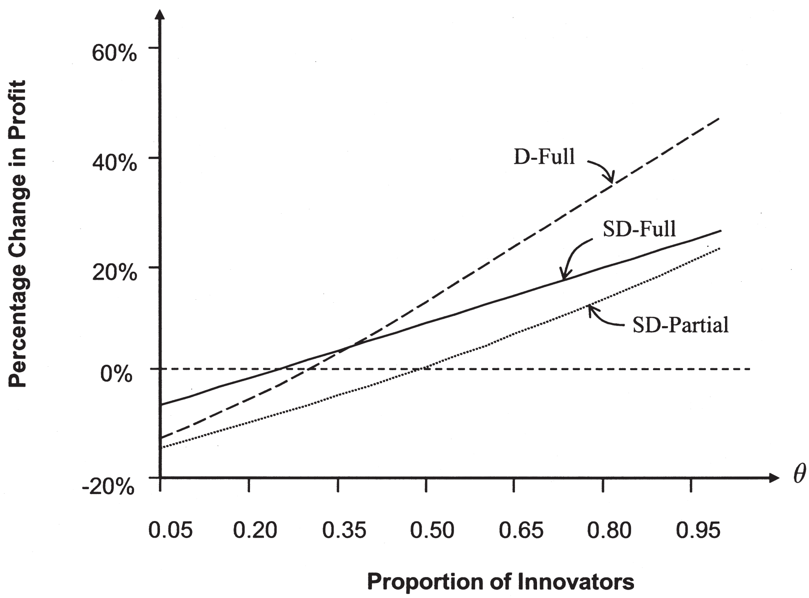

Figure 5. Impact of Proportion of Innovators on Channel Profitability

Additional Results and Insights

FROM PREVIOUS ANALYSIS, WE SEE that both service provision and pricing decisions collectively contribute to flexible channel design and profit optimization. In this section, we provide more insights into optimal channel strategy to clarify their respective effects under different market conditions.

Absence of Service Provision Effect

It is increasingly evident that IT contributes to service innovation and should be tightly integrated in the digital product distribution. For example, a digital product should be sold together with a service agreement, which may govern the usage, transfer, or storage of the product. The ability to offer product-specific services can influence consumers' willingness to pay for the product, thus potentially affecting the seller's pricing strategies. In this section, we quantify the benefits of service provision in both the dual-channel and the single-channel distribution.

Optimal Channel Strategy Without Service

Simply setting $s_1 = 0$, we have the optimal prices

$$p_2 = \frac{a(3-\theta)-d}{4-\theta}$$

$$R=\frac{a(2-\theta)-2d}{4-\theta},$$

and optimal channel profit

$$\Pi_2(p_2,R)=\frac{(a-d)^2+\theta ad}{4-\theta}$$

for the dual channel. The single-channel price and profit are $p_1 = a/2$ and $\Pi_1(p_1) = a^2/4$, respectively.

Proposition 3: In the absence of service provision, the optimal channel strategy is to choose dual channel when the proportion of innovators $\theta > \theta_4$, *where*

$$\theta_4=\frac{4d(2a-d)}{a(a+4d)}. \tag{11}$$

Comparative statics shows that the threshold level θ_4 decreases in the maximum valuation a, and increases in the redistribution cost d. Further comparing Equation (11) with (10) we see that in a market that can be fully covered with both the single-channel and dual-channel strategies under service provision, the same qualitative insights for choosing the optimal dual-channel strategy hold in the absence of service provision.

Proposition 4: Under the optimal dual-channel strategy without service provision, the seller sets a higher price in the B2C channel but a lower royalty fee in the C2C channel than the price in the single channel, that is, $p_2 > p_1 > R$.

Comparing Propositions 2 and 4, we see that pricing strategies in the dual channel without service have similar qualitative insights as those in the dual channel with service provision.

Dual Channel With and Without Service

To better understand the effects of key parameters on pricing strategies, market demand, and channel profit in the dual-channel design, we perform comparative statics on the proportion of innovators θ in the B2C channel and the C2C channel redistribution cost d. Signs of the first derivatives are shown in Table 2.

Not surprisingly, the qualitative effects on θ or d are the same regardless of service provision, except the impact of θ on the B2C channel price. An increase of θ will lead to a decrease of the B2C channel price in the dual channel without service, indicating the seller's willingness to offer lower price to attract demand from the innovators in the B2C channel. However, an increase of θ does not necessarily lead to a decrease of the B2C channel price in the dual channel with service provision, implying that service does reduce the seller's dependence on the B2C channel sales to generate profit.

Evidently, the C2C channel redistribution cost d has a positive effect on the B2C channel demand but a negative effect on the C2C channel demand. Because the total

Table 2. Comparative Statics in the Dual-Channel Distribution

	Sign of derivative with respect to θ		Sign of derivative with respect to *d*	
	With service	Without service	With service	Without service
B2C price	+/–	–	–	–
C2C royalty fee	–	–	–	–
Service	+	N/A	–	N/A
B2C channel demand	+	+	+	+
C2C channel demand	–	–	–	–
Total channel profit	+	+	–	–

Note: N/A = not applicable.

channel profit decreases as *d* increases, there is a threshold value beyond which the single-channel outperforms the dual-channel distribution. The following proposition compares the maximum affordable redistribution costs that make dual-channel distribution feasible in the presence or absence of service provision:

> *Proposition 5: The threshold redistribution cost in the dual channel with service is higher than that in the dual channel without service, that is,* $\bar{d} < \bar{d}^s$.

This implies that service provision in the dual-channel distribution can more effectively tolerate consumers' relatively higher redistribution cost. Consequently, the seller can make more profit from the service-enhanced B2C channel sales and becomes less dependent on the C2C channel distribution for revenue generation. The following result shows another benefit of service provision on the seller's pricing strategy:

> *Proposition 6: Under optimal pricing, the dual channel with service strategy has higher pricing flexibility than that in the dual channel without service, that is,* $p_2 - R < p_2^s - R^s$.

Recall that the C2C prices falls on the interval $[R + d, p]$. Simply deducting d on both sides of the above inequality we can easily compare the C2C price ranges. Therefore, given the consumer redistribution cost *d*, the C2C price range in the dual channel with service provision is larger than that in the dual-channel without service provision. This demonstrates the value of service provision in improving the dual-channel pricing flexibility.

Dual Channel Without Service Versus Single Channel With Service

From Table 1, we know that under optimal pricing, the seller always prefers to provide a positive level of service. From a different perspective, the following proposition compares the relative effectiveness between choosing dual-channel distribution without service and single channel with service:

Proposition 7: If

$$f < \sqrt{\frac{(a-2d)^2}{2\left(a^2 - ad + d^2\right)}},$$

the seller prefers dual-channel distribution without service to single-channel distribution with service if the proportion of innovators $\theta > \theta_5$, *where*

$$\theta_5 = \frac{2\left(2d(2a-d) + (a-d)^2 f^2\right)}{a\left(a + 4d - 2df^2\right)}. \tag{12}$$

The conditions state that, when the proportion of innovators is high and demand responsiveness to service is not big enough, the seller would prefer a dual channel without service provision to a single channel with service provision.

In further comparison of the different threshold values in Equations (8)–(12) we find the following relation:

Proposition 8: Service provision can decrease the channel indifference threshold, that is, $\theta_3 < \theta_2 < \theta_1 < \theta_4 < \theta_5$.

Since the seller will prefer the dual-channel distribution only if the proportion of innovators is higher than the threshold value, the result $\theta_3 < \theta_2 < \theta_1 < \theta_4$ shows that service provision can reduce the seller's dependence on the innovative consumers to find the dual-channel distribution more profitable. Moreover, the relationship $\theta_4 < \theta_5$ indicates another aspect of the service benefit, as it requires a higher threshold value to justify the dual channel without service provision strategy in comparison to the single channel with a service provision.

Absence of Monopolistic Pricing Power

In a competitive market environment, it is increasingly difficult for firms to exercise market power. A firm that is unable to exercise market power is known as a price taker. For example, we observe that the price in the online music market is relatively stable across digital music providers.[4] Since Apple priced music at a flat fee $0.99 per track in 2003, it has formed a consumer expectation that everyone else has to follow. Therefore, a price-taking firm can employ a competitive pricing strategy which simply sets its prices on the basis of the prices charged by competitors or the price established by an industry leader. Price-taking firms must rely on other differentiating factors such as services to attract customers.

To understand the effect of competitively determined B2C channel price on price-taking firms' service provision and channel strategy, now we extend the general model to a special scenario in which the B2C channel price *p* is assumed competitively determined by the industry or market. The only decision variable for the seller is the service level *s* in the single-channel model, while the service level *s* and the royalty fee R are the decision variables in the dual-channel model. Table 3 summarizes the optimal price and service strategies and the optimal-channel profits.

Comparing optimal profits under the single-channel and dual-channel distribution, we have the following results:

Proposition 9: When the B2C channel price is competitively determined, the optimal channel strategy is to choose dual channel when $\theta > \tilde{\theta}$, *where*

$$\tilde{\theta} = \left(B + \sqrt{\Delta}\right) / A$$

and

$$A = (a - p)\left(a - p + 2pf^2\right) + f^2 p\left(2d + pf^2\right)$$

$$B = \left(a - 3p + pf^2\right)\left(a + pf^2\right) + d(p - a) + p\left(2p + df^2\right)$$

$$\Delta = 4dp(a - p)^2 + 2f^2 dp\left(2p(2a + d) - 5p^2 - d^2 + 2p^2 f^2\right).$$

Figure 6 illustrates the relationship between the threshold value $\tilde{\theta}$ and B2C channel price p with a given set of parametric values ($a = 30, f = 0.2, d = 1$).

We see that the threshold value for adopting an optimal dual-channel strategy decreases in the B2C channel price. When p is high enough, the dual-channel strategy outperforms the single-channel strategy regardless of the portion of innovators. However, when p is relatively low, it requires a relatively large portion of innovators in order for the dual-channel distribution to be optimal. When $p \le d$, the dual-channel strategy is infeasible regardless of the portion of innovators.

Concluding Remarks

WITH THE PROLIFERATION OF E-COMMERCE, firms have become increasingly creative in their use of multiple selling channels to distribute digital products. In addition to the popular B2C channel distribution, there are now emerging opportunities to involve consumers in C2C channel transactions. This study has investigated the business value of this emerging dual-channel strategy in facilitating digital content distribution.

Specifically, we have constructed economic models to analyze a digital product seller's optimal channel structure and pricing and service strategies. Under various market conditions, we found that dual-channel distribution is more favorable than single-channel distribution when the portion of innovators in the consumer population is higher than some threshold values. When dual-channel distribution is optimal, the seller always prefers to set a higher price and offer a higher level of service in comparison to those in the single-channel distribution. In addition, we consider other scenarios related to the service provision and the seller's pricing power. We have shown that there is significant value associated with the provision of service. The benefits include reducing the dependence on innovative consumers, tolerating a larger C2C

Table 3. Optimal Channel Strategies When B2C Channel Price Is Comparatively Determined

	Optimal decisions	Channel profits
Single channel	$s_1 = pf$	$\frac{p\left(2(a-p)+pf^2\right)}{2}$
Dual channel	$\begin{cases} R = \frac{1}{2-f^2(1-\theta)^2}\left((1-\theta)\left(a+\theta pf^2\right)+(\theta p-d)\right) \\ s_2 = \frac{f}{2-f^2(1-\theta)^2}\left(\theta p(3-\theta)+(1-\theta)(a-a\theta-d)\right) \end{cases}$	$\frac{2\theta p^2\left(f^2-2\right)+(a-d)^2+\theta^2(a-p)^2+2d\theta(a-p)-2\theta pdf^2(1-\theta)+2a\theta(3p-a)}{2\left(2-f^2(1-\theta)^2\right)}$

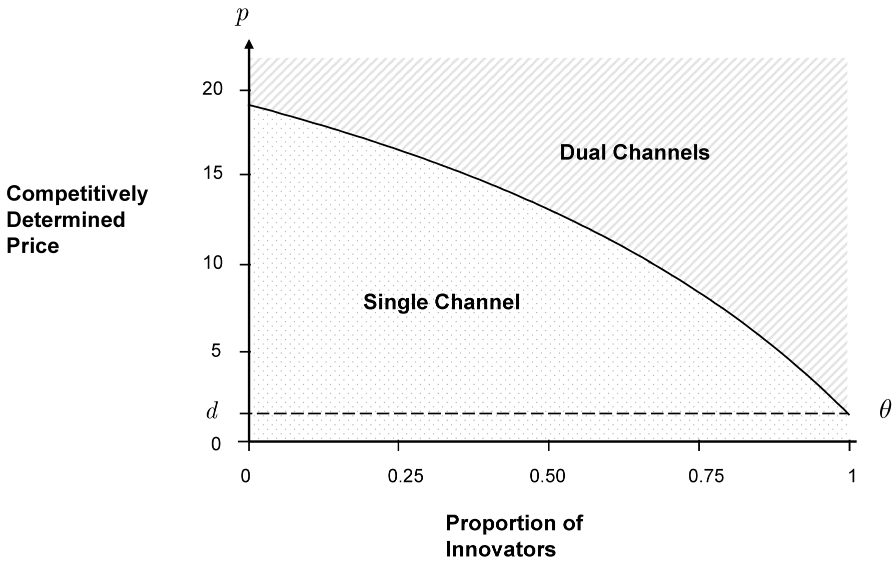

Figure 6. Optimal Channel Strategy When B2C Channel Price Is Competitively Determined

channel redistribution cost, and allowing for additional pricing flexibility. We also found that, when the B2C channel price is competitively determined in the market, the threshold value for choosing an optimal dual-channel strategy decreases in the B2C channel price.

The major contribution of this paper is to provide the first step toward understanding the digital product seller's (or the digital content owner's) dual-channel distribution strategy in an emerging technology–enabled C2C market. However, there are several limitations. First, we adopted a monopoly model framework in this study. We looked at the digital content distribution problem from the perspective of content owner (copyright holder) or a forward integrated online retailer (the content owner has its own distribution channel). From the legal perspective, the monopoly framework can be justified by the fact that digital content is often copyrighted work and is not easily substitutable. The monopoly framework also comes from the recent observation that musicians, for example, are experimenting heavily on the self-distribution model via the Web using revolutionary digital distribution methods such as BitTorrent and other file-sharing technologies [20]. Our model provides important managerial insights for the design and integration of such new distributional channels. At the same time, we also observe that some digital content (e.g., popular files) are available in competing (and potentially free) networks. Conceptually, we can distinguish between content providers who create and supply original content, and network service providers who maintain the distribution network that delivers content. Introducing competition between different networks would be an interesting future research topic.

To model consumers' consumption preferences and purchasing behavior, we assumed the proportion of innovators is a constant that is exogenously determined by the characteristics of the population. One direct benefit of such modeling efforts is the analytical tractability and the clean insights gained in forming an optimal channel strategy. Alternative models, however, could consider it as an endogenous variable that is affected by the seller's price and service choices. How such interaction affects the channel strategy and profitability and, more importantly, how channel structure might affect the consumer's consumption experience are important issues that should be further investigated.

Our model focuses on a scenario where a single version of the digital product is offered. The product has homogeneous quality regardless of the distribution channel. Realistically, the product may be offered with different compression methods (e.g., a codec wrapped with DRM), which results in files of different sizes that are appropriate for different needs for downloading, transfer, and playing on different devices. Higher compression generally comes at the expense of product quality. Although continuous technological improvement holds the promise of allowing greater compression with minimum data loss, understanding the economic implications of product quality on product versioning remains another future research direction.

Finally, static models cannot reveal insights on market dynamics. In a rapidly changing business environment, prices often change dynamically over time in response to evolving market conditions. Future work may also consider dynamic pricing over the entire product planning horizon.

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Notes

1. The huge potential of consumer-oriented dual-channel distribution is the broader reach enabled by the notably low cost of redistribution among consumers. Thus, we implicitly assume that d is substantially lower than the highest possible valuation a. If the redistribution cost is too high, no one would redistribute the product, making analysis of the dual-channel distribution moot.

2. The authors thank an anonymous reviewer who provided insightful comments.

3. For notational convenience, we use subscripts and superscripts to distinguish various scenarios. Subscripts 1 and 2 indicate single and dual channels, respectively. Superscript s indicates channel strategies with service provision.

4. We thank an anonymous referee for bringing this issue to our attention.

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Appendix: Proofs of Propositions

Proof of Proposition 1

(a) The seller's profit difference in the single- and dual-channel strategies in the SD-Partial market can be expressed as

$$\Pi_2^s - \Pi_1^s = \frac{-2d\left(2-f^2\right)\left(2a-d\right)+\theta\left(\left(a-df^2\right)^2+2d\left(2a-df^2\right)\right)}{2\left(4-\theta-2f^2\right)\left(2-f^2\right)}.$$

Because $f \leq 1$ and

$$f \leq \sqrt{\frac{(2-\theta)(a+d)}{2a}},$$

we have $4 - \theta - 2f^2 > 0$ and $2 - f^2 > 0$. So the denominator is positive.

We see that the nominator is a linear function of θ. It is easy to check that the nominator is negative if $\theta = 0$ and is positive if $\theta = 1$. There must exist a threshold value $0 < \theta_1 < 1$ such that $\Pi_2^s - \Pi_1^s = 0$. Solving for θ_1, we have

$$\theta_1 = \frac{2d\left(2-f^2\right)\left(2a-d\right)}{\left(a-df^2\right)^2+2d\left(2a-df^2\right)}.$$

If $0 < \theta \leq \theta_1$, then $\Pi_2^s - \Pi_1^s < 0$. So the single-channel strategy outperforms the dual-channel strategy. If $\theta_1 < \theta \leq 1$, then $\Pi_2^s - \Pi_1^s > 0$. So the dual-channel strategy outperforms the single-channel strategy.

(b) The seller's profit difference in the single- and dual-channel strategies in the D-Full market can be expressed as

$$\Pi_2^s - \Pi_1^s = \frac{-2a\left(a\left(1-f^2\right)^2+2d\left(2-f^2\right)\right)+\theta\left(a+d\right)^2\left(2-f^2\right)}{4\left(2-f^2\right)}.$$

Under conditions $f \leq 1$ and

$$f > \sqrt{\frac{(2-\theta)(a+d)}{2a}},$$

we have $2 - f^2 > 0$. So the denominator is positive. We also have $\theta > 2d/(a + d)$.

It is easy to check that, if $\theta = 2d/(a + d)$, the nominator is negative, and if $\theta = 1$, the nominator becomes positive. Since $\Pi_2^s - \Pi_1^s$ is a linear function of θ, there must exist a threshold value $0 < \theta_2 < 1$ such that $\Pi_2^s - \Pi_1^s = 0$. Solving for θ_2, we have

$$\theta_2 = \frac{2a\left(\left(2-f^2\right)\left(2d-af^2\right)+a\right)}{\left(a+d\right)^2\left(2-f^2\right)}.$$

If $(2d/(a + d)) < \theta \le \theta_2$, then $\Pi_2^s - \Pi_1^s < 0$. So the single-channel strategy outperforms the dual-channel strategy. If $\theta_2 < \theta \le 1$, then $\Pi_2^s - \Pi_1^s > 0$. So the dual-channel strategy outperforms the single-channel strategy.

(c) The seller's profit difference in the single- and dual-channel strategies in the S-Full market can be expressed as

$$\Pi_2^s - \Pi_1^s = \frac{2\left(a^2\left(1-f^2\right)^2 - 2ad + d^2\right) + \theta\left(2ad + a^2f^2 - d^2f^2\right)}{2\left(4-\theta-2f^2\right)}.$$

Under the condition $f > 1$ and

$$f \le \sqrt{\frac{\left(2-\theta\right)\left(a+d\right)}{2a}},$$

we have $4 - \theta - 2f^2 > 0$. So the denominator is positive. We also have $\theta < 2d/(a + d)$.

We see that the nominator is a linear increasing function of θ. It is easy to check that the nominator is negative if $\theta = 2d/(a + d)$. Therefore, $\Pi_2^s - \Pi_1^s < 0$. So it is always optimal to adopt the single-channel strategy.

(d) The seller's profit difference in the single- and dual-channel strategies in the SD-Full market can be expressed as

$$\Pi_2^s - \Pi_1^s = \frac{-4ad + \theta\left(a+d\right)^2}{4}.$$

Clearly, $\Pi_2^s - \Pi_1^s$ is a strictly increasing function of θ. If $\theta = 0$, $\Pi_2^s < \Pi_1^s$, and if $\theta = 1$, $\Pi_2^s \ge \Pi_1^s$. Solving $\Pi_2^s - \Pi_1^s = 0$, we have $\theta_3 = 4ad/(a + d)^2$.

Therefore, if $0 < \theta \le \theta_3$, the single-channel strategy is optimal. If $\theta_3 < \theta \le 1$, the dual-channel strategy is optimal.

Proof of Proposition 2(a)

(i) In the SD-Partial market, the difference between the single-channel price and that in the dual-channel B2C market price can be expressed as

$$p_2^s - p_1^s = \frac{\left(2-f^2\right)\left(a-d-df^2\right)+\theta\left(-df^4+\left(a+2d\right)f^2-a\right)}{\left(4-\theta-2f^2\right)\left(2-f^2\right)}.$$

From Proposition 1, we know that the denominator is positive. Under the condition $f \le 1$, the nominator is positive if $\theta = 0$ and $\theta = 1$. Since the nominator is a linear function of θ, we have $p_2^s > p_1^s$ for all $0 < \theta \le 1$.

(ii) In the SD-Partial market, the difference between the single-channel price and royalty fee in the dual channel can be expressed as

$$R^s - p_1^s = \frac{2d\left(f^2-2\right)+\theta\left(af^2-a-df^4+2df^2\right)}{\left(2-f^2\right)\left(4-\theta-2f^2\right)}.$$

Under the condition $f \le 1$, we have $4 - \theta - 2f^2 > 0$ and $2 - f^2 > 0$. The denominator is positive. It is easy to verify that the nominator is negative if $\theta = 0$. If $\theta = 1$, the nominator is a function of f^2. The two roots are

$$f_1^2 = \frac{1}{d}\left(\frac{1}{2}a+2d-\frac{1}{2}\sqrt{4ad+a^2}\right) > \left(\frac{1}{2}+\frac{d}{2a}\right)$$

$$f_2^2 = \frac{1}{d}\left(\frac{1}{2}a+2d+\frac{1}{2}\sqrt{4ad+a^2}\right) > 1.$$

Therefore, we only need to consider f_1^2. There are two cases.

If $0 < f^2 < f_1^2$, then the nominator is negative. In this case, we have $R^s < p_1^s$ for all $0 < \theta \le 1$.

If $f_1^2 < f^2 < 1$, then the nominator is positive. In this case, the threshold value for $R^s > p_1^s$ is determined by

$$\theta' = \frac{2d\left(2-f^2\right)}{af^2-a-df^4+2df^2}.$$

For all $\theta > \theta'$, $R^s > p_1^s$. However, from the boundary condition

$$f \le \sqrt{\frac{\left(2-\theta\right)\left(a+d\right)}{2a}},$$

we must have

$$\theta < \theta'' = \frac{2\left(a+d-af^2\right)}{\left(a+d\right)}.$$

Under the condition $f_1^2 < f^2 < 1$, we can verify that $\theta' > \theta''$. Thus, we can safely exclude the case $R^s > p_1^s$. Therefore, in the SD-Partial market, the C2C channel royalty fee R^s is lower than the single-channel retail price p_1^s.

The analyses in the D-Full and SD-Full markets are similar. We omit the proofs here.

Proof of Proposition 2(b)

In the SD-Partial market, the service difference between the single channel and dual channel can be expressed

$$s_2 - s_1 = \frac{f\left(-2d\left(2-f^2\right)+\theta\left(a+2d-df^2\right)\right)}{\left(4-\theta-2f^2\right)\left(2-f^2\right)}.$$

Under the condition $f < 1$, we have $4 - \theta - 2f^2 > 0$ and $2 - f^2 > 0$. The denominator is positive. It is easy to check that the nominator is negative if $\theta = 0$ and is positive if $\theta = 1$. Solving $s_2 - s_1 = 0$, we have

$$\theta_s = \frac{2d\left(2-f^2\right)}{a+2d-df^2}.$$

Therefore, $s_2 > s_1$ if $\theta_s < \theta \leq 1$, and $s_2 \leq s_1$ if $0 < \theta \leq \theta_s$.

Recall from Proposition 1 that the condition for the dual channel to be optimal is $\theta > \theta_1$. Write the threshold difference as

$$\theta_1 - \theta_s = \frac{2d\left(a-2d+df^2\right)\left(a+d-df^2\right)\left(2-f^2\right)}{\left(\left(a-df^2\right)^2+2d\left(2a-df^2\right)\right)\left(a+2d-df^2\right)}.$$

It is easy to check that $a - 2d + df^2 > 0$, $a + d - df^2 > 0$, $2 - f^2 > 0$, $a + 2d - df^2 > 0$, and $(a - df^2)^2 + 2d(2a - df^2) > 0$. Therefore $\theta_1 > \theta_s$. We can safely exclude the case for $s_2 \leq s_1$. Hence, $s_2 > s_1$ always holds in the SD-Partial market.

Following a similar approach, the same results can be derived in the D-Full market and SD-Full market. We omit the proof here.

Proof of Proposition 3

Write the optimal profit difference in the single channel and the dual channel without service provision as

$$\Pi_2 - \Pi_1 = \frac{4d\left(d-2a\right)+\theta a\left(a+4d\right)}{4\left(4-\theta\right)}.$$

It is clear that the denominator is positive. Since the nominator is negative if $\theta = 0$ and is positive if $\theta = 1$, solving $\Pi_2 - \Pi_1 = 0$, we have

$$\theta_4 = \frac{4d(2a-d)}{a(a+4d)}.$$

Therefore, if $0 < \theta \le \theta_4$, then $\Pi_2 \le \Pi_1$. So the single-channel strategy is optimal. If $\theta_4 < \theta \le 1$, then $\Pi_2 > \Pi_1$. So the dual-channel strategy is optimal.

Proof of Proposition 4

From the optimal pricing strategies without service provision, we have

$$p_2 - p_1 = \frac{a(1-\theta)+(a-2d)}{2(4-\theta)}$$

and

$$R - p_1 = -\frac{\theta a + 4d}{2(4-\theta)}.$$

Obviously, $R - p_1 < 0$. By the assumption $p_2 > R + d$, we have the inequality $a - (3 - \theta)d > 0$, which implies $a < 2d$. Therefore, we have $p_2 - p_1 > 0$.

Proof of Proposition 5

In the case of dual channel without service provision, substituting p_2 and R into the condition $p_2 - R - d > 0$, we have $d < a/(3 - \theta)$. There are two cases.

In the D-Full and SD-Full markets under the dual-channel structure with service provision, substituting optimal prices into the condition $p_2^s - R^s - d > 0$, taking into account the condition

$$f < \sqrt{\frac{(2-\theta)(a+d)}{2a}},$$

we have $d^s < 3/((3 - \theta) - f^2)$. Notice that $d < a/(3 - \theta)$ and the denominator $(3 - \theta) - f^2 < (3 - \theta)$, we have

$$\frac{a}{(3-\theta)} < \frac{a}{(3-\theta)-f^2}.$$

In the D-Full market, we have $d^s < af^2$. It is easy to show that $(a/(3 - \theta)) < af^2$.

Overall, we have $\bar{d} \equiv \max(d) < \bar{d}^s \equiv \max(d^s)$.

Proof of Proposition 6

The price difference in the absence of service provision is

$$p_2 - R = \frac{a+d}{4-\theta}.$$

According to Table 1, there are two cases for the optimal pricing strategies with service provision.

If

$$f \leq \sqrt{\frac{(2-\theta)(a+d)}{2a}},$$

then

$$p_2^s - R^s = \frac{a+d-df^2}{4-2f^2-\theta}.$$

Calculating the price differences gives

$$\left(p_2^s - R^s\right) - \left(p_2 - R\right) = \frac{f^2\left(2a-2d+\theta d\right)}{\left(4-2f^2-\theta\right)\left(4-\theta\right)} > 0.$$

If

$$f > \sqrt{\frac{(2-\theta)(a+d)}{2a}},$$

then

$$p_2^s - R^s = \frac{a+d}{2}.$$

Since $0 < \theta \leq 1$, $4 - \theta > 2$. Therefore, we have $p_2^s - R^s > p_2 - R$.

Proof of Proposition 7

Under optimal pricing, the channel profit difference in the single channel with service provision and the dual channel without service provision can be expressed as

$$\Pi_2 - \Pi_1^s = \frac{-2\left(\left(a-d\right)^2 f^2 + 2d\left(2a-d\right)\right) + \theta a\left(a+4d-2df^2\right)}{2\left(4-\theta\right)\left(2-f^2\right)}.$$

We see that the denominator is positive. If $\theta = 0$, the nominator is negative. If $\theta = 1$, there are two cases.

If

$$f > \sqrt{\frac{\left(a-2d\right)^2}{2\left(a^2-ad+d^2\right)}},$$

then the nominator is negative. We have $\Pi_2 < \Pi_1^s$ for all $0 < \theta \leq 1$.

If

$$f < \sqrt{\frac{(a-2d)^2}{2\left(a^2 - ad + d^2\right)}},$$

then the nominator is positive. Solving $\Pi_2 - \Pi_1^s = 0$, we have

$$\theta_5 = \frac{2\left(2d(2a-d) + (a-d)^2 f^2\right)}{a\left(a + 4d - 2df^2\right)}.$$

If $\theta_5 < \theta \leq 1$, then $\Pi_2 > \Pi_1^s$. If $0 < \theta \leq \theta_5$, then $\Pi_2 \leq \Pi_1^s$.

Proof of Proposition 8

Following Proposition 1, we can easily verify that, under the condition $f^2 \leq 1$, we have

$$\frac{\partial\theta_1}{\partial f^2} = \frac{-2d(2a-d)\left(a^2 - d^2\left(f^2-2\right)^2\right)}{\left(a^2 - 2adf^2 + d^2 f^4 + 4da - 2d^2 f^2\right)} < 0$$

and

$$\frac{\partial\theta_2}{\partial f^2} = \frac{-2a^2\left(f^2-1\right)\left(f^2-3\right)}{(a+d)^2\left(f^2-2\right)^2} < 0.$$

Thus, the channel indifference threshold values decreases in f^2.

We also see that $\theta_1 = \theta_2$ if

$$f = \sqrt{\frac{(2-\theta)(a+d)}{2a}},$$

and

$$\theta_2 = \theta_3 = \frac{4ad}{(a+d)^2}$$

if $f^2 = 1$. Therefore, $\theta_3 < \theta_2 < \theta_1$. Now write the difference between the channel indifference threshold values as

$$\theta_4 - \theta_1 = \frac{2df^2(2a-d)\left(a^2 - 4d^2 + 2d^2 f^2\right)}{a(a+4d)\left(\left(a - df^2\right)^2 + 2d\left(2a - df^2\right)\right)}.$$

It is easy to check that $(2a - d) > 0$, $(a^2 - 4d^2 + 2d^2f^2) > 0$, $(a + 4d) > 0$, and $(a - df^2)^2 + 2d(2a - df^2) > 0$. Therefore, $\theta_4 > \theta_1$.

Further comparing θ_5 with θ_4, we have

$$\theta_5 - \theta_4 = \frac{2f^2(a+d)^2}{(a+4d)(a+4d-2df^2)}.$$

The condition

$$f < \sqrt{\frac{(a-2d)^2}{2(a^2 - ad + d^2)}}$$

implies that $(a + 4d - 2df^2) > 0$. Therefore, $\theta_5 > \theta_4$.

Proof of Proposition 9

To ease the proof, we assume $0 < f < \sqrt{2}$. Other cases can be analyzed in a similar way without affecting any analytical insights derived under this condition. We focus on this because we have normalized the price effect on demand to 1 (see Equation (2)). Now we assume the responsiveness of service to demand falls in a comparable range $(0, \sqrt{2})$.

In order for dual channel to be feasible, we need the following inequality to hold:

$$R^s = \frac{1}{2 - f^2(1-\theta)^2}\Big((1-\theta)\big(a + \theta p f^2\big) + (\theta p - d)\Big) \le p - d.$$

Solving this inequality for p, we have

$$p \ge \frac{(1-\theta)\big(a - df^2(1-\theta)\big) + d}{(1-\theta)(1-f^2) + 1}.$$

Denote θ_p as the threshold value when equality holds in the above expression. Write

$$\frac{\partial p}{\partial \theta_p} = \frac{-a + df^2\left(2 - 4\theta_p + \theta_p^2\right) - df^4\left(1-\theta_p\right)^2}{\left[1 + \left(1-\theta_p\right)\left(1-f^2\right)\right]^2}.$$

It is easy to check that, when $0 < f < \sqrt{2}$, the nominator is a decreasing function of θ_p on the interval $(0, 1]$. Therefore,

$$-a + df^2\left(2 - 4\theta_p + \theta_p^2\right) - df^4\left(1-\theta_p\right)^2 < -a + 2df^2 - df^4 = d\left[1 - \frac{a}{d} - \left(1-f^2\right)^2\right] < 0.$$

Hence, we have $(\partial p/\partial\theta_p) < 0$. Then, given p, the dual channel is feasible when $\theta \geq \theta_p$.

Substituting the boundary condition $R = p - d$ into the general dual channel profit function (7) we have $\Pi_2^s = p(a - p + fs) - d(1 - \theta)(a - p + fs) - s^2/2$. Note that any profit Π_2^s achievable by pair (p, s) is strictly less than the single channel profit Π_1^s defined in Equation (6) for all $\theta < 1$. Therefore, when $\theta = \theta_p$, $\Pi_1^s > \Pi_2^s$.

When p is competitively determined, write the profit difference between the single channel and dual channel as

$$\Pi_2^s - \Pi_1^s =$$

$$\frac{1}{2\left(2-f^2\left(1-\theta\right)^2\right)}\begin{pmatrix} 4p^2+a^2+d^2+p^2f^4-4p^2f^2-4pa-2ad+2paf^2 \\ -2p^2f^4\theta-4p^2\theta-2a^2\theta+6p^2f^2\theta+6pa\theta \\ -2pd\theta+2ad\theta-4paf^2\theta-2pdf^2\theta \\ +p^2f^4\theta^2+p^2\theta^2+a^2\theta^2-2pa\theta^2-2p^2f^2\theta^2+2paf^2\theta^2+2pdf^2\theta^2 \end{pmatrix}.$$

Solving $\Pi_2^s - \Pi_1^s = 0$ we get two roots:

$$r_1 = \frac{B-\sqrt{\Delta}}{A}$$

$$r_2 = \frac{B+\sqrt{\Delta}}{A},$$

where

$$A = (a-p)\left(a-p+2pf^2\right)+f^2p\left(2d+pf^2\right)$$

$$B = \left(a-3p+pf^2\right)\left(a+pf^2\right)+d\left(p-a\right)+p\left(2p+df^2\right)$$

$$\Delta = 4dp\left(a-p\right)^2+2f^2dp\left(2p\left(2a+d\right)-5p^2-d^2+2p^2f^2\right).$$

Note that the nominator (terms in the last parentheses) in the expression $\Pi_2^s - \Pi_1^s$ is a quadratic function of θ. It is easy to check that the coefficient for θ^2 is positive. Under the assumption that $0 < f < \sqrt{2}$, the denominator is positive. Therefore, $\Pi_2^s < \Pi_1^s$ for $r_1 < \theta < r_2$. So, we must have $r_1 < \theta_p < r_2$.

Accordingly, the threshold value for adopting dual-channel strategy is determined by the large root r_2, that is,

$$\tilde{\theta} = \frac{B+\sqrt{\Delta}}{A}.$$

If $\theta > \tilde{\theta}$, dual-channel strategy is optimal. If $\theta_p < \theta < \tilde{\theta}$, dual-channel strategy is feasible but single-channel strategy is optimal. If $\theta < \theta_p$, dual-channel strategy is infeasible so single-channel strategy is optimal. This completes our proof.