Pricing Knowledge Services Based on Meta-knowledge: From the Perspective of Knowledge Payment Platform

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Abstract

The emergence of knowledge payment platforms (KPPs) has accelerated the sharing and flow of knowledge. However, in the traditional business model, knowledge consumers cannot predict the quality of the answers in advance, nor can they get any product information other than the price. Value-added services of KPPs can increase consumers' meta-knowledge, allowing them to obtain prior knowledge of other consumers and providers. This helps them find better knowledge services when paying for consultations. This paper explores the optimal pricing strategy of the KPPs considering value-added services in a monopoly and a duopoly market from the perspective of meta-knowledge, filling the research gap of KPPs' value-added service pricing.

Keywords: Meta-knowledge, Knowledge sharing, Knowledge Payment Platform, Pricing, On-demand Service.

1. Introduction

In the era of the knowledge sharing economy, knowledge and information are regarded as the two of the most valuable assets. Knowledge is seen as a commodity that can be bought and sold. Therefore, knowledge payment platform (KPP) came into being, effectively connecting knowledge consumers and providers, providing a convenient channel for knowledge sharing and acquisition (Li et al., 2022).

Typical KPPs, such as Zhihu (China), Quora (USA), Skillshare (USA), Zaihang (China), etc., always include two types of users, that is, knowledge providers and knowledge consumers. Among them, knowledge providers usually are domain experts with professional knowledge and skills, who are willing to deal with other people's questions. Knowledge consumers purchase online fragmented knowledge services as commodities for clear learning purposes (Qu et al., 2022). The business model of the KPP is becoming mature, especially in China, the knowledge payment industry is experiencing strong momentum, with the market scale of the knowledge payment reaching 112.65 billion RMB in 2022 (Li et al., 2023).

Due to the knowledge management industry's rapid growth and its significance in knowledge management. Many scholars have conducted research on KPPs, which can be categorized into three streams: business model, behavioral, and pricing research. Business model research focuses on turning knowledge into products or services through different models to realize business value (Qi et al., 2019; Wu and Lu, 2018). Behavioral research examines factors and motivations for knowledge sharing, including self-determination theory, customer satisfaction, and interpersonal trust (Chen et al., 2019; Zhang et al., 2019). The pricing research has analyzed optimal bundled pricing strategies as well as subsidy strategies (Li et al., 2023).

Zhihu is the largest Q&A knowledge payment platform in China (Li et al., 2023), and its sub-product "Zhi" is a typical paid Q&A model. This model has obvious customization characteristics, but the shortcoming is that it can only solve superficial problems and cannot meet deep knowledge needs (Qi et al., 2019). Interestingly, nowadays, Zhihu provides a value-added service—the "Pangting" module—based on core services. This module allows knowledge consumers need to pay only 1 yuan for eavesdropping on the answer to the question raised by others. Before this module was available, questioners could not predict the quality of the answer in advance and could not obtain any product information other than the price (Zhao et al., 2018). The eavesdropping mechanism increases knowledge consumers' awareness of

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knowledge content and structure owned by knowledge providers. In other words, consumers can improve their meta-knowledge through eavesdropping, which can help consumers to seek better knowledge services when they pay for consultations.

When KPPs provide the "Pangting" module, for knowledge consumers, they are able to access a priori knowledge from both fellow consumers and providers, enhancing their meta-knowledge and seeking better knowledge services when they pay for consultations. From the perspective of knowledge providers and the platform, the inclusion of this value-added module enables additional revenue generation through the provision of answers. The value-added service not only facilitates knowledge sharing but also contributes to an increase in financial returns. These are essential for the sustainability of knowledge payment platforms. While there is a large body of literature that has examined KPPs, the research on optimal pricing strategy is still unclear, especially considering value-added services.

To fill this research gap, this paper takes a perspective from meta-knowledge and explores the optimal pricing strategy considering the value-added services of KPP in a monopoly and a duopoly market. Specifically, we seek answers to the following issues: (1) What is the optimal pricing strategy of KPP? (2) How value-added services influence the pricing strategy of the platform under the same market conditions? (3) What is the optimal pricing strategy of the platform under different competition intensities?

2. Literature Review

2.1. Knowledge Payment and On-demand Service

Knowledge payment is a new form of sharing economy in which users purchase knowledge products from knowledge providers in the professional field according to their own knowledge needs (Zhang et al., 2020). This is a specific type of on-demand service, which connects consumers seeking services with independent agents who provide them, such as ride-hailing and short-rental platforms (Taylor, 2018). In KPPs, consumers pay independent agents for specific knowledge or answers, while the agents receive fixed or variable wages from the platform.

Pricing strategies for on-demand services have been extensively studied by scholars, with a focus on analyzing optimal platform performance under varying contracts and market conditions (Bai et al., 2019; Wei et al., 2020). As for the KPP, only a few scholars have conducted research on its pricing strategy. Zhang et al. (2022) constructed a tripartite game model, in which they analyzed the impact of the knowledge products' quality level, price and transaction commission ratio on the decision of each game player.

2.2. Meta-knowledge and "Pangting" Function

Meta-knowledge, which includes the location and label information of other members, plays a crucial role in knowledge management (Ren and Argote, 2011). Although early research lacks a unified definition of meta-knowledge, it is generally understood as "knowledge about knowledge", encompassing the content, structure, and general characteristics of known knowledge. Leonardi (2014, 2015, 2018) defines meta-knowledge as the accuracy of "who knows who" and "who knows what". Both refer to the ability to comprehend the extended dimensions of others' social networks and the ability to recognize who holds particular knowledge, respectively. Meta-knowledge enhances the management and application of organizational knowledge, ensuring greater benefits from knowledge management systems (Borgatti and Cross, 2003).

To facilitate knowledge sharing and transfer on KPPs, scholars have conducted behavioral studies on platforms and users with different capabilities (Li et al., 2023; Zhang et al., 2019). Zhihu has introduced the "Pangting" function in its paid consultation service. Paying for Pangting allows knowledge consumers to view previous Q&A interactions between prior consumers and knowledge providers. This improves the meta-knowledge of the consumer and enables them to assess the depth and breadth of knowledge providers, and thereby select the most appropriate one.

Our work builds on a broad range of literature, ranging from knowledge payment to on-demand service and meta-knowledge, considers Pangting as a value-added service, and analyzes optimal pricing strategies for the platform based on meta-knowledge theory and network effects (Jing, 2007; Prasad et al., 2010; Pang and Etzion, 2012).

3. Modelling Framework

KPP(Zhihu) differs from on-demand platforms that offer various services such as carpooling and food delivery. These platforms compete for both consumers and workers, which leads to the platform setting prices for products and wages for workers (Cohen and Zhang, 2022). In contrast, KPP allows knowledge providers to set prices for their services, while the price for the Pangting function is set by the platform. To simplify the model, we assume that the pricing of knowledge services and Pangting function is jointly determined by the knowledge providers and the platform, thereby ignoring the interaction between the two.

We analyze optimal prices and customer demands for a monopoly and duopoly situation. In the duopoly model, two platforms in the competition are considered, the platforms offer differentiated knowledge consultation services, consisting of a core service and a value-added function module driven by consumers' meta-knowledge. Consumers have varying demands and tastes, making the service focus on quality and suitability. The intrinsic value of a service depends on quality, while the fit attribute represents the misfit between a consumer's ideal service and the actual service obtained. When the service perfectly matches the consumer's demand, the misfit cost is 0.

Among the existing studies, Li et al. (2023) studied the pricing and subsidy strategies of two KPPs with different capabilities, and Zhang et al. (2016) studied the duopoly model of information products with value-added services, both using the Hotelling model. Based on these, we use the Hotelling model to analyze duopoly competition with pricing strategies incorporating KPP value-added services. Assume a continuous group of D consumers in a paid consultation market. Each consumer has a preference for the core knowledge advisory service and value-added service and purchases one from either of the two platforms. Consumers' preferences are evenly distributed on the Hotelling line with a range of [0,1], with endpoint 0 representing Platform 1 and endpoint 1 representing Platform 2. Consumers incur a misfit cost that increases with distance from their ideal platform.

In both the monopoly and duopoly models, we use t to represent the unit misfit cost of a consumer' receiving a particular service. Consumer meta-knowledge drives the usage of value-added services, which reduces the misfit cost associated with core services. Enjoying value-added services prior to purchasing core services can aid in selecting knowledge providers that are of higher quality and better suited to individual requirements. Thus, we use α $(0<\alpha<1)$ to denote the discount of a consumer's misfit cost, while a consumer's misfit cost for using both the core service and value-added service is denoted by αt. More meta-knowledge acquired by a user, α is smaller. In addition, the core services of the platform involved in this paper provide consumers with the same intrinsic value r, and if consumers also use the value-added function, the platform will provide consumers with the intrinsic value $r+\delta$ or $r+\delta_i$, where $i=1,2$. Some studies have pointed out that the intrinsic value obtained by consumers may be positively influenced by factors such as reputation and integrity (Zhao et al., 2018). In order to build a generalized model, this paper does not consider the factors affecting parameter r. Improving consumer meta-knowledge through value-added services, assisting consumers in selecting knowledge providers that can offer higher quality core services. Thus, our initial simplifying assumption is that $\delta, \delta_i \geq 0$.

Since the knowledge services show positive network effects, we regard network effects as a function with regard to user size and service quality (Jing, 2007). When a consumer purchase the core consulting service, he (or she) will not only obtain the intrinsic value of the core service, but also gain additional utility of $\tau(r+M_i)$, $i=1,2$, where τ is used for the intensity of network effects, and M_i for the consumer size under rational expectation equilibrium of the duopoly (Katz and Shapiro, 1985), and this size is denoted by D in the monopoly model. Table 1 summarizes the relevant variables for this paper.

Table 1. Summary of Key Notations.

Notation	Description
D	Market size
α	The discount rate of a knowledge demander's misfit cost after using the value-added function.
ω	A heterogeneous parameter describing the misfit between consumers.
t_{S_0}, t	Unit misfit cost of heterogeneous consumers in monopoly (under Case $S_0=\{N,Y\}$) and duopoly.
r	Intrinsic value of consulting service.
δ, δ_i	Incremental value of using value-added function before purchasing core service in monopoly and duopoly (Platform i, $i=1,2$).
τ	Intensity of network effects.
c	The average cost per consumer to use value-added (*Pangting*) function.
C_{S_0}	The operational cost of a monopolistic Platform under Case $S_0=\{N,Y\}$.
P_S^i	Price of Platform i's consulting service under Case S, where S= $\{NN,NY,YN,YY\}$.
π_S^i	Profit of Platform i under Case S.
M_S^i	Size of Platform i's consumer base under Case S.

3.1. Monopoly

We solve the monopoly model in reverse, first determining the purchase decision of the consumer and then determining the profit-maximizing price of the Platform's service. In a monopoly, the Platform's consumer size is equal to D.

3.1.1. Case N: Monopoly with Offering Only Core Knowledge Service. We first consider the consumer utility function for the platform only to provide consumers with core knowledge service.

$$U = r - P - \omega t_N + \tau(r + D). \quad (1)$$

The marginal consumer indifference to using and not using the core knowledge service is derived by setting utility U in equation (1) to zero. Then, the indifference point is $\omega = \frac{r-P+\tau(r+D)}{t_N}$. Considering the individual rationality principle, consumers will choose the knowledge service only when $U > 0$, and the actual size of users on KPP is $d = \omega D$. When each consumer pays P, excluding operational costs the platform gets Pd , the revenue the platform can obtain is $\pi = P\omega D - C_N$. Solving the first-order condition of the profit function, we summarize the optimal results in Proposition 1.

Proposition 1 (Optimal Outcomes for Case N)

Under this case, the optimal size of KPP's users, the optimal price, and the profit of the platform are $d^* = \frac{r+\tau(r+D)}{2t_N} D$,$P^* = \frac{r+\tau(r+D)}{2}$,$\pi^* = \frac{[r+\tau(r+D)]^2}{4t_N} - C_N$.

3.1.2. Case Y: Monopoly with Offering a Value-added Function. The value-added function allows consumers to judge knowledge providers, and through access to information, consumers' meta-knowledge can also be improved. In this case, compared to the case N where only core services, the consumer's utility function takes into account the intrinsic value of value-added services, misfit costs, and network externalities. The consumer utility function for the platform offering value-added function is $U' = r + \delta - P - c - \alpha\omega t_Y + \tau(r + \delta + D)$. To simplify our exposition, let $r' = r + \delta$ denote the intrinsic value that the consumer can get from the core and value-added. We assume $P' = P + c$, P' is the total cost paid by the customer to obtain the service. Thus, $U' = r' - P' - c - \alpha\omega t_Y + \tau(r' + D)$. Similar to Case N, we can get the difference point $\omega = \frac{r\prime-P\prime+\tau(r\prime+D)}{t_N}$. The profit function of the platform is $\pi = P'\omega D - C_Y$. We formulate the best conclusions in Proposition 2 after resolving the profit function's first-order.

Proposition 2 (Optimal Outcomes for Case Y)

According to this scenario, the optimal size of KPP's users, the optimal price, and the profit of the platform are $d^* = \frac{r\prime+\tau(r\prime+D)}{2\alpha t_Y} D$, $P'^* = \frac{r\prime+\tau(r\prime+D)}{2}$, $\pi^* = \frac{[r\prime+\tau(r\prime+D)]^2}{4t_Y} - C_Y$.

3.2. Duopoly

The following is the consumer utility function for different choices.

$$U_1 = r - tx + \tau(r + M_1) - P_1, \quad (7)$$

$$U_1' = r + \delta_1 - \alpha tx + \tau(r + \delta_1 + M_1) - P_1 - c, \quad (8)$$

$$U_2 = r - t(1 - x) + \tau(r + M_2) - P_2, \quad (9)$$

$$U_2' = r + \delta_2 - \alpha t(1 - x) + \tau(r + \delta_2 + M_2) - P_2 - c. \quad (10)$$

Equation (7) represents the consumer utility of purchasing when they only buy the core knowledge service of Platform 1. Equation (8) shows the utility of purchasing both Platform 1's core service and value-added function. Equation (9) indicates the consumer utility of only purchasing Platform 2's core knowledge service, and Equation (10) represents the utility of purchasing both Platform 2's core service and value-added function. Similar to Ghoshal et al. (2021), we ignored platform operating costs and focused on platform revenue.

3.2.1. Case NN: Duopoly with Both Offering Only Core Knowledge Service. In this model, consumers decide to purchase services from either platform. Different rational consumers have different purchasing choices. Thus, consumers are divided into two parts. In Figure 1, the consumer distribution for both platforms is plotted.

Of these two choices, consumers will prefer the one that brings them the maximum utility. Since the consumer utility functions are all linear functions of x, the market is carved into two sections. As shown in Figure 1, the section with the same color means consumers making the same purchasing decision. For instance, a consumer located in the region $[0, x_0]$, prefers the knowledge service provided by Platform 1 because the utility obtained from receiving the service of Platform 1 is greater than that from Platform 2. According to symmetry, a consumer located in the region $[x_0, 1]$ prefers the service from Platform 2. Consumers located at x_0 is indifferent between the knowledge service provided by Platform 1 and that by Platform 2, because they get the same utility from buying services from either platform.

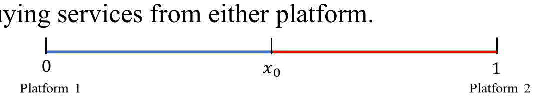

Figure 1. Consumer choice of Case NN.

By solving utility function $U_1 = U_2$ with $M_{NN}^1 = x_0 D$ and $M_{NN}^2 = (1 - x_0)D$, we obtain the consumers' indifference point indicating that the marginal consumer who is indifferent between receiving service from Platform 1 and Platform 2 is located at $x_0 = \frac{\tau D + P_{NN}^1 - P_{NN}^2 - t}{2(\tau D - t)}$.

In equilibrium, P_{NN}^1 and P_{NN}^2 represent the prices set by Platform 1 and Platform 2 in order to maximize their respective profit under Case NN. Under this price setting, the profit functions of the two platforms are given respectively as follows: $\pi_{NN}^{1} = P_{NN}^{1} x_0 D$, $\pi_{NN}^{2} = P_{NN}^{2}(1 - x_0)D$, $s.t. 0 < x_0 < 1$.

Substituting x_0 into the above profit functions. In order to ensure that the marginal utility of profit to price is diminishing, that is, the second-order differential is required to be less than 0, we derive the condition that $\tau D < t$. This condition indicates that the maximum value of the network effect of the service is t. In other words, it is dominated by the negative effects of consumers receiving services that do not fully match their tastes. Therefore, under this condition, the two platforms divide up the market, and neither of them can monopolize the market through fair competition. However, if the network effects are such large that they go beyond the misfit cost t, which means that consumers value the network effects more than personal preferences, all consumers will purchase service only from Platform 1 or Platform 2 in equilibrium. By setting the first derivative of the two platforms' profit functions with respect to x be 0 and solving them simultaneously, we obtain the optimal prices $P_{NN}^{1*} = P_{NN}^{1*} = t - \tau D$. Accordingly, the market demands and platforms' profits under the optimal prices are $M_{NN}^{1*} = M_{NN}^{2*} = \frac{D}{2}$, $\pi_{NN}^{1*} = \pi_{NN}^{2*} = \frac{D(t-\tau D)}{2}$.

Through the analysis of the above equilibrium solutions, we observe that when the two platforms sell only core services, the equilibrium price will increase in consumers' misfit cost. Intuitively, if a consumer has a higher misfit cost for receiving a particular consultation service, which means that he (or she) relies more on the services offered by the platform, the platform may take advantage of this situation to raise its price. In addition, there is a negative correlation between equilibrium price and network effects intensity of the service, indicating that the existence of the network effects has intensified price competition.

Here we analyze a situation where the network effects are so significant that they surpass the misfit cost t, that is, $\tau D \geq t$. Under this condition, the competition pattern in this market will be different from that when $\tau D < t$. From the view of economics, if the value of the network effects exceeds the misfit cost t, all consumers will purchase service only from Platform 1 or Platform 2 in equilibrium. Assuming that Platform 1 plans to gain a monopoly through price competition, its price must be low enough to appeal to all Platform 2's consumers. At such a low price, the marginal consumers located at endpoint 1 gain non-negative consumer utility, that is, $r - t + \tau(r + D) - P_{NN}^{1} \geq 0$. Therefore, the maximum price set by Platform 1 is $P_{NN}^{1} = r - t + \tau(r + D)$. If the price set by Platform 2 is higher than $P_{NN}^{1} = r - t + \tau(r + D)$, the customer will turn to its competitor's platform to purchase the service. This makes Platform 1's knowledge service more competitive, and leads more consumers to choose Platform 1. The following Proposition shows the market equilibrium outcomes.

Proposition 3 (Market Equilibrium Outcomes for Case NN)

a. *If the network effects are below the misfit cost for receiving the service ($\tau D < t$), both Platform 1 and Platform 2 compete and coexist. The prices in equilibrium are $P_{NN}^{1*} = P_{NN}^{2*} = t - \tau D$.*

b. *If the network effects surpass the cost of misfit, that is, $\tau D > t$, only one platform occupies the whole market in equilibrium.*

   i. *In one equilibrium, Platform 1 occupies the entire market and the equilibrium prices are $P_{NN}^{1*} = r - t + \tau(r + D)$, $P_{NN}^{2*} = 0$.*

   ii. *In the other equilibrium, Platform 2 occupies the entire market and the equilibrium prices are $P_{NN}^{2*} = r - t + \tau(r + D)$, $P_{NN}^{1*} = 0$.*

3.2.2. Case NY/YN: Duopoly with Only One Platform Offering a Value-added Function. Here we analyze the situation where a platform provides extra value-added function to compete with competitors' single knowledge service. Due to the symmetry, we assume that Platform 1 provides core knowledge service and value-added function, and charges for value-added function separately. The solution when only Platform 2 offers value-added function can be derived in a similar manner.

Figure 2. Consumer choice of Case NY/YN.

Figure 2 shows that consumers can be divided into three groups based on their valuation of services. Consumers on the left tend to purchase only the core service of Platform 1, while those on the right tend to purchase only the core service of Platform 2. Consumers in the middle region prefer to use Platform 1's core service and its value-added service, which generates profits for Platform 1 and promotes its network effects by expanding its consumer base. This is illustrated using Case YN as an example of modeling instructions. Setting the equation $U_1 = U_1'$ and $U_2 = U_1'$, then solving them respectively, where $M_{YN}^{1} = x_2 D$ and $M_{YN}^{2} = (1 - x_2)D$, we obtain the indifferent point x_1 and x_2, that is, $x_1 = \frac{-\delta_1(\tau+1)+c}{t(1-\alpha)}$, $x_2 = \frac{\tau D-\delta_1(\tau+1)+P_{YN}^{1}-P_{YN}^{2}+c-t}{2\tau D-(1+\alpha)t}$.

In equilibrium, P_{YN}^{1} represent the price set by Platform 1 to maximize its profit under Case YN, while P_{YN}^{2} representing the price set by Platform 2. The profit functions of these two platforms can be written as $\pi_{YN}^{1} = (P_{YN}^{1} x_2 + c\Delta x)D$ ($\Delta x = x_2 - x_1$), $\pi_{YN}^{2} = P_{YN}^{2}(1 - x_2)D$, $s.t. 0 < x_1 < x_2 < 1$.

According to the law of diminishing marginal utility, it is required that $2\tau D < (1 + \alpha)t$. If this condition is violated, all consumers will purchase service only from Platform 1 or Platform 2 in equilibrium. Similarly, setting the first derivative of these two platforms' profit functions to zero, we derive the platforms' optimal prices under Case YN: $P_{YN}^{1*} = \frac{\delta_1(\tau+1)+(\alpha+2)t-3\tau D-3c}{3}$, and $P_{YN}^{2*} = \frac{-\delta_1(\tau+1)+(2\alpha+1)t-3\tau D}{3}$.

Accordingly, we derive the market demands of these two platforms under the optimal prices are $M_{YN}^{1*} = x_2 D = \frac{3\tau D-\delta_1(1+\tau)-(2+\alpha)t}{3[2D\tau-(1+\alpha)t]} D$, $M_{YN}^{2*} = (1-x_2)D = \frac{(3D+\delta_1)\tau-2\alpha t-t+\delta_1}{3[2D\tau-(1+\alpha)t]} D$. Therefore, the two platforms' profits are $\pi_{YN}^{1*} = \frac{[\delta_1(\tau+1)+(\alpha+2)t-3\tau D]^2}{9[(1+\alpha)t-2D\tau]} D + cD[\frac{\delta_1(1+\tau)-c}{t(1-\alpha)}]$, $\pi_{YN}^{2*} = \frac{[(1+2\alpha)t-3\tau D-\delta_1(\tau+1)]^2}{3[(1+\alpha)t-2\tau D]} D$.

Under equilibrium prices, to ensure that the core service of both platforms has positive demands, the condition that $0 < x_1 < 1$ and $0 < x_2 < 1$ should be satisfied. In addition, to ensure the effectiveness of the strategy of offering the value-added function, the demand for Platform 1's value-added function is required to be positive, that is, $x_1 < x_2$. Taking all these conditions into consideration, the limiting conditions on the marginal point is $0 < x_1 < x_2 < 1$. Hence, by solving the inequality, we derive that:

$$\frac{(\alpha^2+\alpha+2)t^2+3(1-\alpha)\tau Dt+3c(1+\alpha)t-6c\tau D}{2(1+\tau)(\alpha t+2t-3\tau D)} < \delta_1 < \frac{2\alpha t+t-3\tau D}{1+\tau}. \tag{11}$$

Based on the equilibrium results, it is possible for us to analyze the relationships among different parameters with these two platforms' profits, demands and prices. The network effects are found to have a remarkable negative impact on Platform 2's optimal price and consumer demand. The reason for this situation is that the release of Platform 1's value-added function makes the direct competition between Platform 2's core service and Platform 1's core service more intense. With the existence of strong network effects, consumers who are supposed to belong to Platform 2 may gain more utility through purchasing the value-added function of Platform 1. This allows them to move from simply purchasing Platform 2's core services to utilizing Platform 1's core services with value-added functionality, thus obtaining a greater return on their investment. As a result, the release of the value-added function by Platform 1 has negatively impacted Platform 2's market share. In this case, Platform 2 has to cut the price so that it can compete with Platform 1 for consumers that would shift to the service of Platform 1.

We now examine what would happen if the condition $2\tau D < (1+\alpha)t$ is violated. With the existence of large positive network effects, consumers that would have purchased Platform 2's single core service switch to purchasing Platform 1's portfolio of services. As a result, Platform 2 will be forced to withdraw from the market by the launching of Platform 1's value-add function. At this point, the equilibrium prices are $P_{YN}^{1*} = \frac{\delta_1(\tau+1)+(\alpha+2)t-3\tau D-3c}{3}$ and $P_{YN}^{2*} = 0$.

Here we analyze the situation where the range $[x_1, x_2]$ is null. If condition (11) is not met, all of Platform 1's consumers tend to purchase its core service rather than the service portfolio and thus no consumer takes the value-added function provided by Platform 1. Intuitively, if the intrinsic value of the core service is much higher than the incremental positive utility brought by the value-added function, all platform 1's users will only purchase the core service. In such circumstances, Platform 1's core service competes directly with Platform 2's core service. It turns out that both the platforms occupy the same amount of consumers' demands, that is, $M_{YN}^{1*} = M_{YN}^{2*} = D/2$. The optimal pricing for core services is the same for both platforms, that is, $P_{YN}^{1*} = P_{YN}^{2*} = t - \tau D$.

Therefore, the market competition in this case is the same as the market in Case NN where both platforms adopt the strategy of offering a single core service. Under this circumstance, the strategy of releasing a value-added function evolves into the strategy of providing a single core service. The corresponding equilibrium results under Case YN are shown in Proposition 4.

Proposition 4 (Market Equilibrium Outcomes for Case NY/YN)

a. *When the network effects are comparatively weak (i.e., $2\tau D < (1+\alpha)t$), both Platform 1 and Platform 2 compete and coexist.*

   i. *When the region $[x_1, x_2]$ in Figure 2 is not empty, the equilibrium prices are $P_{YN}^{1*} = \frac{\delta_1(\tau+1)+(\alpha+2)t-3\tau D-3c}{3}$ and $P_{YN}^{2*} = \frac{-\delta_1(\tau+1)+(2\alpha+1)t-3\tau D}{3}$.*

   ii. *When the region $[x_1, x_2]$ in Figure 2 is empty, Platform 1's strategy of providing a service portfolio evolves into a strategy of offering only a core service, and each platform occupies half of the market. The prices in equilibrium are $P_{YN}^{1*} = P_{YN}^{2*} = t - \tau D$.*

b. *When the network effects are comparatively high (i.e., $2\tau D \geq (1+\alpha)t$), Platform 1 dominates the entire market, while Platform 2 fails and with-draws from the market. The equilibrium prices are $P_{YN}^{1*} = \frac{\delta_1(\tau+1)+(\alpha+2)t-3\tau D-3c}{3}$, $P_{YN}^{2*} = 0$.*

3.2.3. Case YY: Duopoly with Both Platforms Offering a Value-added Function. Now we discuss the situation where both platforms provide value-added functions. When both platforms provide core services and paid value-added functions, consumers who are eager to solve their problems precisely will choose to use the value-added function before they paying for the core service. Consequently, consumers can fall into four types: those who stand between 0 and x_1 prefer only the core service of Platform 1, and consumers who stand between x_2 and 1 only pay for the core service from Platform 2. The consumers located between x_1 and x_0 want their problems solved better and use value-add function before purchasing core services from Platform 1, while consumers between x_0 and x_2 use value-added function before purchasing core service from Platform 2. Under this circumstance, Platform 1 offers its core service to a fraction $x_1 D$ of the consumers and its service portfolio to a fraction $(x_0 - x_1)D$ of the consumers. While Platform 2 offers core service to a fraction $(1 - x_2)D$ of the consumers and provides a service portfolio to a fraction $(x_2 - x_0)D$ of the consumers. Figure 3 shows the corresponding consumer choice.

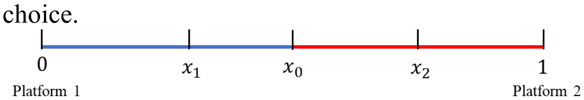

Figure 3. Consumer choice of Case YY.

Taking consumer choice into consideration, the platform's goal is to choose the optimal prices P_{YY}^1 and P_{YY}^2 respectively to gain as much profit as possible. Both platforms' profit functions are $\pi_{YY}^1 = P_{YY}^1 x_0 D + (x_0 - x_1)cD$, $\pi_{YY}^2 = P_{YY}^2(1 - x_0)D + (x_2 - x_0)cD$, $s.t.\ 0 < x_1 < x_0 < x_2 < 1$.

Where x_1 is gained by solving $U_1 = U_1'$ with respect to x. x_0 is derived by setting $U_1' = U_2'$ and x_2 is derived by solving $U_2' = U_2$. In addition, the equations $M_{YY}^1 = x_0 D$ and $M_{YY}^2 = (1 - x_0)D$ hold in the utility functions. Hence, we obtain the following critical points: $x_1 = \frac{c-(1+\tau)\delta_1}{t(1-\alpha)}$, $x_0 = \frac{1}{2} + \frac{(1+\tau)(\delta_1-\delta_2)}{6(\alpha t-\tau D)}$, $x_2 = 1 - \frac{c-(1+\tau)\delta_2}{t(1-\alpha)}$.

By analyzing the above results, we conclude that the size of a platform's consumers is mainly determined by the network effects and the intrinsic value of using the value-added function. A platform with greater intrinsic value of value-added service will bring more utility to consumers, which will help attract more consumers. If the intrinsic values of the two platforms' value-added functions are the same (i.e., $\delta_1 = \delta_2$), the indifference point x_0 is equal to $1/2$, suggesting that both platforms account for half of the total market demands.

The equilibrium results of these two platforms can be solved by setting the first derivative of the profit functions to zero simultaneously. The corresponding equilibrium results of the two platforms are: $P_{YY}^{1*} = \frac{1}{3}[3\alpha t - 3D\tau - 3c + (1+\tau)(\delta_1 - \delta_2)]$, $P_{YY}^{2*} = \frac{1}{3}[3\alpha t - 3D\tau - 3c + (1+\tau)(\delta_2 - \delta_1)]$, $M_{YY}^{1*} = \frac{1}{2}D + \frac{(1+\tau)(\delta_1-\delta_2)}{6(\alpha t-N\tau)}D$, $M_{YY}^{2*} = \frac{1}{2}D + \frac{(1+\tau)(\delta_2-\delta_1)}{6(\alpha t-D\tau)}D$.

Consequently, the equilibrium profits of the two platforms are $\pi_{YY}^{1*} = \frac{[3\alpha t-3D\tau+(1+\tau)(\delta_1-\delta_2)]^2}{18(\alpha t-\tau D)}D + cD[\frac{\delta_1(1+\tau)-c}{t(1-\alpha)}]$, $\pi_{YY}^{2*} = \frac{[3\alpha t-3\tau D+(1+\tau)(\delta_2-\delta_1)]^2}{18(\alpha t-\tau D)}D + cN[\frac{\delta_2(1+\tau)-c}{t(1-\alpha)}]$.

Assume that the strategy of launching value-added functions in this case is valid for each platform, it is tantamount to the limiting conditions on the marginal point, that is, $0 < x_1 < x_0 < x_2 < 1$. To meet this inequality, it is required that: $\frac{(1-\alpha)t}{(1-\alpha)t+6(\alpha t-\tau D)}\delta_j + \frac{6c(\alpha t-\tau D)-3(\alpha t-\tau D)(1-\alpha)t}{(1+\tau)(1-\alpha)t+6(1+\tau)(\alpha t-\tau D)} < \delta_i < \frac{c}{1+\tau}$ for $i, j = 1,2\ and\ i \neq j$.

According to the equilibrium solutions, if the value-added function strategy is effective, the platform's profit is positively correlated with the network effects and with the intrinsic value of its value-added service (i.e., $\delta_i\ and\ \delta_j$). Intuitively, if the intrinsic value of a platform's value-added function is higher than that of another platform, then it will always achieve greater market shares and higher profits. Likewise, increases in the intensity of network effects always benefit to the platform. These conclusions are significantly different from those in Case NN, where the intensity of network effects has a negative effect on the optimal prices and profits of both platforms.

Here we analyze situations where the inequality $0 < x_1 < x_0 < x_2 < 1$ in Case YY is violated. If $\delta_i \geq \frac{c}{1+\tau}$ for $i = 1,2$, all Platform i's consumers will choose to use its value-added function before taking core service. Thus, the optimal prices in this situation are the same as that in the scenario of $x_1 < x_0 < x_2$.

Due to space limitations, the part that overlaps with Proposition 5 was not elaborated on.

Proposition 5 (Market Equilibrium Outcomes for Case YY)

a. *If the indifference points in Figure 3 meet $x_1 < x_0 < x_2$, the prices in equilibrium are:*

$$P_{YY}^{1*} = \frac{1}{3}[-3\tau D + 3\alpha t - c + (1+\tau)(\delta_1 - \delta_2)],$$
$$P_{YY}^{2*} = \frac{1}{3}[-3\tau D + 3\alpha t - c + (1+\tau)(\delta_2 - \delta_1)].$$

b. *If $x_1 < x_0 < x_2$ is violated, different situations hold different competitive landscapes and equilibrium outcomes.*

   i. *When $x_0 \leq x_1$, no consumer tends to use the value-added function from Platform 1. The equilibrium prices are:*

$$P_{YY}^{1*} = \frac{-\delta_2(\tau+1)+(2\alpha+1)t-3\tau D}{3},$$

$P_{YY}^{2*} = \frac{\delta_2(\tau+1)+(\alpha+2)t-3\tau D-3c}{3}$.

ii. When $x_2 \le x_0$, no consumer will use the value-added function from Platform 2. The equilibrium prices are:

$P_{YY}^{1*} = \frac{\delta_1(\tau+1)+(\alpha+2)t-3\tau D-3c}{3}$,

$P_{YY}^{2*} = \frac{-\delta_1(\tau+1)+(2\alpha+1)t-3\tau D}{3}$.

iii. When $x_2 \le x_1$, no consumer will use the value-added function from either platform. The equilibrium prices are: $P_{YY}^{1*} = P_{YY}^{2*} = t - \tau D$.

4. Market Equilibrium Analysis

In the previous sections, we analyzed the equilibrium outcomes of different platform choices in monopoly and duopoly. Our duopoly model is a two-stage game where platforms decide whether to attach value-added modules in Stage 1 and set prices in Stage 2 to maximize profits after observing their competitor's decision. The market equilibrium is obtained using subgame perfectness. Proposition 6 shows the optimal choice of the two platforms under different parameter ranges. We first consider price decisions in Stage 2 and then strategy decisions in Stage 1, following backward induction.

Proposition 6 (Market Equilibrium Under Different Cases of duopoly)

a. Case NN is an equilibrium in which both platforms provide only core service, if and only if $\delta_1 < \hat{\delta}$ and $\delta_2 < \hat{\delta}$.

b. Case YN is an equilibrium in which only Platform 1 provides value-added module, if and only if $\delta_1 > \hat{\delta}$ and $\delta_2 < \delta_1 + f(\delta_1)$.

c. Case NY is an equilibrium in which only Platform 2 provides value-added module, if and only if $\delta_1 < \delta_2 + f(\delta_2)$ and $\delta_2 > \hat{\delta}$.

d. Case YY is an equilibrium in which both platforms provide value-added module, if and only if $\delta_1 > \delta_2 + f(\delta_2)$ and $\delta_2 > \delta_1 + f(\delta_1)$.

Where $\hat{\delta} = \frac{1}{1+\tau}[-A_1 - A_2 - \frac{H}{2B_1} + \frac{\sqrt{H^2+4(A_1+A_2)B_1H-4B_1E}}{2B_1}]$, $f(\delta_i) = \frac{1}{1+\tau}\{-3A_1 - \frac{H}{2B_2} - \frac{\sqrt{12B_1B_2[2A_1+A_2-(1+\tau)\delta_i]^2+4B_2[3A_1-(1+\tau)\delta_i]H+H^2+4B_2cH}}{2B_2}\}$, *and* $A_1 = \alpha t - \tau D$, $A_2 = t - \tau D$, $B_1 = \frac{D}{9(A_1+A_2)}$, $B_2 = \frac{D}{18A_1}$, $H = \frac{cD}{t(1-\alpha)}$, $E = cH - A_2 D/2$.

From Proposition 6, we can mine its strategic significance. When deciding whether to offer value-added modules, the platform must take into account the value of its competitors' value-added modules. Different selection of model parameters will yield varying market equilibrium outcomes. We illustrate the equilibrium analysis graphically in Figure 4, where different regions represent distinct competitive strategies of platforms. The horizontal axis of the coordinates represents δ_1 and the vertical axis represents δ_2. Capital letters NN/YN/NY/YY in the Figure 4 represent the corresponding equilibrium.

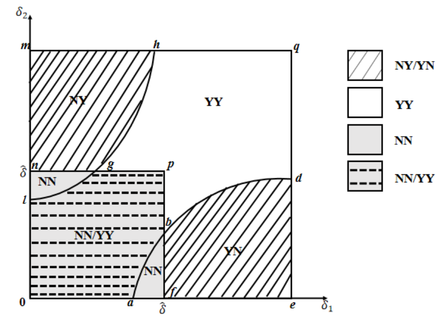

Figure 4. Market equilibrium under different duopoly cases.

From Figure 4, it is easy for us to observe that if a platform's intrinsic value of the value-added module is significantly higher than that of another platform, the dominant strategy for this platform is to offer the value-added function. For instance, if the intrinsic value that consumers obtained by buying Platform 1's value-added function is considerably larger than that from Platform 2's (i.e., $\delta_1 \gg \delta_2$), Platform 1's most profitable strategy is to offer core services together with the value-added module, while Platform 2's strategy is to provide only the core services. The region $b - d - e - f$ with YN represents the strategies of both platforms in this situation. Similarly, if Platform 2's value-added function is significantly better than that of Platform 1 in terms of intrinsic value, it is more rewarding for Platform 2 to offer a value-added module, while Platform 1's most profitable strategy is to sell only core services, as shown in region $g - h - m - n$ labeled NY. To sum up, whether a platform provides value-added service depends on the difference in the intrinsic value of the value-added services between the two platforms. As long as the intrinsic value of the value-added functionality is superior to that of competitors, the platform will benefit from selling a portfolio of services.

Another conclusion from Figure 4 shows that when the intrinsic value of a platform's value-added function is sufficiently small, the strategy of offering only core services will be the wisest choice no matter what its competitor's choice is. In region $o - f - p - n$ labeled NN, as $\pi_{NN}^{1*} > \pi_{YN}^{1*}$ and $\pi_{NN}^{2*} > \pi_{NY}^{2*}$, no platform would accept the strategy of introducing a value-added function. There are two equilibriums, labeled NN/YY, in region $a - b - p - g - l - o$, representing the same service offerings on both platforms at the same time.

When the intrinsic values consumers derived from the value-added function are close, in other words, when the values of δ_1 and δ_2 fall in region $o-a-d-q-h-l$ labeled YY. The corresponding region contains an outcome that both platforms consider offering a value-added function regardless of their competitor's strategy because they can earn more profit than providing only core service (i.e., $\pi_{YY}^{1*} > \pi_{NY}^{1*}$ and $\pi_{YY}^{2*} > \pi_{YN}^{2*}$).

However, once the values of using value-added functions are less than $\hat{\delta}$, offering the service portfolio can also be part of the equilibrium. If the other platform doesn't have value-added functions, it's best for the platform to stick to the core service instead of introducing value-added functions. Although the region $a-b-p-g-l-o$ represents the coexistence of equilibrium NN and YY, only equilibrium NN is the better choice in terms of the profits obtained by both platforms. Proposition 7 shows this conclusion.

Proposition 7 (Dominant Equilibrium)

When the optimal strategy for both platforms is to offer only the core service or both offer additional value-added, the best option for each platform is to offer only the core service.

It is easy to understand the reason for Proposition 7, as the value-added strategy intensifies competition between the two platforms' core services. As shown in Figure 4, when the values of δ_1 and δ_2 fall in the region $a-b-p-g-l-o$, there exist two equilibrium strategies. In this area, the strategy of providing a value-added function is less profitable for a platform compared with offering only core service. Consumers who are satisfied with a platform's current quality of core service, even if the value-added function can bring them more utilities, are still not willing to purchase the value-added function.

5. Discussion and Concluding Remarks

This paper analyzes the optimal pricing strategy of monopoly and duopoly knowledge payment platforms under network effects from the perspective of meta-knowledge. In our model, the platform can only provide core consulting services to knowledge consumers, or it can consider adding a charging value-added module based on core consulting services. Our research examines how the KPP decides to introduce value-added modules based on the quality structure of existing knowledge providers on the platform, as well as how to modify the knowledge providers' structure in response to competition. In addition, we also derive the optimal price decision for KPP.

Our research has produced several interesting findings. The general intuition is that the higher the quality of the platform's experts, the better for the platform. However, we find that by keeping the average quality of service providers of the platform constant, the platform can appropriately allow low-quality experts to enter based on introducing high-quality experts. This indicates that the expert access threshold of the platform can be set lower, which allows more users to sell their knowledge, experiences and other intangible asset on the platform. Moreover, contrary to intuition, platforms should aggressively introduce value-added modules when the average quality of platform experts is significantly higher than that of their competitors. Likewise, if the average quality of experts on both platforms is low, both platforms cannot gain more profits from value-added services. When the average quality of experts in both platforms is higher, both platforms can gain more profits from value-added modules.

Our paper contributes to the literature in several aspects. First, we study the pricing strategy of knowledge payment platform from the perspective of meta-knowledge, which provides a new direction for the follow-up research. Second, our research expands the role of meta-knowledge in the knowledge payment field and emphasizes the importance of meta-knowledge in knowledge management again. Third, we find that the higher the quality of experts, the more actively the platform should launch relevant value-added modules so that knowledge consumers can acquire more meta-knowledge. In this way, the information asymmetry between experts and knowledge consumers can be reduced as much as possible, which can lead to a decline in consumers' purchase concerns.

Our results provide valuable managerial insights that can help the platform's decision makers consciously adjust their expert quality structure, and help consumers find service providers that match their demands. For example, when the overall quality of the platform's experts is not high, the platform should consider bringing in some high-level experts in their specialized fields, rather than expending efforts on providing additional functionality or software optimization. Furthermore, knowledge payment platform should reduce the information asymmetry between experts and consumers as much as possible through various means, so as to bring more profits to the platform. Additionally, consumers should be aware that more and better value-added modules being provided by the platform do not mean that the platform's service is of better quality. Instead, they should be aware that some experts in the platform are of low quality and should be more cautious when paying for the consultation.

This paper has several limitations that propose future research directions. For example, we consider knowledge consumers and knowledge providers separately, but in fact, a knowledge consumer may also become a knowledge provider after acquiring knowledge, and future research could examine market strategies and pricing options when KPP(s) users have dual identities. In addition, we treat the amount of "Pangting" fees that consumers are willing to pay as a constant value, so it stands to reason that research that assumes that consumers' choices about "Pangting" fees are heterogeneous may yield other important insights. Furthermore, to streamline the model, our current approach overlooks some specific and intricate interactions, such as the interactions between knowledge consumers and providers, as well as between the platform and knowledge providers. In future work, we plan to expand our analysis from these perspectives and support the model with empirical analysis.

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