Hindawi
Discrete Dynamics in Nature and Society
Volume 2023, Article ID 3461050, 10 pages
https://doi.org/10.1155/2023/3461050

Research Article

Channel Management for Digital Products in the Two-sided Market with Network Externality Effects

Wei Li, Yan-Peng He, and Shu-Gang Ma

Research Center for Contemporary Commercial Services, School of Business, Hebei University of Economics and Business, Shijiazhuang, Hebei 050061, China

Correspondence should be addressed to Shu-Gang Ma; mashugang@126.com

Received 24 October 2022; Revised 9 March 2023; Accepted 10 March 2023; Published 28 June 2023

Academic Editor: Manuel De la Sen

Channel selection is a critical trade-off for digital products firms whose products are characterized by network externality. This work develops the models of consumers' utility impacted by the network externality for two channel strategies of the digital product firms in the two-sided market: direct channel strategy and platform channel strategy. Deriving from the consumers' utility, the optimization models of the two channel strategies are presented. The optimization models are solved through the Lagrangian method, and the comparative statics analysis is conducted to investigate the effect of network externality on optimality. Mathematical results show that if the intensity of network externality in the online platform surpasses that in the direct channel, the platform channel strategy dominates the other channel strategy; otherwise, the direct channel strategy is the firms' optimal decision. In addition, the two channels share the equal optimal price, and the firms' profit (and demand) would be positively impacted by the network effect and the products' features but negatively impacted by the consumers' learning cost. This work provides decision support for the digital product firms on channel selection in the context of the two-sided market.

1. Introduction

The two-sided market in which the third-party online platforms connect suppliers and consumers provides more choices for digital product vendors on their distribution channels. With online platforms contributing increasingly to the economic growth of many nations, plenty of digital product firms choose to participate in a third-party online platform to supply their products through the platform. For example, mobile application developers publish their products in the App Store which is a typical online platform. Hence, third-party online platforms have become the significant distribution channels of digital products in such a market. However, it keeps several providers still stick to selling their products through traditional direct channels; for instance, Oracle communicates with its consumers through the official website to provide database products and services. It follows that, in the two-sided market, digital products firms have to manage the issue of choosing their distribution channels from the emerging platform or the existing direct channel.

Both the direct and platform channels have their own benefits and drawbacks. Direct channels are often owned by sellers; therefore, digital product vendors can take the whole revenue generated from direct channels. However, vendors might lose the benefits of platforms' functions such as market coverage and information collection if they choose the direct channels and have to struggle to enlarge their market demands. By contrast, vendors supplying digital products in an online platform could enlarge their potential market through the market power of the platform but obtain only parts of the revenue; that is, the platform deprives vendors of profit. For instance, Apple Inc. would take 30% of the revenue generated by applications sold in the App Store, and only 70% of the revenue goes to publishers. Both the channel strategies have advantages and disadvantages; therefore, in reality, digital product firms have to face the dilemma to trade-off between the direct channel and the platform channel. Accordingly, the channel strategy of digital product vendors becomes more complex in the context of the two-sided market.

The problem of channel selection for digital products has been widely explored in the existing literature. For example, researchers have been investigating the firms' trade-off between the direct channel and the retail channel, as well as the trade-off between the online channel and the offline channel. However, despite a plethora of research on this problem, our knowledge is limited to the channel strategy in the context of the one-sided market in which providers sell products to consumers without intermediaries, and if we turn the situation to the two-sided market, little is known about digital products vendors' optimal channel decisions, especially the following two issues: first, digital product firms trade-off on the channel selection when platforms become a significant distribution channel in the context of the two-sided market and second, how the pricing of digital product and benefits of the firms are affected when both providers and consumers interact with the third-party online platform.

Taking these gaps in the extant research into account, the current work intends to investigate the optimality of trade-off between the direct channel and the platform channel. For digital products, the decisions of providers are supposed to be basing on the value of products rather than the cost, which is quite different from physical products [1]. The reason is the special cost structure of digital products: providers commonly invest vast cost to produce the first copy; however, after that, the marginal cost is extremely low. For example, the marginal production of mobile applications is to upload them to Apple Store or Google Play Store and let consumers download. Hence, the current work formulates the models of the customers' utility, which is related to the value of products, in the situations that digital product firms sell their products through the direct channel or the online platform. In these models, the customers' utility is impacted by network externality, which means the consumers' utility increases with the installed base of the products and is the significant economic characteristic of digital products [2, 3]. The current work presents the optimization models for these channel strategies. The optimization models are derived from the utility models; in these optimization models, digital product firms determine the prices of products to maximize their profit, and optimality is affected by network externality and other factors. The closed-form analysis shows that (1) the prices of digital products and the profits of firms increase with the network externality and products' features; (2) if the intensity of network externality in the online platform exceeds that in products (or not), then the platform channel strategy (or the direct channel strategy) is just the firms' optimal channel selection.

The contribution of the current work is thus to extend the story of channel selection of digital product firms. In this work, we investigate the optimality on the channel decision issue of digital product firms in the context of the two-sided market, whereas the existing literature generally discusses this issue under the one-sided market; moreover, we explore the mathematical mechanism of the channel selection of digital product firms and that of the effect of network externality and other factors on firms' decisions. Therefore, the findings of the current work are beneficial to digital product firms in making decision in the two-sided market.

The rest of this paper is organized as follows: Section 2 reviews the existing literature about the channel selection problem and then discusses the merits of the current work compared with such literature. Section 3 presents the models of the consumers' utility and then develops the firm's optimization models in different channel strategies. Section 4 solves the optimization models in a closed-form solution, explores the optimality of channel selection in the presence of network externality, and investigates the impact of the characteristics of digital products on the benefits of firms. Section 5 concludes the current work with a discussion on its implications and limitations.

2. Literature

The current work aims to investigate the channel selection problem faced by digital product firms, and researchers have addressed this issue by exploring the dual-channel distribution of digital products.

One stream of the existing literature investigates the digital products firms' channel selection between the online and offline channels. Consumers, in the past decades, have already been familiar with Internet-related merchandises and services, such as websites and smart devices [4], which have deeply affected the consumers' (and providers') behaviors about the adoption (and distribution) of digital products. For example, consumers have been used to adopting music copies (the typical digital product) by downloading them from the Internet; hence, many music firms choose to distribute their copies digitally through the Internet, and this impacts the operation strategies of the music industry [5]. Thus, there are plenty of literature studies investigating the online distribution of digital products and exploring the trade-off between online and offline channels.

Comparing the online and offline channel strategies, many factors would impact the channel selection of digital product providers, for instance, the network effect [6], the customization cost of products [7], security externality [8], the similarities between the channels [9], product availability [10], the market capacity [11], the impact of free riders [12], and the secondary marketplace [13], as well as the spillover effect [14]. In recent years, mobile Internet subscriptions have grown much more quickly than fixed line broadband subscriptions [15], which make mobile Internet a significant online channel to distribute digital products. Comparing with the fixed line channel, consumers in the mobile Internet channel tend to choose "head" products, which are the most popular products or the most sold products [16]; thus, digital product firms could launch the versions with the most demand through the mobile Internet. These literature studies intending to make trade-off between the online and offline channel deem that online channels are useful to improve the transaction effectiveness of digital product suppliers; however, in some situations, they might still be suboptimal for suppliers.

There is another stream of the literature exploring the firms' selection between the direct and retail channels. The channels discussed in the aforementioned literature studies,

including the online and offline channels, are the direct channels in which providers directly sell products to end users. However, digital products are also able to be distributed through the retail channel in which retailers resell products to end users [17]. Such suppliers who sell products through the direct channel would become the competitor of their retail partners [18]. Researchers argue that network externality [19], retailers' attitude towards the risk [20], governments' policies [21–23], strategies of competitors [24], and market demands [25], as well as the similarity between the channels [26], would deeply impact digital products firms' selection between the direct and retail channels.

In reality, digital product suppliers often find that the retailer create an artificially low price, which is harmful for the suppliers' benefits. Hence, suppliers would adopt a strategy that suppliers set official price for retailers [27]. Zhu and Yao [28] compared this strategy with the traditional wholesale model of the e-book, a typical digital product, and demonstrated that the strategy that providers set price for retailers is often suboptimal to the traditional wholesale model.

The prior literature abovementioned reveals the situations in which the certain channel strategy (online/offline channel and direct/retail channel) would become the optimal decision for digital product firms. However, all of those literature studies explored the channel strategy in the context of the one-sided market. Recently, with the development of the two-sided market, online platforms have been playing an increasingly important role in the distribution of digital products. For example, airlines often distribute electronic tickets through online travel agency platforms [29], and in these years, data transactions are also conducted through trading platforms such as the Shanghai Data Exchange Corporation of China [30]. Therefore, astute managers would recognize the significance of third-party platforms as distribution channels in the two-sided market and make a trade-off between the emerging platform channel and other traditional channels [31]. However, little is known about the channel selection when digital product firms face the platform channel in the context of the two-sided market, and this would restrict the benefit of firms. Hence, the current work extends the story of channel selection by exploring digital products vendors' optimal decisions on distribution channels in the context of the two-sided market. Some researchers, for instance, Wei et al. [32], Zhao et al. [33], and Xu et al. [34], have explored the network externality in the two-sided platform, and inspired by these recent works, the current work examines how network externality and some other factors affect the optimal channel strategies and benefits of vendors.

3. Model Settings

It is assumed that a firm with a monopoly position develops and releases digital products to consumers whose type is denoted as v_i uniformly distributed between 0 and 1 (i.e., $v_i \sim U[0, 1]$, and the subscript i means that consumers are heterogeneous). The features of digital products are denoted as s, and the monopolist has two choices on distributing the products: first, the provider adopts the direct channel strategy; that is, digital products are distributed through the direct channel in price p_1. Second, the provider adopts the platform channel strategy; that is, digital products are distributed through the platform channel in price p_2. The notations and their definitions in the situations of the two channel strategies are shown in Table 1, and the current work intends to investigate the optimality of the monopolist's pricing decision and channel selection facing the two available channel strategies in the context of the two-sided market.

3.1. Direct Channel Strategy. This section presents the consumers' utility model and the monopolist's optimization model when digital products are distributed through the direct channel.

3.1.1. Consumers' Utility. When consumers adopt digital products, the values that they enjoy are twofold: the first is the inherent value of products deriving from the features of digital products; hence, this part of the value is defined as $s \cdot v_i$. The second is the value deriving from network externality, and because of the network externality effect, consumers would obtain more utility from the increasing installed base of the digital product [35]; hence, network externality is defined as $\lambda \cdot Q_1$, where λ represents the intensity of network externality in the direct channel and Q_1 represents the installed base of digital products. Consumers also need to pay the cost for obtaining the products' value. This cost contains economic cost (i.e. the price of digital products) and the learning cost c ($s > c$). The consumers' utility U_1 is shown in equation (1). In reality, the aim of consumers adopting digital products is to enjoy the features of products; therefore, it is assumed that the value deriving from the products' features actually dominate that deriving from the network externality effect, that is, $s \gg \lambda$:

$$U_1 = s \cdot v_i + \lambda \cdot Q_1 - p_1 - c. \quad (1)$$

3.1.2. Firm's Profit. When digital products are launched through the direct channel, consumers whose utility is nonnegative would purchase digital products. There exists a consumer v_1 whose utility equals 0; that is, v_1 is indifferent in purchasing s or not, and the consumer $v_i \geq v_1$ would pay for products. The market segmentation in the direct channel is shown in Figure 1.

Since $U_1(v_1) = 0$, it could be obtained that $v_1 = p_1 + c - \lambda \cdot Q_1/s$ and that the demand of the product $D_1 = 1 - v_1$. Inspired by Cheng and Liu [2], the demand of products is just the products' installed base; hence, $D_1 = Q_1 = s - (p_1 + c)/s - \lambda$, and then, the optimization model for the direct channel strategy is obtained in equations (2) and (3), where the price p_1 is the decision variable, the firm's profit π_1 is the objective function, and the intensity of network externality λ is an important parameter that might impact the optimality of the price p_1 and profit π_1:

Table 1: Notations and definitions in the current work.

Notations	Definition
v_i	Heterogeneous consumers
v_1/v_2	The consumer who is indifferent between buying and not buying products the from direct/platform channel
v_T	The consumer who is indifferent between adopting and not adopting platform services
s/s^T	Features of the digital product/platform service
p_1/p_2	Price in the direct/platform channel (decision variable)
π_1/π_2	Profit in the direct/platform channel (objective function)
λ/λ^T	Intensity of network externality in the direct/platform channel
Q_1/Q_2	Installed base of the digital products in the direct/platform channel
Q^T	Installed base of platform services
D_1/D_2	Demand of the digital products in the direct/platform channel
D^T	Demand of platform services
c/c^T	Learning cost of the consumers in adopting digital products/platform service

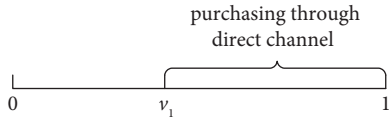

Figure 1: Market segmentation in the direct channel.

$$\max_{p_1} \ \pi_1 = p_1 \cdot \frac{s - (p_1 + c)}{s - \lambda}, \tag{2}$$

$$\text{s.t. } p_1 \geq 0. \tag{3}$$

3.2. Platform Channel Strategy. This section presents the utility model for consumers and the optimization model for the monopolist in the situation that digital products are launched through the online platform channel.

3.2.1. Consumers' Utility. If the monopolist launches digital products through the platform channel, then consumers must adopt the online platform service before they purchase products. The features of the online platform are defined as s^T, and the inherent value obtained by the consumer v_i from the online platform is $s^T \cdot v_i$. In reality, online platforms are often more complex and contain more features than digital products distributed through them (compare Apple's App Store and the mobile applications sold in the App Store). Hence, it is assumed that the features of digital products and online platforms satisfy $s^T > s$.

Online platforms have also characteristics of network externality [36], this makes the network externality also have effects in platform channels, and platforms with most users be most valuable to other users [37]. The intensity of the network externality in the platform is denoted as λ^T, and the installed base of the platform service is denoted as Q^T; therefore, consumers would enjoy the value $\lambda^T \cdot Q^T$ generated by the network externality of the platform service. Adopting the online platform service is often for free (e.g., Amazon and Netflix) but incurs the learning cost c^T ($s^T > c^T$); therefore, the consumers' utility from adopting the online platform is shown in equation (4). Consumers who have adopted the online platform would determine whether to purchase digital products from the platform. The utility of consumers who purchase products through the online platform is shown in equation (5), in which Q_2 represents the installed base of the digital products sold in the online platform:

$$U^T = s^T \cdot v_i + \lambda^T \cdot Q^T - c^T, \tag{4}$$

$$U_2 = s \cdot v_i + \lambda^T \cdot Q_2 - p_2 - c. \tag{5}$$

In reality, the products' value derived from their functionalities and the learning cost needed to pay for enjoying the value are explicit to consumers; however, the network effect is somewhat implicit to consumers. Therefore, the current work assumes that $s, s^T \geq \lambda, \lambda^T$ and $c \geq \lambda, \lambda^T$. Moreover, consumers often need to pay more learning cost to conquer the online platform service. For example, the users of the App Store need to learn how to search and pay for applications and how to distinguish the best products from the applications with similar functionalities. Therefore, this work assumes that the quality-cost ratio in the direct channel dominates that in the platform channel, that is, $(s - \lambda)/(c - \lambda) > (s^T - \lambda^T)/(c^T - \lambda^T)$.

3.2.2. Firm's Profit. If the monopolist releases digital products through the platform channel, then consumers would determine whether to adopt the platform service first. There exists the consumer v_T satisfying $U^T(v_T) = 0$; that is, v_T is indifferent between adopting and not adopting the platform, and the consumer $v_i \geq v_T$ would participate in the online platform. Hence, it could be obtained from (4) that $v_T = c^T - \lambda^T \cdot Q^T/s^T$. In addition, within those who have adopted the platform service, the consumer whose utility obtained from digital products is nonnegative would purchase products. The products' indifferent consumer among platform users is denoted as v_2 satisfying $U_2(v_2) = 0$, and the consumer $v_i \geq v_2$ would purchase the digital product. It could be obtained from equation (5) that $v_2 = p_2 + c - \lambda^T \cdot Q_2/s$. The market segmentation for the platform channel strategy is shown in Figure 2.

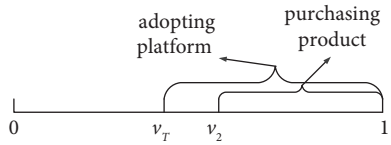

Figure 2: Market segmentation in the platform channel.

Therefore, the demand of the online platform is $D^T = 1 - v_T = 1 - c^T - \lambda^T \cdot Q^T/s^T$, and the demand of products is $D_2 = 1 - v_2 = 1 - p_2 + c - \lambda^T \cdot Q_2/s$. For $D^T = Q^T$ and $D_2 = Q_2$, it could be obtained that $D^T = s^T - c/s^T - \lambda^T$ and $D_2 = s - (p_2 + c)/s - \lambda^T$. Hence, the optimization model of the provider in the situation of the platform channel strategy is shown in equations (6) and (7), in which the price p_2 is the decision variable, the profit π_2 is the objective function, and the optimality might be impacted by the parameter λ^T:

$$\max_{p_2} \ \pi_2 = p_2 \cdot \frac{s - (p_2 + c)}{s - \lambda^T}, \tag{6}$$

$$\text{s.t. } p_2 \geq 0. \tag{7}$$

4. Results and Analysis

This section solves the optimization model of each channel strategy, explores the optimal pricing in the two channel strategies, investigates how the intensity of the network effect impacts the optimal price and profit in each channel strategy, and compares the optimal profits of the two possible channel strategies to find the equilibrium of the channel strategy. In this section, the closed-form formulations of optimality are presented and illustrated by the numerical analysis. In reality, the parameter s represents the number of digital products' functionalities, c represents the effort of consumers to learn how to use products, and λ and λ^T represent the value created by the individual user in the direct and platform channels, respectively; it follows that the units of parameters are various. Therefore, in order to avoid the problem of units, these parameters are normalized into [0, 1] in the numerical examples.

4.1. The Solutions of the Optimization Models. The current work investigates the optimality of the direct channel strategy first. In this situation, the optimization model on the provider's decision is shown in equations (2) and (3); thus, the Lagrangian function and the corresponding Kuhn–Tucker conditions of the optimization model are as follows:

$$L(p_1) = p_1 \cdot \frac{s - (p_1 + c)}{s - \lambda} + \varepsilon p_1, \tag{8}$$

$$\begin{cases} \dfrac{\partial L}{\partial p_1} = \dfrac{s - (p_1 + c)}{s - \lambda} - \dfrac{p_1}{s - \lambda} + \varepsilon = 0, \\ \dfrac{\partial L}{\partial \varepsilon} = p_1 \geq 0, \\ \varepsilon p_1 = 0. \end{cases} \tag{9}$$

According to equation (9), it could be known that the second-order condition of $\partial^2 L/\partial p_1^2 = -2/s - \lambda < 0$; therefore, $L(p_1)$ is a concave function, the optimization model has the inner-point solution, and then, optimality is obtained that $p_1^* = s - c/2$, $D_1^* = s - c/2(s - \lambda)$, and $\pi_1^* = (s - c)^2/4(s - \lambda)$.

Let us turn to the optimality of the platform channel strategy. When digital products are distributed through the platform channel, the optimization model of the provider's decision is shown in equations (6) and (7); hence, the Lagrangian function and the Kuhn–Tucker conditions are as follows:

$$L(p_2) = p_2 \cdot \frac{s - (p_2 + c)}{s - \lambda^T} + \eta p_2,$$

$$\begin{cases} \dfrac{\partial L}{\partial p_2} = \dfrac{s - (p_2 + c)}{s - \lambda^T} - \dfrac{p_2}{s - \lambda^T} + \eta = 0, \\ \dfrac{\partial L}{\partial \eta} = p_2 \geq 0, \\ \eta p_2 = 0. \end{cases} \tag{10}$$

Therefore, the second-order condition of $\partial^2 L/\partial p_2^2 = -2/s - \lambda^T < 0$, and $L(p_2)$ is a concave function; then, it could be calculated that $p_2^* = s - c/2$, $D_2^* = s - c/2(s - \lambda^T)$, and $\pi_2^* = (s - c)^2/4(s - \lambda^T)$.

The optimality of the optimization models for the direct and platform channel strategies is listed in Table 2.

The optimality shown in Table 2 reveals that the optimal price in the direct channel (p_1^*) is the same as that in the platform channel (p_2^*), and technically, p_j^* ($j = 1,2$) is positively impacted by the products' features (s) and negatively impacted by the consumers' learning cost (c), see equations (11) and (12). Hence, it could be obtained the following proposition, and the impact of parameter s and c are illustrated in Figure 3depicted depending on the formulations ofp_j^*shown in Table 2.

$$\frac{\partial p_i^*}{\partial s} = \frac{1}{2} > 0, \tag{11}$$

$$\frac{\partial p_i^*}{\partial c} = -\frac{1}{2} < 0. \tag{12}$$

Proposition 1. *The direct and platform channels share the same optimal price which is positively and negatively impacted by the features of digital products and the learning cost of consumers, respectively.*

Let us explain the finding of Proposition 1. Actually, digital product providers need to make pricing decision before they launch products to the market; thus, even though network externality might affect the pricing of digital products, providers could not precisely evaluate this effect before products are distributed in the market because

Table 2: The optimality for each channel strategy.

	Optimal price	Optimal demand	Optimal profit
Direct channel	$p_1^* = s - c/2$	$D_1^* = s - c/2(s-\lambda)$	$\pi_1^* = (s-c)^2/4(s-\lambda)$
Platform channel	$p_2^* = s - c/2$	$D_2^* = s - c/2(s-\lambda^T)$	$\pi_2^* = (s-c)^2/4(s-\lambda^T)$

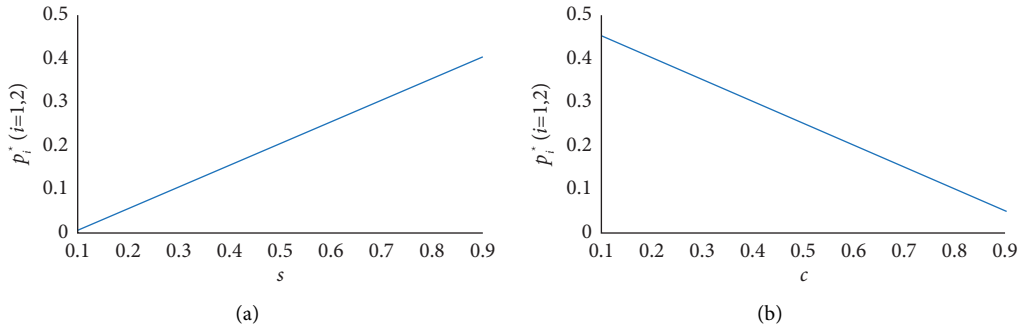

Figure 3: (a) Impact of s on prices ($c = 0.9$). (b) Impact of c on prices ($s = 0.9$).

providers do not know the future scale of the user base on which network externality depends. This finding is the theoretical complement of the existing literature, such as Geng and Chen [38], holding the viewpoint that the network externality effect positively impacts the optimality in the pricing of digital products.

Therefore, what is more realistic for providers is pricing digital products, depending mainly on their characteristics such as the products' features and consumers' learning cost. It could be known from (1) that consumers would obtain more utility from products with more features and less learning cost. If consumers are able to obtain more utility from products, they would have more willingness to pay for products; hence, digital products' prices increase (decrease) with products' features (learning cost). In addition, it might be optimal for providers to make digital products in direct and platform channels share the same price, for this would be beneficial to avoid the possible cannibalization between the two channels.

4.2. Impacts of the Parameters on the Benefits of Suppliers. Let us turn to the comparative statics analysis on parameters λ, λ^T, s, and c to investigate how the network externality, products' features, and consumers' learning cost impact the monopolist's benefits. It could be known that the impact of comparative statics analysis on those parameters is studied to explore their effect on the monopolist's optimal demand and profit. According to the closed-form solution listed in Table 2, equations (13)–(18) could be obtained, and then, the following proposition which is illustrated in Figures 4–6 could also be obtained. Figures 4–6 are depicted depending on the formulations of D_j^* and π_j^* ($j = 1, 2$) in Table 2:

$$\begin{cases} \dfrac{\partial D_1^*}{\partial \lambda} = \dfrac{s-c}{2(s-\lambda)^2} > 0, \\ \dfrac{\partial \pi_1^*}{\partial \lambda} = \left[\dfrac{s-c}{2(s-\lambda)}\right]^2 > 0, \end{cases} \tag{13}$$

$$\begin{cases} \dfrac{\partial D_2^*}{\partial \lambda^T} = \dfrac{s-c}{2\left(s-\lambda^T\right)^2} > 0, \\ \dfrac{\partial \pi_2^*}{\partial \lambda^T} = \left[\dfrac{s-c}{2\left(s-\lambda^T\right)}\right]^2 > 0, \end{cases} \tag{14}$$

$$\begin{cases} \dfrac{\partial D_1^*}{\partial s} = \dfrac{c-\lambda}{2(s-\lambda)^2} > 0, \\ \dfrac{\partial \pi_1^*}{\partial s} = \dfrac{(s-c)(c-\lambda)}{2(s-\lambda)^2} > 0, \end{cases} \tag{15}$$

$$\begin{cases} \dfrac{\partial D_2^*}{\partial s} = \dfrac{c-\lambda^T}{2\left(s-\lambda^T\right)^2} > 0, \\ \dfrac{\partial \pi_2^*}{\partial s} = \dfrac{(s-c)\left(c-\lambda^T\right)}{2\left(s-\lambda^T\right)^2} > 0, \end{cases} \tag{16}$$

$$\begin{cases} \dfrac{\partial D_1^*}{\partial c} = -\dfrac{1}{2(s-\lambda)} < 0, \\ \dfrac{\partial \pi_1^*}{\partial c} = -\dfrac{s-c}{2(s-\lambda)} < 0, \end{cases} \tag{17}$$

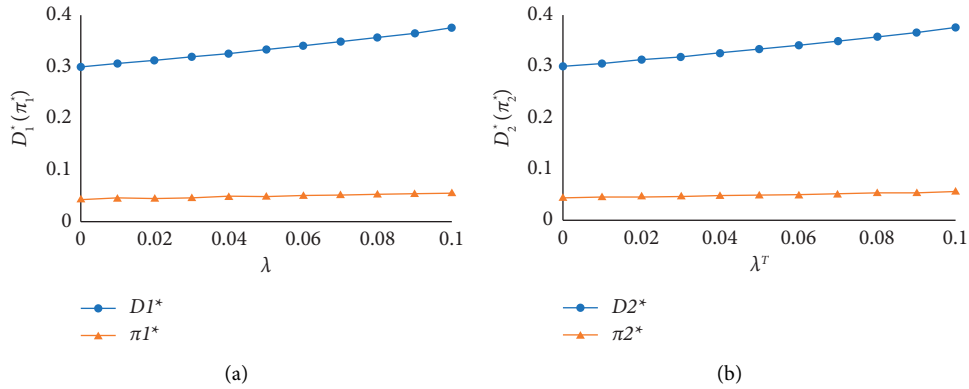

FIGURE 4: (a) Impact of λ in the direct channel ($s = 0.5$, $s^T = 1$, $c = 0.2$, and $c^T = 0.5$). (b) Impact of λ^T in the platform channel ($s = 0.5$, $s^T = 1$, $c = 0.2$, and $c^T = 0.5$).

$$\begin{cases} \dfrac{\partial D_2^*}{\partial c} = -\dfrac{1}{2\left(s - \lambda^T\right)} < 0, \\ \dfrac{\partial \pi_2^*}{\partial c} = -\dfrac{s - c}{2\left(s - \lambda^T\right)} < 0. \end{cases} \tag{18}$$

Proposition 2. *When digital products are distributed through the direct and platform channels, the firm's demand/profit increases with the network externality effect and product's features but decreases with the consumers' learning cost. Moreover, the installed base is beneficial to the firm.*

We first analyze the impact of the network effect on optimality. In the situation where digital products are distributed through the direct channel, the consumer's utility is affected by the network externality effect of products. It could be known from equation (1) that consumers would obtain more utility if the parameter λ increases, and then, more consumers would obtain nonnegative utility from products. Therefore, the demand of products D_1^* and the firm's profit π_1^* increase with λ, as shown in Figure 4(a). Similarly, when digital products are distributed through the online platform, the consumers' utility would be impacted by network externality in the platform and increase with the parameter λ^T (see equation (5)). Therefore, the products' demand D_2^* and the monopolist's profit π_2^* would in turn increase with the parameter λ^T, as depicted in Figure 4(b).

We next explore the impact of product features and consumers' learning cost. It could also be known from equation (1) that the consumers' utility increases (decrease) with product features s (learning cost c). Therefore, if products have more features, or are easier to use, there would be more consumers obtaining enough utility and choosing to purchase products, and this means that the demand in the two channels increases (decrease) with product features (learning cost), see Figure 5. The increasing demand is also beneficial to the profit of the provider; hence, digital products with more features and lower learning cost would lead to higher profit, see Figure 6. Moreover, it is found from equations (13)–(18) and Figures 4–6 that network externality, product features, and learning cost have the same effect to the products' demand and the provider's profit; that is, the products' demand would change synchronously with the provider's profit. Thus, it could be deduced that the market demand (i.e., the installed base of the products) positively impacts the profit of digital product firms.

4.3. Equilibrium of Channel Selections. The equilibrium of the monopolist's channel strategies is supposed to be explored to determine the optimal channel structure in different situations. Comparing the optimal profit in direct and platform channel strategies, π_1^* and π_2^*, then $\pi_1^* - \pi_2^* = (s - c)^2/4 \cdot \lambda - \lambda^T/(s - \lambda)(s - \lambda^T)$. It has been known from the settings in Section 3 that $s > c$, λ, λ^T, and $s - c$, $s - \lambda$, $s - \lambda^T > 0$; therefore, if $\lambda > \lambda^T$, $\pi_1^* > \pi_2^*$, the firm is supposed to choose the direct channel strategy, and if $\lambda \le \lambda^T$, $\pi_1^* \le \pi_2^*$, the firm is supposed to adopt the platform channel strategy. Thus, equation (19) could be obtained and is illustrated in Figure 7, and then, the channel equilibrium is characterized in Proposition 3.

$$\begin{cases} \pi_1^* \ge \pi_2^* \text{ and } D_1^* \ge D_2^*, \text{if } \lambda \ge \lambda^T, \\ \pi_1^* < \pi_2^* \text{ and } D_1^* < D_2^*, \text{if } \lambda < \lambda^T. \end{cases} \tag{19}$$

Proposition 3. *Digital products are supposed to be distributed through the platform channels if the intensity of the network externality in the platform channel dominates that in the direct channel; otherwise, digital products should be distributed through the direct channel.*

When the intensity of network externality in the online platform is stronger than that in the direct channel, that is, $\lambda^T > \lambda$, consumers obtain more utility from the platform service (see equation (4)), and the online platform becomes more attractive. In this situation, the monopolist releasing its products through the platform channel could enlarge its demand with the help of the installed base of the online platform; hence, π_2^* may exceed π_1^*. However, when the intensity of network externality in the direct channel is stronger than that in the platform channel (i.e., $\lambda^T \le \lambda$), the platform service becomes less attractive, and participating in the online platform would not help the firm enlarge its

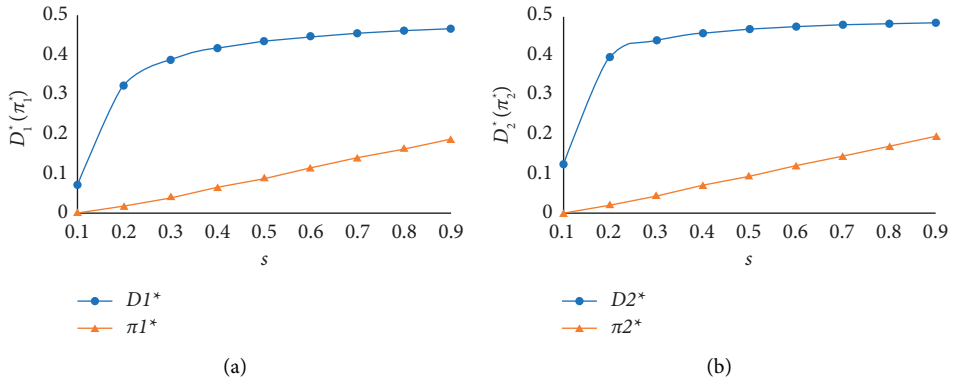

Figure 5: (a) Impact of s in the direct channel ($\lambda = 0.03$ and $c = 0.09$). (b) Impact of s in the platform channel ($\lambda^T = 0.06$ and $c = 0.09$).

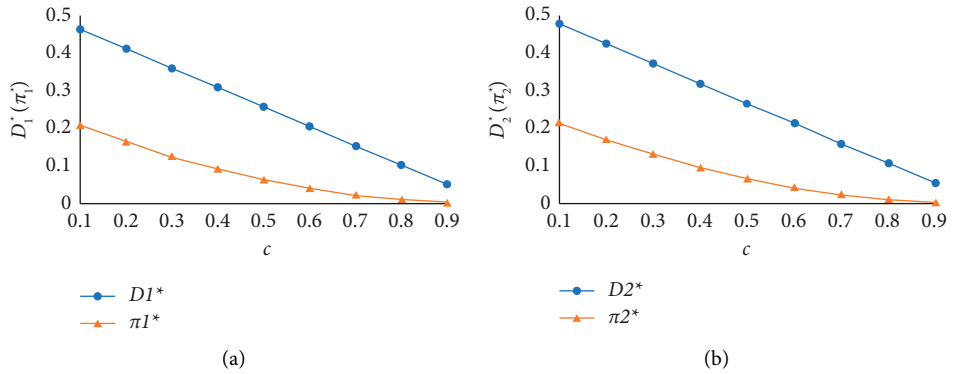

Figure 6: (a) Impact of c in the direct channel ($\lambda = 0.03$ and $s = 1$). (b) Impact of c in the platform channel ($\lambda^T = 0.06$ and $s = 1$).

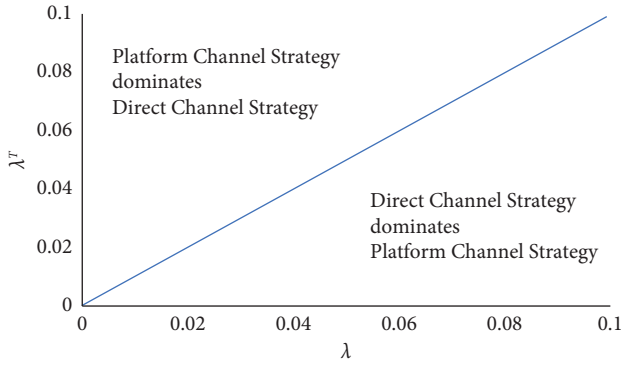

Figure 7: Channel strategy of the digital product firm.

market coverage, which may lead to $\pi_1^* > \pi_2^*$. In this case, it is optimal for the firm to distribute its products through the direct channel to squeeze more profit, and the benefit of the firm would increase with higher willingness to pay and utility derived from the stronger intensity of the network effect in the direct channel.

4.4. Managerial Insights. The findings of the current work provide the following insights that are helpful for digital product firms when they make channel decision in the context of the two-sided market.

First, the network effect in the direct and platform channels is extraordinarily significant and supposed to be taken into account seriously by digital product suppliers when they determine the distribution channel. For digital product firms, they need to choose the channel that contributes more to the network effect. If firms provide small digital products, for instance, the mobile application, they could launch their products in third-party platforms (e.g., Google Play Store), for the platforms often have a vast number of users and might provide a huge potential installed base that positively impacts the network effect. However, if firms provide large digital products, they need to choose the direct channel (e.g., Oracle, the enterprise database firm, provides its product through its official website), and the reason is that the target markets of large digital products are smaller. Hence, the network effect of these products mainly depends on transaction communications between those enterprises, rather than the number of the users, and obviously, the direct channel would provide more information and technology support that are conducive to transaction communications which would generate network effect.

Second, some other factors, such as the features of products and the learning cost of consumers, would also impact the profit of digital products firms; therefore, digital product firms need to take into account these factors when they develop products. Firms could make their digital products contain more functionalities; for instance, the

instant message software (such as Facebook, Messenger, and WeChat) is often able to turn the voice into text; in addition, firms also need to make their products easy to use. For example, digital product suppliers always devote to reinforcing user-friendly interfaces.

Third, digital products are supposed to price the same price in the direct or platform channels. When digital product firms intend to change distribution channels, for instance, some firms decide to participate into the platforms to sell their digital products and not to distribute products through former direct channels any more, firms need to make the prices in the new channels same as those in former channels: if the prices are higher than before, the demand would decrease; however, if prices become lower, consumers who have purchased products might feel unfair, and this feeling of consumers is also not beneficial to digital product firms [39].

5. Conclusion

In the context of the two-sided market, online platforms have brought about opportunities for the distribution of digital products, and digital product firms also face challenges on channel selection. To investigate the feasibility of different channel strategies and explore their range of applications, the current work develops optimization models in the situations that digital products are distributed through the direct and platform channels, compares the optimality of the two channels, and then analyzes the channel selections of digital product vendors. The results show that there is no single best channel strategy that exists in different scenarios; that is, digital product vendors are supposed to launch their products through direct channels if the network effect in direct channels dominates that in platform channels. Otherwise, platforms are the optimal channels of those vendors. In addition, the profits and demand of digital product firms would be positively affected by the network effect, and the two channels would share the same prices impacted by some other factors such as product features and the consumers' learning cost.

There are several possible directions for the future research following this paper. First, the future work could investigate the channel strategy when digital product firms adopt some other pricing schema. Although the current work has considered a relevant pricing decision, there are still some interesting pricing strategies, such as freemium and pay-per-use, which might impact the channel strategy of digital product firms. Therefore, future work may take into account the effect of different pricing schemes on the channel preferences of digital product firms. Second, the future work could explore the impact of some other market structures. The current work focuses on the monopoly setting and the optimal channel strategies of digital product firms in the monopoly market. However, the other market structures may lead to another strategy in channel selection. For example, in the duopoly market, digital product firms would choose the distribution channel that depends not only on the characteristics of products but also on channel strategies adopted by their counterparty. Third, future research could also consider the roles of the cooperation within those distribution channels. The main concern in the current work is the competition between different channels; however, these channels could also cooperate with each other to grab profits. For instance, in reality, Microsoft adopts the hybrid channel strategy to sell Mac Office; that is, Microsoft distributes Mac Office through both the direct channel (i.e., the official website of Microsoft) and the platform channel (i.e., the App Store of Apple Inc.). Thus, how to cooperate these diverse channels via pricing or the other strategies would definitely be a challenge.

Data Availability

All the data used in the numerical analysis are listed in detail and available in the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

This research was funded by the Hebei Provincial Department of Science and Technology (G2022207003), the Hebei Provincial Department of Education (SY2022002), the Hebei University of Economics and Business (JXT2020YB07, 2023JYZ06 and 202311832004), and the Key Research Institute of Humanities and Social Science at Universities of Hebei Province.

References

[1] H. Varian, "Versioning information goods," 1997, https://www-inst.cs.berkeley.edu/%7Eeecsba1/sp97/reports/eecsba1b/Final/version.pdf.

[2] H. K. Cheng and Y. Liu, "Optimal software free trial strategy: Optimal Software Free Trial Strategy: The Impact of Network Externalities and Consumer Uncertaintyhe impact of network externalities and consumer uncertainty," *Information Systems Research*, vol. 23, no. 2, pp. 488–504, 2012.

[3] H. K. Cheng, S. Li, and Y. Liu, "Optimal software free trial strategy: limited version, time-locked, or hybrid?" *Production and Operations Management*, vol. 24, no. 3, pp. 504–517, 2015.

[4] A. Rangaswamy and G. H. Van Bruggen, "Opportunities and challenges in multichannel marketing: Opportunities and challenges in multichannel marketing: An introduction to the special issuen introduction to the special issue," *Journal of Interactive Marketing*, vol. 19, no. 2, pp. 5–11, 2005.

[5] G. J. Lewis, G. Graham, and G. Hardaker, "Evaluating the impact of the internet on barriers to entry in the music industry," *Supply Chain Management: An International JournalInternational Journal*, vol. 10, no. 5, pp. 349–356, 2005.

[6] S. Li, H. K. Cheng, Y. Duan, and Y. C. Yang, "A study of enterprise software licensing models," *Journal of Management Information Systems*, vol. 34, no. 1, pp. 177–205, 2017.

[7] S. Li, H. K. Cheng, and Y. Jin, "Optimal distribution strategy for Enterprise software: retail, SaaS, or dual channel?" *Production and Operations Management*, vol. 27, no. 11, pp. 1928–1939, 2018.

[8] Z. Zhang, G. Nan, and Y. Tan, "Cloud services vs. On-premises software: competition under security risk and

product customization," *Information Systems Research*, vol. 31, no. 3, pp. 848–864, 2020.

[9] R. Mencarelli, A. Riviere, and C. Lombart, "Do myriad e-channels always create value for customers? A dynamic analysis of the perceived value of a digital information product during the usage phase," *Journal of Retailing and Consumer Services*, vol. 63, Article ID 102674, 2021.

[10] N. Ertekin, M. Gümüş, and M. E. Nikoofal, "Online-exclusive or hybrid? Channel merchandising strategies for ship-to-store implementation," *Management Science*, vol. 68, no. 8, pp. 5828–5846, 2022.

[11] S. S. Sana, "Sale through dual channel retailing system—a mathematical approach," *Sustainability Analytics and Modeling*, vol. 2, Article ID 100008, 2022.

[12] C. Tian, T. Xiao, and J. Shang, "Channel differentiation strategy in a dual-channel supply chain considering free riding behavior," *European Journal of Operational Research*, vol. 301, no. 2, pp. 473–485, 2022.

[13] Z. Zhang, H. Xu, K. Chen, Y. Zhao, and Z. Liu, "Channel mode selection for an E-platform supply chain in the presence of a secondary marketplace," *European Journal of Operational Research*, vol. 305, no. 3, pp. 1215–1235, 2023.

[14] L. Chen, G. Nan, M. Li, B. Feng, and Q. Liu, "Manufacturer's online selling strategies under spillovers from online to offline sales," *Journal of the Operational Research Society*, vol. 74, no. 1, pp. 157–180, 2023.

[15] J. Xu, C. Forman, and Y. J. Hu, "Battle of the internet channels: how do mobile and fixed-line quality drive internet use?" *Information Systems Research*, vol. 30, no. 1, pp. 65–80, 2019.

[16] Y. Park, Y. Bang, and J.-H. Ahn, "How does the mobile channel reshape the sales distribution in E-commerce?" *Information Systems Research*, vol. 31, no. 4, pp. 1164–1182, 2020.

[17] M. Khouja, H. K. Rajagopalan, and E. Sharer, "Coordination and incentives in a supplier–retailer rental information goods supply chain," *International Journal of Production Economics*, vol. 123, no. 2, pp. 279–289, 2010.

[18] A. A. Tsay and N. Agrawal, "Channel conflict and coordination in the e-commerce age," *Production and Operations Management*, vol. 13, no. 1, pp. 93–110, 2009.

[19] Z. Liu, M. Li, and J. Kou, "Selling information products: sale channel selection and versioning strategy with network externality," *International Journal of Production Economics*, vol. 166, pp. 1–10, 2015.

[20] T. Chernonog, T. Avinadav, and T. Ben-Zvi, "How to set price and quality in a supply chain of virtual products under bi-criteria and risk consideration," *International Journal of Production Economics*, vol. 209, pp. 156–163, 2019.

[21] S. S. Sana, "Price competition between green and non green products under corporate social responsible firm," *Journal of Retailing and Consumer Services*, vol. 55, Article ID 102118, 2020.

[22] S. S. Sana, "A structural mathematical model on two echelon supply chain system," *Annals of Operations Research*, vol. 315, no. 2, pp. 1997–2025, 2022.

[23] A. Barman, R. Das, P. K. De, and S. S. Sana, "Optimal pricing and greening strategy in a competitive green supply chain: Optimal Pricing and Greening Strategy in a Competitive Green Supply Chain: Impact of Government Subsidy and Tax Policympact of government subsidy and tax policy," *Sustainability*, vol. 13, no. 16, p. 9178, 2021.

[24] Y. Zhang and B. Hezarkhani, "Competition in dual-channel supply chains: Competition in dual-channel supply chains: The manufacturers' channel selectionhe manufacturers' channel selection," *European Journal of Operational Research*, vol. 291, no. 1, pp. 244–262, 2021.

[25] P. Chen, R. Zhao, Y. Yan, and C. Zhou, "Promoting end-of-season product through online channel in an uncertain market," *European Journal of Operational Research*, vol. 295, no. 3, pp. 935–948, 2021.

[26] W. Chen, F. Jing, and L. Zhong, "Coordination strategy for a dual-channel electricity supply chain with sustainability," *Journal of Industrial and Management Optimization*, vol. 18, no. 6, pp. 3879–3895, 2022.

[27] L. Sun, X. Jiao, X. Guo, and Y. Yu, "Pricing policies in dual distribution channels: Pricing policies in dual distribution channels: The reference effect of official priceshe reference effect of official prices," *European Journal of Operational Research*, vol. 296, no. 1, pp. 146–157, 2022.

[28] C. Zhu and Z. Yao, "Comparison between the agency and wholesale model under the e-book duopoly market," *Electronic Commerce Research*, vol. 18, no. 2, pp. 313–337, 2018.

[29] B. Koo, B. Mantin, and P. O Connor, "Online distribution of airline tickets: should airlines adopt a single or a multi-channel approach?" *Tourism Management*, vol. 32, no. 1, pp. 69–74, 2011.

[30] L. Huang, Y. Dou, Y. Liu et al., "Toward a research framework to conceptualize data as a factor of production: the data marketplace perspective," *Fundamental Research*, vol. 1, no. 5, pp. 586–594, 2021.

[31] Y. Shen, S. P. Willems, and Y. Dai, "Channel selection and contracting in the presence of a retail platform," *Production and Operations Management*, vol. 28, no. 5, pp. 1173–1185, 2019.

[32] W. Wei, W. Liu, O. Tang, C. Dong, and Y. Liang, "CSR investment for a two-sided platform: CSR investment for a two-sided platform: Network externality and risk aversionetwork externality and risk aversion," *European Journal of Operational Research*, vol. 307, no. 2, pp. 694–712, 2023.

[33] B. Zhao, H. Tan, C. Zhou, and H. Feng, "Optimal delivery time and subsidy for it-enabled food delivery platforms considering negative externality and social welfare," *Industrial Management and Data Systems*, vol. 123, 2023.

[34] Y. Xu, X. Wang, and Q. Zhou, "Pricing and quality strategies in crowdfunding with network externality," *Journal of Optimization Theory and Applications*, vol. 196, no. 1, pp. 98–125, 2023.

[35] M. L. Katz and C. Shapiro, "Network externalities, competition, and compatibility," *The American Economic Review*, vol. 75, no. 3, pp. 424–440, 1985.

[36] Y. Dou and D. J. Wu, "Platform competition under network effects: piggybacking and optimal subsidization," 2019, https://ssrn.com/abstract=3109183.

[37] Y. J. Chen, T. Dai, C. G. Korpeoglu et al., "OM forum—innovative online platforms: research opportunities," *Manufacturing and Service Operations Management*, vol. 22, no. 3, pp. 430–445, 2020.

[38] W. Geng and Z. Chen, "Optimal pricing of virtual goods with conspicuous features in a freemium model," *International Journal of Electronic Commerce*, vol. 23, no. 3, pp. 427–449, 2019.

[39] Y. Dou, M. F. Niculescu, and D. J. Wu, "Engineering optimal network effects via social media features and seeding in markets for digital goods and services," *Information Systems Research*, vol. 24, no. 1, pp. 164–185, 2013.