OPERATIONS AND SUPPLY CHAIN MANAGEMENT
Vol. 19, No. 1, 2026, pp. 114 – 134
ISSN 1979-3561 | EISSN 2579-9363

Partial vs Full Technology Adoption: Strategic Implications for Two-Sided Platforms

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ABSTRACT

With the rapid development and widespread adoption of digital technology, two-sided platforms increasingly leverage digital technology to enhance operations and facilitate transactions. However, varying levels of acceptance among consumers and providers present platforms with three strategic options for technology adoption: no adoption, partial adoption, or full adoption. Although previous studies have explored technology adoption decisions in two-sided platforms, there remains a research gap in the choice between partial and full technology adoption. This paper aims to address this gap by developing a game-theoretic model to analyze the impact of different technology adoption strategies on two-sided platforms, consumers, and providers. Our findings reveal that the adoption of digital technology can increase both service supply and demand but decrease service prices and commission rates. Notably, in the scenario of partial technology adoption, the price of traditional services is higher than when technology is not adopted. Moreover, we demonstrate that higher operating costs do not necessarily incentivize the platform to adopt digital technology. Specifically, platforms are more likely to partially adopt technology when operating costs are low and fully adopt it when costs are moderate. Furthermore, we find that partial technology adoption can generate more consumer and provider surplus but may reduce overall social welfare. Our study provides strategic guidance for platform managers regarding adopting digital technology within their operations management.

Keywords: *digital technology, game-theoretic model, supply-demand balance, technology adoption strategy, two-sided platform.*

1. INTRODUCTION

Two-sided platforms have become essential intermediaries connecting consumers and providers. According to a recent report, the total global revenue of two-sided platforms reached $40.2 billion in 2022 (Chhabra, 2023). Spanning industries such as e-commerce (e.g., Amazon and JD.com), ride-sharing (e.g., Uber and Lyft), social media (e.g., Facebook and Twitter), and healthcare (e.g., Teladoc and Sesame), these two-sided platforms have become ubiquitous, reshaping traditional business models and fostering seamless interactions between consumers and providers. Recently, many two-sided platforms have adopted digital technology, such as artificial intelligence (AI), machine learning (ML), and blockchain, to expand their user base and facilitate transactions. For example, Amazon leverages AI and ML to enhance the consumer experience (Jr, 2022), and Uber employs blockchain to improve transaction transparency and efficiency (LeewayHertz, 2024).

The adoption of digital technology in two-sided platforms is critical for enhancing consumer services and reducing operating costs (Bigcommerce, 2024). Traditionally, consumers invest a lot of time and effort in manually searching for desired services or products. However, when two-sided platforms integrate digital technology, the transaction process becomes more automated and intelligent, enabling consumers to access services or products more efficiently and leading to higher transaction rates (FasterCapital, 2024). Moreover, platforms can leverage digital technology to collect and analyze consumer data, thereby reducing marketing and labor costs (Flatt, 2024). However, despite the growing adoption of digital technology, limited research has explored its impact on two-sided platform profitability and the utilities of consumers and providers. To bridge this research gap and further promote the digitization of two-sided platforms, our research aims to address the following questions: *Which technology adoption strategy should a two-sided platform* *implement?* Moreover, *how does this strategy influence supply and demand?*

Reducing operating costs is a key driver of technology adoption for two-sided platforms. By integrating digital technologies, these platforms can significantly lower operational costs but improve overall efficiency. For example, JD.com's adoption of smart warehouse technology has reduced its order fulfillment expense rate to a world-leading 6.5%, with the construction of smart warehouses projected to save the company hundreds of millions of dollars annually (Qin *et al*., 2022). Similarly, L'Oréal has realized at least 19% in cost savings by migrating its SAP business applications from on-premises infrastructure to the cloud (Microsoft, 2023). Additionally, the company has implemented AI-driven product recommendations, leading to a 6-12% increase in average order value (SaltClick, 2024). Therefore, the adoption of digital technologies not only helps two-sided platforms reduce operational costs but also enhances the platform's competitiveness.

However, the adoption of digital technology is not always beneficial. A research survey shows that only 40% of Americans accept the use of AI in healthcare services, whereas 60% do not want it (Tyson *et al*., 2023). Similarly, a survey by the American Medical Association reveals that 66% of physicians see the benefits of AI, and 34% perceive it as having disadvantages or no benefits (Adams, 2023). This resistance from consumers and providers can hinder the adoption of digital technology by two-sided platforms. As a result, some two-sided platforms fully adopt digital technology, whereas others opt for partial adoption, maintaining technology-free channels alongside digital ones. For example, specialized human resources (HR) platforms, such as Eightfold and Beamery, employ AI models to provide intelligent recommendations and keep humans in the loop (Bersin, 2023). Some hotels, like Marriott and Hilton, invest in digital technology by developing websites and apps to encourage travelers to book accommodations online and providing the option for travelers to call the hotel directly to make reservations (Stavac *et al*., 2024). Therefore, strategic decisions about whether and how to adopt digital technology are crucial for two-sided platforms.

Although the adoption of digital technology can facilitate transactions and create more value for two-sided platforms, the associated costs and consumer resistance may be detrimental to the full diffusion of the technology. Hence, two-sided platforms have three strategies for technology adoption: no adoption, partial adoption, and full adoption. The no adoption strategy maintains the platform's traditional model, in which consumers purchase products or services from providers who do not utilize digital technology. The partial adoption strategy represents a hybrid model, allowing both traditional and technology-supported products or services to coexist. In contrast, full adoption involves the comprehensive integration of digital technology, such that consumers can only access technology-enabled products or services.

The partial adoption strategy offers greater flexibility by accommodating heterogeneous user preferences and enabling a gradual technological transition. It allows providers and consumers to opt into digital services at their own pace, mitigating potential resistance and maintaining platform inclusiveness. On the other hand, the full adoption strategy seeks to maximize operational efficiency through complete digitalization. However, it may exclude consumers or providers unwilling to adapt, thereby risking reduced participation. These trade-offs illustrate the strategic complexity of technology adoption decisions. By analyzing both partial and full adoption strategies, our study offers a comprehensive understanding of how technology choices influence platform performance and the equilibrium between supply and demand.

Although prior studies have explored digital technology adoption in two-sided platforms (Mantena & Saha, 2012; Xu *et al*., 2023), there is still a lack of in-depth analysis on whether two-sided platforms should choose partial or full adoption and how these strategies affect the equilibrium between supply and demand. Our study focuses on the technology adoption strategies in two-sided platforms, providing managerial insights for platform managers to optimize pricing and operations, as well as policy recommendations for fostering the development of two-sided markets. Specifically, this study addresses the following research questions:

(1) Does the adoption of digital technology necessarily reduce prices and increase demand?
(2) Which technology adoption strategy should a two-sided platform choose?
(3) Does the adoption of digital technology always improve consumer surplus?

To answer these questions, we develop a game-theoretic model involving three types of players in a two-sided market: a platform, a group of consumers, and a group of providers. In this model, the service price is determined by the interaction between supply and demand. As the leader and intermediary, the platform first determines the commission rates, after which consumers and providers decide whether to engage in transactions. By maximizing the platform's profits, we analyze whether it should opt for partial or full adoption of digital technology. Additionally, we explore the impact of different technology adoption strategies on consumers and providers. Our analysis yields several interesting findings and offers valuable insights for both platform managers and policymakers.

In summary, this study contributes to the understanding of technology adoption strategies for two-sided platforms in three key areas:

(1) This paper examines the equilibrium prices and demand under different technology adoption strategies. Pallathadka *et al*. (2023) suggest that AI and ML can optimize pricing and boost sales in the e-commerce industry. Consistent with their findings, our study shows that technology adoption reduces service prices and increases demand. However, we also uncover a counterintuitive result: In the scenario of partial technology adoption, the price of services that do not involve technology may be higher than in the scenario where technology is entirely forgone. Hence, platform managers should consider the competitive dynamics between services with technology and services without technology when setting prices under partial technology adoption.

(2) This paper contributes to the understanding of technology adoption decisions in two-sided platforms. Intuitively, one might expect that platforms with high

operating costs would tend to adopt digital technology to mitigate expenses (He *et al*., 2024). However, our findings indicate that when a platform's operating costs are high or moderate, it may forgo technology adoption. Conversely, when operating costs are low, the platform is more likely to partially adopt digital technology. Additionally, within a specific moderate cost range, full adoption becomes the preferred strategy. These insights suggest that higher operating costs do not necessarily drive platforms to adopt digital technology. Platform managers should carefully assess cost structures and strategic benefits when making technology adoption decisions.

(3) This paper investigates the impact of technology adoption strategy on consumer surplus. While some studies suggest that technology adoption on e-commerce platforms could increase consumer surplus (Wang *et al*., 2024), our findings indicate that this is not always the case. We find that consumer surplus is influenced by the platform's operating costs. When operating costs are high, consumers achieve the greatest surplus if the platform forgoes digital technology. When the operating costs are moderate, full technology adoption yields the highest consumer surplus. Finally, when operating costs are low, partial technology adoption maximizes consumer surplus. These findings highlight the complex relationship between technology adoption, operating costs, and consumer welfare.

Additionally, we examine which technology adoption strategy maximizes provider surplus and find results similar to those observed for consumer surplus. Our results identify three scenarios in which provider surplus is maximized: (i) When operating costs are low and the platform adopts digital technology partially; (ii) when operating costs are moderate and the platform adopts digital technology fully; (iii) when operating costs are high and the platform forgoes adopting digital technology. Hence, policymakers should be aware of the impact of the platform's operating costs on consumers and providers when formulating regulations and incentives related to technology adoption in two-sided markets.

The remainder of our study is organized as follows. Section 2 summarizes the relevant literature. Section 3 presents our model. Section 4 summarizes the results. Section 5 provides analysis and discussion. Section 6 presents an extended model. Section 7 concludes the study and provides managerial and policy implications. For ease of narration, proofs are suppressed to the appendix.

2. LITERATURE REVIEW

This research is closely related to two areas of literature: (i) pricing strategies of two-sided platforms and (ii) the adoption of digital technology for two-sided platforms. Therefore, this section reviews the relevant research on the two contents and highlights our contributions. For clarity, we illustrate our research context and contributions in Figure 1. platform delivery in the sharing economy: Membership-based pricing, transaction-based pricing, and cross-subsidization, and analyze which strategy is optimal for the platform. Kim *et al*. (2021) introduce two different pricing strategies for e-commerce platforms based on buyers' sensitivity to usage fees and shipping costs. Feldman *et al*. (2022) suggest a

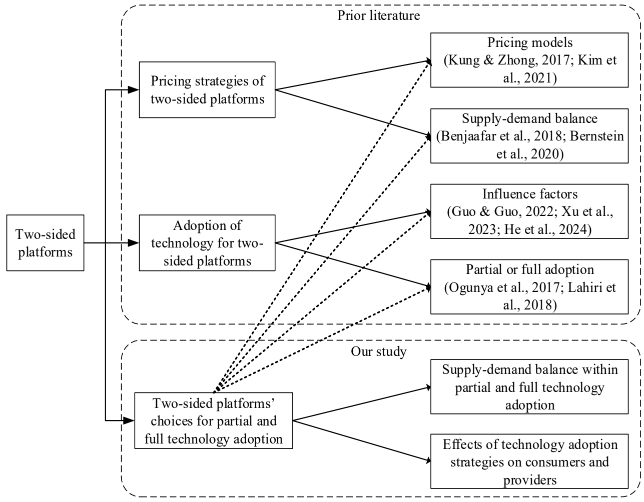


Figure 1 Related literature stream

pricing contract in which a food delivery platform pays a percentage revenue share and a fixed fee to a restaurant, thereby increasing revenues for both the platform and providers. Our research aligns with these studies by focusing on optimal pricing strategies for two-sided platforms, including differentiated pricing. However, our study is unique in examining the impact of technology adoption models on the platform's pricing decisions across different adoption strategies. By analyzing pricing strategies under various technology adoption scenarios, this study contributes to the literature by deepening the understanding of two-sided platform pricing and elucidating the role of technology adoption in shaping pricing behavior.

2.1 Pricing Strategies of Two-sided Platforms

Numerous studies in this stream focus on the optimal pricing of two-sided platforms. Specifically, Kung and Zhong (2017) propose three pricing strategies for two-sided

Our research is also related to the stream of literature on supply-demand balance in two-sided platforms. In this stream, Jiang and Tian (2016) and Benjaafar *et al*. (2018) explore the match between owners and renters to analyze rental prices, the firm's profit, consumer surplus, and social welfare in peer-to-peer sharing platforms. Bernstein *et al*. (2020) incorporate a measure of market congestion—the relative balance between the number of drivers and the number of consumers—in the utility functions of both drivers and consumers, using detailed queueing models to capture supply-demand balance issues. Zhou *et al*. (2024) suggest that platforms can adjust actual supply and demand through two-sided pricing to achieve an equilibrium between customers and agents that maximizes platform profit. These studies focus on supply-demand balance when analyzing the pricing strategies of platforms. Similarly, our study follows their setting to assume that in equilibrium, supply equals demand. This setting allows us to provide insightful managerial implications about technology adoption for firms in industries with strict requirements on the matching between supply and demand, such as product sharing, ride-sharing, and health sharing. Additionally, contributing to the research stream, our study highlights the effect of digital technology on the supply-demand balance.

Table 1 Notations

Symbol	Definition
v	Basic value that consumers derive from services
λ	Degree of consumer network effect
x	Marginal dissatisfaction cost of consumers
ρ	Extent to which digital technology reduces the cost of consumer dissatisfaction
f	Marginal cost of using technology for consumers
D	Proportion of consumers joining the platform
D_T/D_I	Proportion of consumers who purchase traditional/improved services
U_T/U_I	Utility of consumers who purchase traditional/improved services
CS	Consumer surplus
n	Number of providers in the market
φ	Degree of provider network effect
y	Marginal service cost of providers
N	Proportion of providers joining the platform
N_T/N_I	Proportion of providers who offer traditional/improved services
V_T/V_I	Utility of providers who offer traditional/improved services
PS	Provider surplus
c	Marginal operating cost of the platform
δ	Extent to which digital technology reduces the operating cost of the platform
k	Investment level of digital technology
$C(k)$	Technology investment cost of the platform
π	Profit of the platform
SW	Social welfare
Variable	
α	Transaction commission rate
β	Technical commission rate
p_T/p_I	Unit price of traditional/improved services in the differential pricing scenario

2.2 Adoption Of Technology For Two-sided Platforms

In recent years, the rise of digital technology has attracted the attention of the research community. Several studies concentrate on factors affecting technology adoption by two-sided platforms. For example, Guo and Guo (2022) examine blockchain technology investment and pricing strategies for two asymmetric sharing platforms, finding that when users perceive high value in blockchain, both platforms are motivated to adopt it, and conversely, a stronger platform may exit the blockchain market if the perceived value is low. Xu *et al.* (2023) develop an analytical model to evaluate whether two traditional platforms should utilize private blockchains as an operational strategy, highlighting that the difference in service quality between the platforms plays a critical role in blockchain adoption decisions. He *et al.* (2024) investigate capacity-sharing platforms' decisions on pricing and blockchain adoption, showing that platforms prefer to introduce blockchain technology when the relevant fixed cost is less than the profit increment it generates. While previous studies have explored various factors influencing technology adoption, our research highlights the critical role of operating costs in the decision-making process of two-sided platforms. From an operational perspective, operating costs are often regarded as a key driver of digital technology adoption. Conventional wisdom suggests that higher operating costs incentivize platforms to adopt digital solutions to improve efficiency. However, our findings challenge this assumption by demonstrating that, even under conditions of elevated operating costs, a platform may still choose not to adopt digital technology. This counterintuitive result contributes to the literature by offering a nuanced understanding of the relationship between operating costs and technology adoption strategies.

Our study also contributes to the literature on technology adoption models. Ogunya *et al.* (2017) examine technology adoption strategies among farmers, including non-adoption, partial adoption, and full adoption, and explore how these models vary based on socio-economic characteristics. Lahiri *et al.* (2018) model technology choice based on "appropriate technology" and find that dual economies, where some agents in the model are trapped in low-level wealth, whereas others achieve sustained growth, can occur with full and partial adoption of the potentially more productive technology. Ruzzante *et al.* (2021) propose that adoption is a dynamic process, including a trial stage, early/late adoption, partial adoption, and disadoption. While existing studies have made significant progress in modeling technology adoption, there remains a gap in the literature regarding the decision-making process of two-sided platforms when considering partial or full technology adoption. This study aims to address this gap by examining technology adoption strategies from both profitability and social welfare perspectives. In doing so, it broadens the application scope of technology adoption research and offers deeper insights into strategic decision-making within two-sided platform ecosystems.

3. MODEL

In this section, we introduce our analytical model, with key notations summarized in Table 1.

3.1 Platforms

We consider a monopolistic two-sided platform that connects providers and customers. On this platform, providers offer services, and consumers purchase them from providers. Prior research on two-sided platforms has often focused on the coordination of supply and demand in peer-to-peer service environments, typically assuming that the platform reaches equilibrium with balanced supply and demand (Bai *et al*., 2018). Building on this foundational assumption, we also adopt a market-clearing mechanism in which service supply equals demand in equilibrium. Specifically, any provider willing to offer services at price p can do so, and any consumer willing to purchase at price p can buy accordingly (Tian & Jiang, 2018). Hence, the service price p is determined by the interaction of supply and demand. The platform generates revenue by charging commissions on each successful transaction (Lin & Zhou, 2019).

When consumers purchase traditional services offered by providers, consumers should pay a unit price p_T. Traditional services refer to services where providers do not use technology that interferes with the delivery process, denoted with subscript T. In this transaction, the platform takes a commission of αp_T, where $\alpha \in (0,1)$ denotes the endogenous transaction commission rate (Du *et al*., 2024). In practice, two-sided platforms usually incur operating costs, such as transaction costs and marketing expenses (Pereira, 2023). Therefore, we assume the platform incurs a marginal operating cost of c.

Recently, several leading two-sided platforms have adopted digital technology to reduce operating costs and increase revenue. When a platform adopts digital technology, providers can leverage it to improve services delivered to consumers, resulting in faster responses and improved user experiences. For ease of exposition, such services are referred to as improved services, as denoted by subscript I. Meanwhile, the platform needs to bear a technology investment cost $C(k)$, where $k \in (0,1)$ represents the investment level of digital technology. According to a recent report, Netflix spends $1.5 billion annually on technology, with a significant portion allocated to AI for personalizing recommendations and automating processes (Reilly, 2024). However, since the acceptance of technology by consumers and providers varies, some platforms, like Eightfold and Beamery, have partially implemented digital technology, allowing consumers to choose between traditional and improved services. Other platforms, like L'Oréal, opt for comprehensive digital technology adoption, driving consumers to choose only improved services. Therefore, when a platform decides to adopt digital technology, it has two strategies: full or partial technology adoption.

Under full technology adoption, providers enhance their service delivery process with the support of digital technology, allowing consumers to purchase services more conveniently. In exchange for adopting digital technology, the platform charges providers a technical service fee. For example, Kaola, an e-commerce platform for imported goods in China, imposes a technical service fee on online retailers ranging from 0.6% to 10% (Huld, 2022). Hence, in addition to the transaction commission αp_I, we assume the platform charges providers a technical commission βp_I, where p_I denotes the unit price of improved services and $\beta \in (0,1)$ is the endogenous technical commission rate. In this case, the platform's total revenue from the service transaction is $(\alpha + \beta)p_I$. Following Lee *et al*. (2011), we assume that under full technology adoption, the platform's operating cost is reduced to $(1 - \delta k)c$, where δ denotes the marginal reduction in the operating cost brought by technology.

Under partial technology adoption, the platform makes the digital technology available for providers to choose whether to use it. Providers can either offer traditional services without technology or offer improved services with digital technology. The supply and demand dynamics vary between these two scenarios. For example, doctors can enhance the supply of medical services by leveraging AI assistants (Suleyman & King, 2019). Therefore, we assume that the price of improved services, p_I, differs from that of traditional services, p_T.[1] For providers that offer traditional services, the platform takes a commission of αp_T and incurs the operating cost c. For providers that offer improved services, the platform takes a commission of $(\alpha + \beta)p_I$ and incurs the operating cost $(1 - \delta k)c$.

3.2 Providers

There are n providers in the market, and the proportion of providers joining the two-sided platform is N, where $n \in [0,1]$ and $N \leq n$. After the platform collects a commission, providers can obtain their revenue from transactions. If providers offer traditional services, then their unit revenue is $(1 - \alpha)p_T$. If providers offer improved services, then they obtain a revenue of $(1 - \alpha - \beta)p_I$. Moreover, providers receive an extra utility φD due to the network effect, where parameter $\varphi > 0$ denotes the degree of provider network effect, which means the marginal utility that each provider obtains from their interaction with an additional consumer, and variable $D \in [0,1]$ represents the proportion of consumers who join the platform (Anderson *et al*., 2013). The cross-side network effect means that more providers attract more consumers and vice versa. For example, Facebook leverages the cross-side network effect, in which two participants—users and app developers—attract each other. Uber similarly exploits the cross-side network effect, as more drivers attract more riders (Zhu & Iansiti, 2019).

The costs incurred by providers to offer services could vary considerably (Chen *et al*., 2018). For example, telehealth visits with a primary care physician may have a different cost structure compared to those with a specialist (Gascon, 2023). We capture the heterogeneity of providers' service costs by assuming that their unit service cost y for traditional services is uniformly distributed within $[0,1]$ (Liu *et al*., 2019). Further, the application of AI in healthcare can identify conditions more precisely, enabling physicians to make more informed clinical decisions, thus reducing their service costs (HITRUST, 2023). Hence, when the platform adopts digital technology and providers use the technology to offer improved services, the cost of providers decreases to $(1 - \omega k)y$, where ω denotes the extent to which digital technology reduces the service cost of providers.

[1] In this study, we set different prices for traditional services (without technology) and improved services (with technology) based on real-world cases to enhance the generalizability of our findings. In practice, there are cases where two-sided platforms set a uniform price for these two types of services. Hence, we also conducted an analysis under this uniform pricing model and found that our main findings and insights remain robust in such cases. These outcomes are available upon readers' request.

3.3 Providers

In the market, the total number of consumers is normalized to 1. Among them, $D \in [0,1]$ consumers participate in the two-sided platform, with each consumer demanding at most one unit of service. When consumers purchase services, they derive a basic value v from the services (Zhao *et al.*, 2019). Due to the cross-side network effect, consumers also gain additional utility λN from the presence of providers, where $\lambda > 0$ represents the degree of the consumer network effect (Li, 2021). Moreover, consumers may experience dissatisfaction due to poor purchase experience. For example, consumers of healthcare platforms often report frustration with long waiting times and high registration costs during the pre-consultation stage (Zhang *et al.*, 2018). To capture consumer dissatisfaction, we assume that consumers of traditional services incur a dissatisfaction cost x, which also follows a uniform distribution over $[0,1]$, consistent with prior study Katsamakas and Sanchez-Cartas (2023).

The adoption of digital technology can significantly reduce consumer dissatisfaction cost of x. For instance, Unity, a 3D development platform, reduced its first response time by 83% and improved its customer satisfaction score to 93% by implementing Zendesk automation and bots (Eyo, 2024). Hence, we assume that when consumers purchase improved services, the dissatisfaction cost reduces to $(1 - \rho k)x$, where ρ represents the extent to which digital technology reduces the dissatisfaction cost of consumers. However, the use of digital technology may also incur additional costs for consumers, such as learning costs and privacy costs (Okta, 2020). To capture the adverse effects of technology on consumers, we assume that the cost of using technology for consumers is denoted as f, where $f \in [0,1]$.

3.4 Game Sequence

Given the strategic options available to the two-sided platform in practice, this study considers three distinct scenarios: (i) benchmark scenario (scenario B), where the platform forgoes digital technology adoption; (ii) the scenario of partial technology adoption (scenario P), where the platform adopts digital technology but only partially applies it; (iii) the scenario of full technology adoption (scenario F), where the platform adopts digital technology and fully applies it. We illustrate the game sequence in Figure 2. For clarity, we also elaborate on the game sequence below.

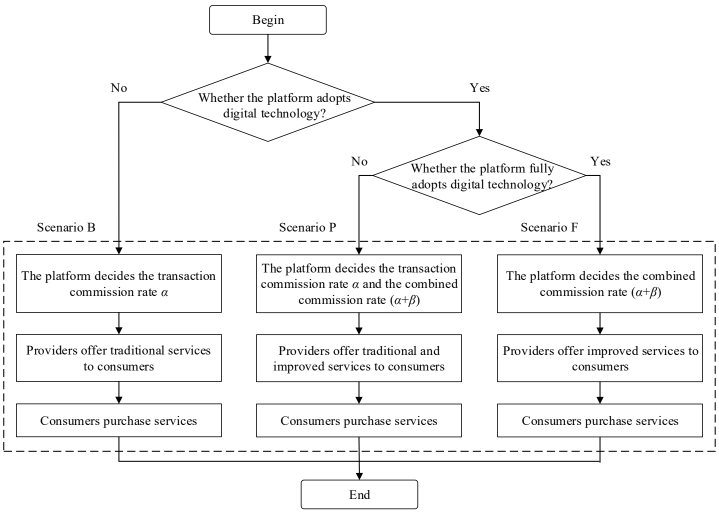


Figure 2 Game sequence

(1) The platform makes two decisions regarding technology adoption: Whether to adopt digital technology and, if so, whether to integrate technology into its operations fully.
(2) The decisions under each scenario are summarized as follows:
  (a) In scenario B, the platform does not adopt digital technology. In this case, the platform determines the transaction commission rate α. Subsequently, providers decide whether to offer traditional services based on their utility function. Then, consumers decide whether to purchase traditional services based on their own utility function.
  (b) In scenario P, the platform decides the transaction commission rate α and the combined transaction and technical commission rate $(\alpha + \beta)$. Subsequently, providers choose whether to offer traditional or improved services. Consumers decide whether to purchase traditional or improved services.
  (c) In scenario F, the platform implements digital technology comprehensively. It sets the combined transaction and technical commission rate $(\alpha + \beta)$. Providers decide whether to offer improved services. Then, consumers decide whether to purchase services.

4. RESULTS

In this section, we derive the equilibrium profits of the platform and the consumer surplus and provider surplus under each scenario and solve for the final game equilibrium. More details can be found in the Appendix.

4.1 Scenario B

In scenario B, the platform forgoes digital technology adoption, and providers offer traditional services to consumers. Consumers pay p_T for traditional services, derive a basic value v from services, gain extra utility λN from providers, and face a dissatisfaction cost x. Hence, the consumer utility is

$$U_T = v - x - p_T + \lambda N. \quad (1)$$

A consumer will join the platform and purchase services only when the consumer's utility is non-negative (Lin *et al*., 2024). According to Eq. (1), only consumers with a service dissatisfaction cost $x \le v - p_T + \lambda N$ will join the platform. Therefore, the service demand is $D = v - p_T + \lambda N$. The consumer surplus is

$$CS = \int_0^D U_T \, dx. \quad (2)$$

Providers earn a revenue of $(1-\alpha)p_T$ and gain extra utility φD, but incur a service cost y. The provider utility is

$$V_T = (1-\alpha)p_T + \varphi D - y. \quad (3)$$

A provider will join the platform and offer services only when $V_T \ge 0$. Similar to the situation with consumers, providers with a service cost $y \le (1-\alpha)p_T + \varphi D$ will join the platform. Therefore, the service supply is $N = n\big((1-\alpha)p_T + \varphi D\big)$. The provider surplus is

$$PS = \int_0^N V_T \, dy. \quad (4)$$

The service price p_T is determined by the interaction of consumer demand and provider supply. Subsequently, the platform decides the transaction commission rate α and bears the operating cost c. Hence, the platform's objective function is

$$\max_{\alpha} \pi = D(\alpha p_T - c). \quad (5)$$

Social welfare in this study comprises platform profits, consumer surplus, and provider surplus, and is expressed as

$$SW = CS + PS + \pi. \quad (6)$$

We use the backward induction procedure to solve the platform's profit-maximizing problem. Following the setting of Bernstein *et al*. (2020), we assume a supply-demand equilibrium on the platform, where provider supply matches consumer demand. The service price p_T is derived from this equilibrium. By substituting p_T into the platform's profit function and taking the first-order derivative of the profit function with respect to the transaction commission rate α, we obtain the equilibrium commission rate α^*, which the platform will determine. Then, substituting α^* into the relevant equations, we obtain the equilibrium solution for this scenario. The equilibrium outcomes are presented in Table 2.

Table 2 Equilibrium outcomes in scenario B.

Index	Expression
α_T^{B*}	$\frac{\big(1+n(1-\lambda-\varphi)\big)(v+c)}{v\big(2+n(1-\lambda-2\varphi)\big)+n(1-\lambda)c}$
p_T^{B*}	$\frac{v\big(2+n(1-\lambda-2\varphi)\big)+n(1-\lambda)c}{2+2n(1-\lambda-\varphi)}$
$D_T^{B*}(N_T^{B*})$	$\frac{n(v-c)}{2+2n(1-\lambda-\varphi)}$
π^{B*}	$\frac{n(v-c)^2}{4+4n(1-\lambda-\varphi)}$
CS^{B*}	$\frac{n^2(v-c)^2}{8\big(1+n(1-\lambda-\varphi)\big)^2}$
PS^{B*}	$\frac{(2-n)n(v-c)^2}{8\big(1+n(1-\lambda-\varphi)\big)^2}$
SW^{B*}	$\frac{2n(v-c)^2\big(1+1+n(1-\lambda-\varphi)\big)}{8\big(1+n(1-\lambda-\varphi)\big)^2}$

In Scenario B, the existence of service demand ($D_T^{B*} > 0$) and positive platform profit ($\pi^{B*} > 0$) requires that $v - c > 0$ and $\big(1 + n(1-\lambda-\varphi)\big) > 0$. When these conditions are satisfied, the equilibrium outcome is unique. If they are violated, the equilibrium becomes infeasible and thus does not exist.

4.2 Scenario P

In scenario P, the platform adopts digital technology, and providers decide whether to utilize it. If providers opt out of using the technology and offer traditional services, then the platform determines the transaction commission rate α. If providers adopt technology and provide improved services, the platform determines the combined transaction and technical commission rate $(\alpha + \beta)$. The utility of the consumer who purchases traditional services is

$$U_T = v - x - p_T + \lambda N. \quad (7)$$

When consumers purchase improved services, they face a dissatisfaction cost of $(1-\rho k)x$ and incur a technology use cost of f. The utility of the consumer who purchases improved services is

$$U_I = v - f - (1-\rho k)x - p_I + \lambda N. \quad (8)$$

According to Eqs. (7) and (8), the demands for traditional and improved services are $D_T = \frac{f - p_T + p_I}{\rho k}$ and $D_I = \frac{v - f - p_I + \lambda N}{1-\rho k} - \frac{f - p_T + p_I}{\rho k}$, respectively, and the total demand is $D = D_T + D_I$. Notably, if $D_T = 0$, then scenario P effectively transitions into scenario F, as there will be no demand for traditional services. Similarly, if $D_I = 0$, then scenario P transitions into scenario B, as there will be no demand for improved services. The consumer surplus is

$$CS = \int_0^{D_T} U_T \, dx + \int_{D_T}^{D} U_I \, dx. \quad (9)$$

The utility that a provider derives from traditional services is

$$V_T = (1-\alpha)p_T + \varphi D - y. \quad (10)$$

Providers offering improved services earn $(1-\alpha-\beta)p_I$ and incur a service cost of $(1-\omega k)y$. The utility that a provider derives from improved services is

$$V_I = (1-\alpha-\beta)p_I + \varphi D - (1-\omega k)y. \quad (11)$$

According to Eqs. (10) and (11), the supplies for traditional and improved services are $N_T = n\frac{(1-\alpha)p_T - (1-\alpha-\beta)p_I}{\omega k}$ and $N_I = n\frac{(1-\alpha-\beta)p_I + \varphi D}{1-\omega k} - n\frac{(1-\alpha)p_T - (1-\alpha-\beta)p_I}{\omega k}$, respectively, and the total supply is $N = N_T + N_I$. The provider surplus is

$$PS = \int_0^{N_T} V_T \, dy + \int_{N_T}^{N} V_I \, dy. \quad (12)$$

The platform incurs a technology investment cost of $C(k)$ for adopting digital technology and a cost of $(1-\delta k)c$ for operating improved service. The platform's objective function is

$$\max_{\alpha,(\alpha+\beta)} \pi = D_T(\alpha p_T - c) + D_I\big((\alpha+\beta)p_I - (1-\delta k)c\big) - C(k). \quad (13)$$

In this case, the supply and demand of traditional services are balanced, and the supply and demand of improved services are balanced. Following backward induction, we arrive at the equilibrium outcomes in Table 3.

In Scenario P, the coexistence of demand for traditional and improved services requires $D_T^{P*} > 0$, $D_I^{P*} > 0$, $D_T^{P*} + D_I^{P*} > 0$. These jointly imply that $c <$

Table 3 Equilibrium outcomes in scenario P.

Index	Expression
α_T^{P*}	$\frac{(n\rho+\omega)(c+v)}{f(n\rho+2\omega)+n\rho\delta kc}+\frac{(1+n(1-\lambda-k\rho-\varphi)-k\omega)(c+v)}{(v-f)(2+n(1-\lambda-k\rho-2\varphi)-2k\omega)+n(1-\lambda-k\rho)(1-\delta k)c}$
$(\alpha+\beta)_I^{P*}$	$\frac{(1+n(1-\lambda-k\rho-\varphi)-k\omega)\big(v-f+c(1-k\delta)\big)}{(v-f)(2+n(1-\lambda-k\rho-2\varphi)-2k\omega)+n(1-\lambda-k\rho)(1-\delta k)c}$
p_T^{P*}	$\frac{f(n\rho+2\omega)+n\rho\delta kc}{2(n\rho+\omega)}+\frac{(v-f)(2+n(1-\lambda-k\rho-2\varphi)-2k\omega)+n(1-\lambda-k\rho)(1-\delta k)c}{2(1+n(1-\lambda-k\rho-\varphi)-k\omega)}$
p_I^{P*}	$\frac{(v-f)(2+n(1-\lambda-k\rho-2\varphi)-2k\omega)+n(1-\lambda-k\rho)(1-\delta k)c}{2(1+n(1-\lambda-k\rho-\varphi)-k\omega)}$
$D_T^{P*}(N_T^{P*})$	$\frac{n(f-\delta kc)}{2k(n\rho+\omega)}$
$D_I^{P*}(N_I^{P*})$	$\frac{n(v-f-(1-\delta k)c)}{2(1+n(1-\lambda-k\rho-\varphi)-k\omega)}-\frac{n(f-\delta kc)}{2k(n\rho+\omega)}$
$D_T^{P*}+D_I^{P*}$ $(N_T^{P*}+N_T^{P*})$	$\frac{n(v-f-(1-\delta k)c)}{2(1+n(1-\lambda-k\rho-\varphi)-k\omega)}$
π^{P*}	$\frac{n(v-f-(1-\delta k)c)^2}{4(1+n(1-\lambda-k\rho-\varphi)-k\omega)}+\frac{n(f-\delta kc)^2}{4k(n\rho+\omega)}-C(k)$
CS^{P*}	$\frac{\rho kn^2(f-\delta kc)^2}{8k^2(n\rho+\omega)^2}+\frac{(1-\rho k)n^2(v-f-(1-\delta k)c)^2}{8(1+n(1-\lambda-k\rho-\varphi)-k\omega)^2}$
PS^{P*}	$\frac{n(2-n)(f-\delta kc)^2k\omega}{8k^2(n\rho+\omega)^2}+\frac{n(2-n)(v-f-(1-\delta k)c)^2(1-\omega k)}{8(1+n(1-\lambda-k\rho-\varphi)-k\omega)^2}$
SW^{P*}	$\frac{n(v-f-(1-\delta k)c)^2\big(n(1-\rho k)+(2-n)(1-\omega k)+2(1+n(1-\lambda-k\rho-\varphi)-k\omega)\big)}{8(1+n(1-\lambda-k\rho-\varphi)-k\omega)^2}+\frac{n(f-\delta kc)^2\big(kn\rho+(2-n)k\omega+2k(n\rho+\omega)\big)}{8k^2(n\rho+\omega)^2}-C(k)$

$\min\left\{\frac{f}{\delta k},\frac{k(n\rho+\omega)v-(1+n(1-\lambda-\varphi))f}{k(n\rho+\omega)-k\delta(1+n(1-\lambda-\varphi))},\frac{v-f}{1-\delta k}\right\}$. Additionally, platform profitability ($\pi^{P*}>0$) requires that $C(k)<\frac{n(v-f-(1-\delta k)c)^2}{4(1+n(1-\lambda-\varphi)-k(n\rho+\omega))}+\frac{n(f-\delta kc)^2}{4k(n\rho+\omega)}$. When all of these conditions are met, the resulting equilibrium is unique; otherwise, the model does not yield a feasible or valid equilibrium.

4.3 *Scenario F*

In scenario F, the platform adopts digital technology, and providers offer improved services to consumers. The utility that a consumer derives from improved services is

$$U_I=v-f-(1-\rho k)x-p_I+\lambda N. \quad (14)$$

According to Eq. (14), the service demand is $D=\frac{v-f-p_I+\lambda N}{1-\rho k}$. The consumer surplus is

$$CS=\int_0^D U_I\,dx. \quad (15)$$

The utility that a provider derives from offering improved services is

$$V_I=(1-\alpha-\beta)p_I+\varphi D-(1-\omega k)y. \quad (16)$$

According to Eq. (16), the service supply is $N=n\frac{(1-\alpha-\beta)p_I+\varphi D}{1-\omega k}$. The provider surplus is

$$PS=\int_0^N V_I\,dy. \quad (17)$$

The platform decides the combined commission rate $(\alpha+\beta)$. The objective function of the platform is

$$\max_{(\alpha+\beta)}\pi=D\big((\alpha+\beta)p_I-(1-\delta k)c\big)-C(k). \quad (18)$$

By solving the platform's profit-maximizing problems, we derive the equilibrium outcomes shown in Table 4.

In Scenario F, the existence of service demand ($D_I^{F*}>0$) and positive profit ($\pi^{F*}>0$) requires $c<\frac{v-f}{1-\delta k}$ and $C(k)<\frac{n(v-f-(1-\delta k)c)^2}{4(1+n(1-\lambda-\varphi)-k(n\rho+\omega))}$. Under these conditions, the equilibrium is unique and well-defined.

5. ANALYSIS

In this section, we first compare the equilibrium prices, commission rates, and demands across the three scenarios. Then, we analyze the optimal technology adoption strategy for the platform. Subsequently, we investigate the effects of the platform's strategy on consumer surplus, provider surplus, and social welfare. For brevity, all thresholds and proofs are provided in the Appendix.

5.1 *Equilibrium Prices, Commission Rates, and Demands*

In Proposition 1, we conduct a comparative analysis of the equilibrium prices, commission rates, and demand across the different scenarios.

Proposition 1. By contrasting the equilibrium prices, commission rates, and demand, we have

(1) $p_T^P>p_T^B>p_I^P=p_I^F$;
(2) $\alpha_T^P>\alpha_T^B$, $(\alpha+\beta)_I^P=(\alpha+\beta)_I^F$;
(3) $D_T^P+D_I^P=D_I^F>D_T^B>D_T^P$.

Proposition 1(1) demonstrates that the improved service price is lower than the traditional service price. This is because when the platform adopts digital technology for improved services, it effectively reduces consumers' dissatisfaction costs and providers' unit service costs. However, consumers also need to bear the costs associated with using technology, such as learning and privacy costs. These additional costs may deter some consumers, particularly those with lower dissatisfaction costs for traditional services, from purchasing improved services. On the other side, the reduced unit service costs encourage more

Table 4 Equilibrium outcomes in scenario F

Index	Expression
$(\alpha+\beta)_I^{F*}$	$\dfrac{(1+n(1-\lambda-k\rho-\varphi)-k\omega)(v-f+(1-\delta k)c)}{(v-f)(2+n(1-\lambda-k\rho-2\varphi)-2k\omega)+n(1-\lambda-k\rho)(1-\delta k)c}$
p_I^{F*}	$\dfrac{(v-f)(2+n(1-\lambda-k\rho-2\varphi)-2k\omega)+n(1-\lambda-k\rho)(1-\delta k)c}{2(1+n(1-\lambda-k\rho-\varphi)-k\omega)}$
D_I^{F*}	$\dfrac{n(v-f-(1-\delta k)c)}{2(1+n(1-\lambda-k\rho-\varphi)-k\omega)}$
π^{F*}	$\dfrac{n(v-f-(1-\delta k)c)^2}{4(1+n(1-\lambda-k\rho-\varphi)-k\omega)}-C(k)$
CS^{F*}	$\dfrac{n^2(1-k\rho)(v-f-(1-\delta k)c)^2}{8(1+n(1-\lambda-k\rho-\varphi)-k\omega)^2}$
$\boldsymbol{PS^{F*}}$	$\dfrac{(2-n)n(1-k\omega)(v-f-(1-\delta k)c)^2}{8(1+n(1-\lambda-k\rho-\varphi)-k\omega)^2}$
$\boldsymbol{SW^{F*}}$	$\dfrac{n(v-f-(1-\delta k)c)^2\big(n(1-\rho k)+(2-n)(1-\omega k)+2(1+n(1-\lambda-k\rho-\varphi)-k\omega)\big)}{8(1+n(1-\lambda-k\rho-\varphi)-k\omega)^2}-C(k)$

providers to offer improved services. In this case, to keep the balance between supply and demand for improved services, this results in a lower equilibrium service price (i.e., $p_I^P < p_T^B$ and $p_I^F < p_T^B$). This finding is consistent with the conclusions of Zhang *et al*. (2022), who observe that consumer privacy concerns reduce both retailers' prices and profits when adopting blockchain technology. Moreover, when the platform adopts digital technology fully, consumers who previously chose traditional services are likely to switch to improved services, and providers who previously offered traditional services may also transition to improved services. In this case, to keep the balance, the platform keeps the price of improved services consistent (i.e., $p_I^P = p_I^F$).

Additionally, Proposition 1(1) shows that consumers pay a higher price for traditional services in scenario P than in scenario B. In scenario B, where only traditional services are offered, the platform tends to lower the commission rate (α) to stimulate transactions and increase profits. Conversely, in scenario P, where both traditional and improved services are available, the two service types compete against each other. To mitigate the impact of this internal competition, the platform sets a higher α, which raises the price of traditional services and encourages consumers to switch to improved services. This differentiated pricing strategy allows the platform to balance the two services segments and improve profits. Consequently, the price of traditional services in scenario P is higher than in scenario B (i.e., $p_T^P > p_T^B$).

Proposition 1(2) indicates that the platform charges a higher transaction commission rate for providers in scenario P than in scenario B, while the combined commission rate remains equal in scenarios P and F. As discussed in Proposition 1(1) regarding the prices of traditional services, the platform increases the commission rate for traditional services to mitigate the intensified competition between traditional and improved services in scenario P. Consequently, the transaction commission rate in scenario P is higher compared to scenario B (i.e., $\alpha_T^P > \alpha_T^B$). Moreover, since consumers willing to purchase improved services face the same costs and pay the same prices in both scenarios P and F, and providers incur the same unit service cost for improved services, the platform maintains the same commission rate for improved services in both scenarios (i.e., $(\alpha+\beta)_I^P = (\alpha+\beta)_I^F$) to ensure a balance between supply and demand of improved services.

Proposition 1(3) shows that more consumers prefer to purchase services in scenarios P and F than in scenario B. By analyzing the utility functions of both consumers and providers in scenarios P and F, we find that consumers opt to purchase services when the utility derived from improved services is positive, and providers offer services when their utility from improved services is positive. Hence, the identical prices and commission rates for improved services in scenarios P and F lead to an equal number of consumers willing to purchase in both scenarios (i.e., $D_T^P + D_I^P = D_I^F$). In scenario B, the higher p_T^B reduces consumers' willingness to purchase, resulting in lower demand (i.e., $D_T^B < D_I^F$). Similarly, the higher p_T^P in scenario P causes the demand for traditional services to be lower than in scenario B (i.e., $D_T^P < D_T^B$). Notably, if $D_T^P = 0$, then scenario P effectively becomes scenario F, meaning only scenarios B and F would exist. Conversely, if $D_I^P = 0$, then scenario P reverts to scenario B, leaving only scenarios B and F. Moreover, due to the supply-demand balance in equilibrium, we could obtain $N_T^P + N_I^P = N_I^F > N_T^B > N_T^P$.

These findings offer important managerial insights for platform managers, particularly regarding the impact of technology adoption on service prices and demand. When a platform adopts digital technology to reduce operating costs, it can lower the price of improved services compared to traditional services. This outcome aligns with industry practices. For example, e-commerce platforms like Alibaba and JD.com leverage big data and AI to establish consumer-to-manufacturer (C2M) supply chains, which reduce costs and enhance efficiency. Merchants on these platforms can decide whether to join C2M supply chains, and those who typically experience lower costs can offer reduced prices (Niu, 2021). Additionally, our findings reveal that technology adoption increases consumer willingness to purchase services, driving higher demand. This outcome is consistent with the findings of Hagspiel *et al*. (2020), who demonstrate that firms can use technology to innovate their products, ultimately increasing demand for better products and higher profits.

5.2 The Platform's Technology Adoption Decisions

The platform determines its technology adoption strategy by evaluating equilibrium profits across different scenarios. Our comparative analysis of these profits reveals that the platform's technology adoption strategy is significantly influenced by its operating cost c. Our comparative analysis of these profits reveals that the platform's technology adoption strategy is significantly influenced by its operating cost c, as highlighted in Proposition 2.

Proposition 2. The optimal technology adoption strategy for the platform is as follows:

(1) When c is lower (i.e., $c < c_1$), the platform prefers partial technology adoption;

(2) When c is in a given intermediate range (i.e., $c_2 \leq c < c_3$), the platform favors full technology adoption;

(3) When c is in another given intermediate range (i.e., $c_1 < c < c_2$) or c is higher (i.e., $c > c_3$), the platform would like to forgo technology adoption.

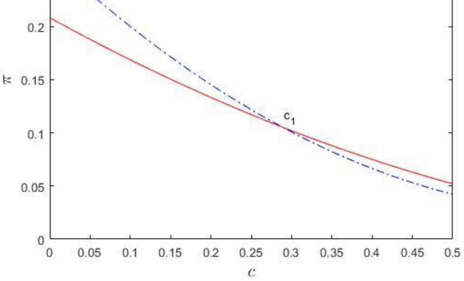
Proposition 2 demonstrates that a lower c could encourage the platform to adopt digital technology partially, whereas a higher c may lead the platform to forgo technology adoption. Analyzing the equilibrium outcomes in scenario P reveals that when $c < c_2$, there are consumers who purchase traditional services (i.e., $D_T^P > 0$). This indicates that when $c < c_2$, the strategy of partial technology adoption is viable, and $\pi^P \neq \pi^F$. The platform faces three options: forgoing technology adoption, partial technology adoption, or full technology adoption. Conversely, when $c \geq c_2$, no consumers choose to purchase traditional services, leading to full technology adoption instead of partial adoption (i.e., $\pi^P = \pi^F$). In this case, the platform chooses between forgoing and full technology adoption.

When $c < c_2$, comparing the equilibrium outcomes in scenarios P and F, we find that consumers have the same demand for services in both scenarios, but they need to pay a higher price for traditional services than for improved services in scenario P. Since the higher price yields higher marginal profit, the platform's profit in scenario P exceeds that in scenario F (i.e., $\pi^P > \pi^F$). Then, we compare the platform's profits in scenarios P and B. Although the traditional service price is higher in scenario P than in scenario B, the lower demand for traditional services caused by the higher price reduces the platform's profit in scenario P. For improved services in scenario P, a higher c positively affects prices (i.e., $\frac{dp_I^P}{dc} > 0$) and negatively affects demand (i.e., $\frac{dD_I^P}{dc} < 0$). As c decreases, its negative impact on improved service demand in scenario P (D_I^P) is insignificant, resulting in higher D_I^P. Conversely, when c is higher, the negative impact on D_I^P is more pronounced, leading to lower D_I^P. Hence, when c is lower (i.e., $c < c_1$), the platform can achieve higher demand and generate more profit in scenario P (i.e., $\pi^P > \pi^B$). Conversely, when c is higher but still within the low-cost range (i.e., $c_1 < c < c_2$), the platform achieves the highest profit in scenario B (i.e., $\pi^B > \pi^P$).

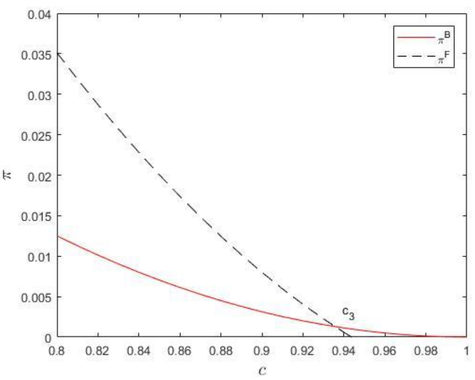
When $c \geq c_2$, by comparing the equilibrium outcomes in scenarios B and F, we find that the higher service price in scenario B (p_T^B) results in lower demand in this scenario than that in scenario F (i.e., $D_T^B < D_I^F$). Similarly, as c decreases, the negative impact on improved service demand becomes weaker, allowing the higher D_I^F to generate more profit for the platform. Thus, when c is lower but within the high-cost range (i.e., $c_2 \leq c < c_3$), the strategy of full technology adoption is more profitable for the platform (i.e., $\pi^F > \pi^B$). However, when c is higher, the significant negative impact on D_I^F narrows the difference between D_I^F and D_T^B. Simultaneously, the higher p_T^B generates more profit for the platform. Hence, when c is higher (i.e., $c > c_3$), the platform is more profitable in scenario B (i.e., $\pi^B > \pi^F$). This result aligns with Demirel and Kesidou (2011), which suggests that cost savings do not necessarily motivate firms to invest in technology.

We validate the analytical results through numerical experiments. Figure 3 illustrates the impact of operating costs c on the platform's profits under scenarios B, P, and F, considering both cases where $c < c_2$ and $c \geq c_2$. For the case of $c < c_2$, the model parameters are set as follows: $v = 1$, $f = 0.4$, $k = 0.5$, $n = 1$, $K = 0.01$, $\lambda = 0.4$, $\phi = 0.4$, $\rho = 0.8$, $\omega = 0.8$, and $\delta = 0.2$. For the case of $c \geq c_2$, the parameters are specified as: $v = 1$, $f = 0.25$, $k = 0.5$, $n = 1$, $K = 0.01$, $\lambda = 0.6$, $\phi = 0.6$, $\rho = 0.6$, $\omega = 0.6$, and $\delta = 0.6$.

Our findings offer valuable managerial insights for platform managers. We find that operating costs influence the viability of the partial technology adoption strategy. When operating costs are relatively low, the platform can choose partial technology adoption. Conversely, if operating costs are relatively high, the businesses of traditional and improved services cannot coexist, and the platform would not adopt digital technology partially. Moreover, when the platform can only choose between forgoing and full technology adoption, lower operating costs would prompt the platform to adopt digital technology fully. This result aligns with the findings of Mishrif and Khan (2023), who suggest that during the COVID-19 pandemic, small and medium enterprises with advanced IT infrastructure and lower operating costs were better positioned to adopt digital technology, thereby enhancing their competitiveness and productivity. Further, when operating costs are high, forgoing technology adoption may be more advantageous. For instance, although RFID technology can efficiently and automatically capture data without human intervention, some medical institutions choose not to adopt it due to high introduction costs and privacy concerns (Yao *et al.*, 2012).



(a) $c < c_2$ and in scenarios B and P



(b) $c \geq c_2$ and in scenarios B and P

Figure 3 The impacts of c on the platform's profits

5.3 Comparisons for Consumer Surplus and Provider Surplus

By comparing the consumer surplus across the three scenarios, we obtain Proposition 3.

Proposition 3. Consumer surplus across the three scenarios is as follows:

(1) When c is lower (i.e., $c < c_2$), the consumer surplus in scenario P (CS^P) is highest;

(2) When c is in a given intermediate range (i.e., $c_2 \leq c < c_4$), the consumer surplus in scenario F (CS^F) is highest;

(3) When c is above a given threshold (i.e., $c > c_4$), the consumer surplus in scenario B (CS^B) is highest.

Proposition 3(1) demonstrates that when c is lower, consumers benefit more from the strategy of partial technology adoption. According to Proposition 1, more consumers purchase improved services in scenario F, leading to a higher consumer surplus from improved services compared to scenario P. However, when c is low (i.e., $c < c_2$), some consumers prefer to pay the higher price p_T^P for traditional services in scenario P (i.e., $D_T^P > 0$). The utility that consumers derive from traditional services raises the total consumer surplus in scenario P, leading to $CS^P > CS^F$. For traditional services, more consumers tend to pay a lower price to purchase traditional services in scenario B compared to that in scenario P (i.e., $D_T^B > D_T^P$). However, the lower improved service price and reduced dissatisfaction cost in scenario P increase consumer utility, attracting consumers to purchase improved services. The increased consumer surplus from improved services raises the total consumer surplus in scenario P, leading to $CS^P > CS^B$. Hence, when c is low (i.e., $c < c_2$), the consumer surplus in scenario P is maximized.

Propositions 3(2) and 3(3) are explained as follows. When c is higher (i.e., $c \geq c_2$), only scenarios B and F are relevant. Higher c increases the service price and reduces demand across both scenarios. In scenario F, there is $p_T^B > p_I^F$.When c is relatively low within this high-cost range (i.e., $c_2 \leq c < c_4$), the impact of c on prices and demand is insignificant. The lower price in scenario F is still attractive to consumers, resulting in $CS^F > CS^B$. However, as c increases, the negative effect of higher c becomes more pronounced, leading to a significant increase in the service price in scenario F. The higher price reduces the number of consumers purchasing services in scenario F, eventually causing $CS^B > CS^F$. Hence, while consumers initially derive more surplus from scenario F, a sufficient higher c (i.e., $c > c_4$) reverses this situation, making scenario B more favorable for consumers.

This result offers valuable insight for consumers, particularly regarding how a platform's operating costs influence their purchasing decisions. Specifically, lower operating costs encourage consumers to purchase services in scenario P. For example, leading hotels like Marriott and Hilton need to pay membership and marketing fees to online travel agencies like Booking.com or Expedia. These fees impact travelers' reservation decisions, and during the pandemic, some travelers opted to book directly with hotels to maximize flexibility (Stavac *et al.*, 2024). Additionally, our findings indicate that the platform's optimal strategy does not always align with consumer benefits. For instance, when operating costs are low or moderate, the platform may gain more by forgoing technology adoption, whereas consumers would benefit more from partial technology adoption. In such cases, consumer-focused policymakers should consider implementing measures that encourage the platform to adopt digital technology partially.

Proposition 4 compares the provider surplus across the three scenarios.

Proposition 4. Provider surplus across the three scenarios is as follows:

(1) When c is lower (i.e., $c < c_2$), the provider surplus in scenario P (PS^P) is maximized;

(2) When c is in a given intermediate range (i.e., $c_2 \leq c < c_5$), the provider surplus in scenario F (PS^F) is maximized;

(3) When c is above a given threshold (i.e., $c > c_5$), the provider surplus in scenario B (PS^B) is maximized.

Proposition 4(1) reveals that when c is lower, providers benefit more from scenario P. As established in Proposition 1, the prices and commission rates for improved services are equal in both scenarios P and F (i.e., $p_I^P = p_I^F$ and $(\alpha + \beta)^P = (\alpha + \beta)^F$), indicating that the utility providers derive from offering improved services is equivalent in these two scenarios. However, due to the higher number of providers offering improved services in scenario F (i.e., $N_I^F > N_I^P$), the provider surplus from improved services is greater in scenario F. Nevertheless, when $c < c_2$, some providers choose to offer traditional services in scenario P (i.e., $N_T^P > 0$). Since the price for traditional services in scenario P is higher (i.e., $p_T^P > p_I^F$), providers derive greater utility from this higher traditional price p_T^P, resulting in $PS^P > PS^F$. For traditional services, although the higher supply in scenario B (i.e., $N_T^B > N_T^P$) increases provider surplus, the higher price in scenario P (i.e., $p_T^P > p_T^B$) offers providers greater utility. Moreover, in scenario P, the reduction in service cost enhances provider utility and increases the supply of improved services, which in turn increases provider surplus, leading to $PS^P > PS^B$.

The explanations of Propositions 4(2) and 4(3) are as follows. When c is high (i.e., $c \geq c_2$), no providers offer traditional services in scenario P, leaving providers to operate only in scenarios B and F. In this context, the combination of a higher price (i.e., $p_I^F > p_T^B$) and higher supply (i.e., $N_I^F > N_T^B$) generates more provider surplus in scenario F, resulting in $PS^F > PS^B$. However, as c increases, the service price also rises. While a higher price leads to more utility for providers, it simultaneously reduces consumers' willingness to purchase, resulting in a decrease in service supply. When c is above a given threshold (i.e., $c > c_5$), this reduction in demand becomes significant in scenario F, leading to a more substantial decline in provider surplus than in scenario B. Hence, if c is lower in the high-cost range (i.e., $c_2 \leq c < c_5$), then $PS^F > PS^B$; if c is higher (i.e., $c > c_5$), then $PS^B > PS^F$.

This result underscores a crucial point: The platform's operating costs significantly influence providers' decisions to join the platform and offer services. We find that when operating costs are low, providers are more inclined to benefit from a platform that partially adopts technology and offers traditional or improved services. Different from the findings of Lin *et al.* (2023), who suggest that driver surplus decreases when operating costs of a ride-sharing platform are relatively moderate, we find that when operating costs are within a given intermediate range, providers will earn more revenue from a platform that fully adopts digital technology. Moreover, when operating costs are high, it is more advantageous for providers to join a platform that forgoes technology adoption. For example, on platforms like Airbnb or Uber, when platform fees or operational costs are high, providers may attempt to bypass the platform's technical support and engage directly with customers after initial contact, thereby avoiding the platform's high commission fees (Storm, 2024).

5.4 Comparisons for Social Welfare

By comparing social welfare across the three scenarios, we derive Proposition 5.

Proposition 5. Social welfare across the three scenarios is as follows:

(1) When c is lower (i.e., $c < c_6$), social welfare in scenario P (SW^P) is highest;
(2) When c is in a given intermediate range (i.e., $c_2 \leq c < c_7$), social welfare in scenario F (SW^F) is highest;
(3) When c is in another given intermediate range (i.e., $c_6 < c < c_2$) or c is higher (i.e., $c > c_7$), social welfare in scenario B (SW^B) is highest.

According to Propositions 2, 3, and 4, when $c < c_2$, the platform's profit, consumer surplus, and provider surplus in scenario P are higher than in scenario F, resulting in $SW^P > SW^F$. Comparing the equilibrium outcomes in scenarios B and P, consumer surplus and provider surplus in scenario P are higher than in scenario B. When c is lower, the platform's profit in scenario P exceeds that in scenario B. Conversely, when c is higher, the platform's profit in scenario B surpasses that in scenario P. The platform's profit significantly affects the industry's social welfare. Therefore, if c is lower (i.e., $c < c_6$), then $SW^P > SW^B$; if c is higher but in the low-cost range (i.e., $c_6 < c < c_2$), then $SW^B > SW^P$. When $c \geq c_2$, only scenarios B and F are relevant. Propositions 2 and 3 indicate that when c is relatively low, the platform's profit, consumer surplus, and provider surplus in scenario F are higher than in scenario B. When c is relatively high, the situation is reversed. Hence, when c is lower within the high-cost range (i.e., $c_2 \leq c < c_7$), we have $SW^P > SW^B$; when c is higher (i.e., $c > c_7$), we have $SW^B > SW^P$.

Our results provide an important implication for policymakers that the platform's optimal technology adoption strategy is beneficial for the industry. For example, Alibaba's Tmall Innovation Center uses AI to reduce product development time by more than half, benefiting not only Alibaba but also the consumer goods industry by accelerating innovation cycles and minimizing product failure risks (Candelon *et al.*, 2020). Additionally, our analysis indicates that when the platform's operating costs are relatively low, although consumers and providers gain from partial technology adoption, forgoing technology adoption may be more profitable for the platform and generate more social welfare within the industry. Hence, in scenarios where the platform opts to forgo technology adoption, policymakers should consider supporting this decision to maximize overall social welfare.

6. EXTENSION

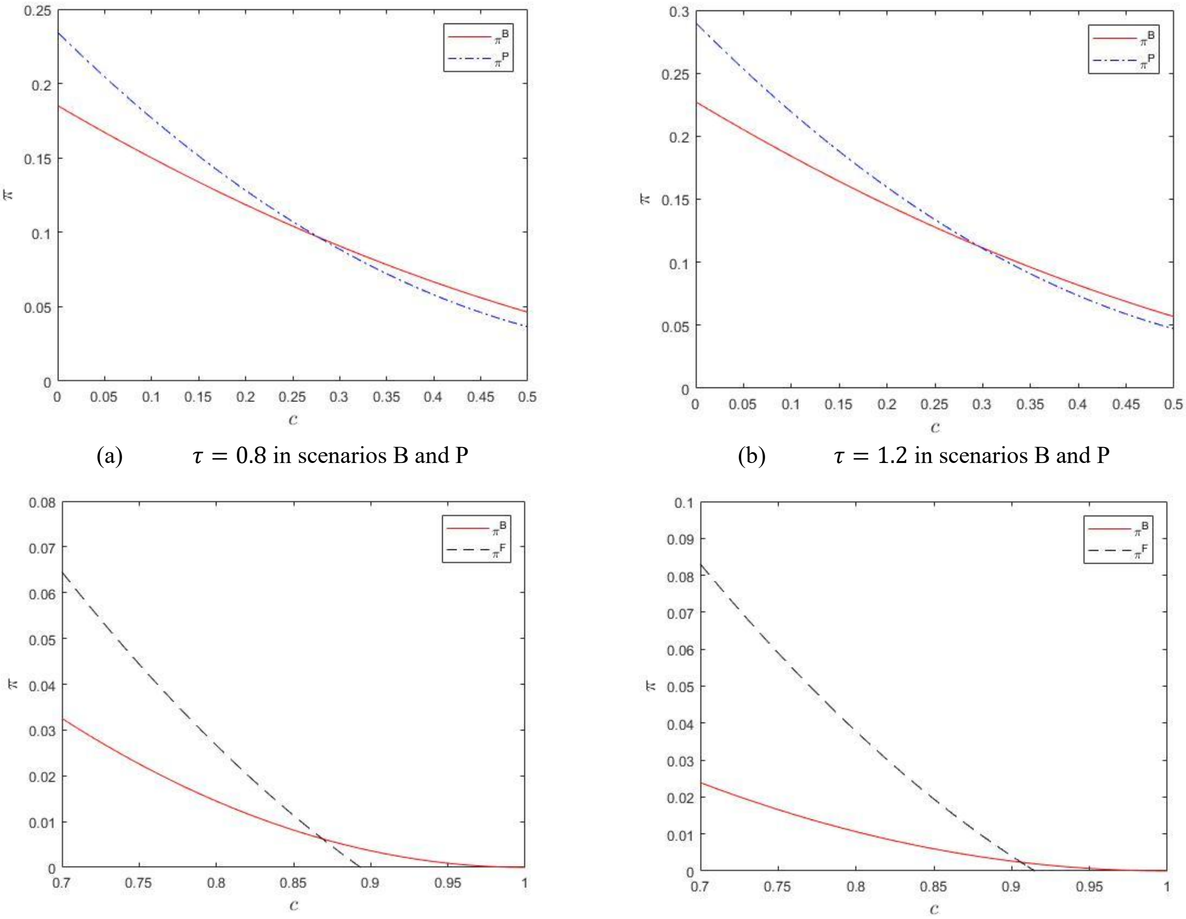
In this section, we examine the robustness of our main results under an alternative modeling assumption. The primary analysis is based on a market-clearing mechanism in which demand equals supply at equilibrium (i.e., $D = N$). However, in practice, demand may deviate from supply. To capture this possibility, we extend the model to allow for demand-supply imbalance by defining $D = \tau N$, where τ reflects the relative magnitude of demand to supply. Specifically, when $0 < \tau < 1$, demand is lower than supply; conversely, when $\tau > 1$, demand exceeds supply.

Under scenarios B, P, and F, the model setup and functional structure remain consistent with the main model. Specifically, demand is derived from the consumer utility function, while supply is derived from the provider utility function. The key distinction lies in the solution process, where we introduce the condition $D = \tau N$ to reflect a potential imbalance between demand and supply. Following a similar procedure to that in the main model, we first derive the price expression based on the condition $D = \tau N$. This price expression is then substituted into the platform's profit function. We proceed by computing the first-order derivative of the profit function with respect to the commission rate to solve for the equilibrium commission rate. Finally, substituting the equilibrium commission rate back into the expressions for price, demand, and profit yields the equilibrium outcomes under each scenario. The detailed results are presented in Table A.2.

In addition, based on the equilibrium outcomes, we establish the equilibrium conditions for each scenario. By comparing the profits of the platform under different technology adoption scenarios, we observe the following patterns:

When $c < c_2$, all three scenarios—B (no adoption), P (partial adoption), and F (full adoption)—are feasible. In this case, we find that $\pi^{P*} \neq \pi^{F*}$, and by comparing the profits under scenarios P and F, it consistently holds that $\pi^{P*} > \pi^{F*}$. Further comparison between scenarios B and P reveals that when $c > c_8$, the platform's profit is higher under scenario B ($\pi^{B*} > \pi^{P*}$). Conversely, when $c < c_8$, partial adoption yields greater profits ($\pi^{P*} > \pi^{B*}$).

When $c \geq c_2$, the profits under scenarios P and F converge ($\pi^{P*} = \pi^{F*}$), and only scenarios B and F remain viable. Comparing these two, we find that when $c < c_9$, full



(a) $\tau = 0.8$ in scenarios B and P (b) $\tau = 1.2$ in scenarios B and P

(c) $\tau = 0.8$ in scenarios B and F (d) $\tau = 1.2$ in scenarios B and F

Figure 4 The profits of the platform in different scenarios across varying values of τ.

adoption is more profitable ($\pi^{F*} > \pi^{B*}$), when $c > c_9$, the platform prefers not to adopt the technology ($\pi^{B*} > \pi^{F*}$). The analytical expressions for c_8 and c_9 are provided in Appendix Table A.1.

Based on these results, we draw the following conclusions regarding the platform's strategic preferences:

(1) When $c < c_8$, the platform prefers partial technology adoption;
(2) When $c_2 \le c < c_9$, the platform favors full technology adoption;
(3) When $c_8 < c < c_2$ or $c > c_9$, the platform would like to forgo technology adoption.

These conclusions are consistent with those derived from the main model. Figure 4 further illustrates the platform's strategy selection under conditions of supply-demand imbalance across varying values of τ.

Subfigures 4(a) and 4(b) compare the profits of scenarios B and P when $c < c_2$, under $\tau < 1$ (supply exceeds demand) and $\tau > 1$ (demand exceeds supply), respectively. In both cases, once c surpasses a certain threshold, the platform achieves higher profits by not adopting the technology. However, the operating cost of non-adoption is lower when supply exceeds demand (i.e., $\tau = 0.8$) than when demand exceeds supply (i.e., $\tau = 1.2$). Subfigures 4(c) and 4(d) compare scenarios B and F under $c \ge c_2$. The research findings further confirm that relatively high operating costs may make it more profitable for platforms to forgo technology adoption. Overall, these results confirm the robustness of our main findings and reinforce the platform's sensitivity to both cost and market structure in determining its optimal technology adoption strategy.

7. CONCLUSION, MANAGERIAL INSIGHTS, AND FURTHER RESEARCH

Two-sided platforms serve as intermediaries that connect consumers and providers, reshaping traditional transaction models. While the adoption of digital technology can significantly enhance transaction efficiency, it may also introduce additional costs for consumers. To determine the optimal technology adoption strategies for a two-sided platform, our study develops three distinct technology adoption models and examines the equilibrium conditions under which each model is preferred. Unlike previous research that primarily considers whether a platform should adopt digital technology, our study also explores the choice between partial and full adoption.

7.1 Conclusions

This work contributes to multiple research streams, including service pricing and technology adoption strategies of two-sided platforms.

First, by investigating the equilibrium prices, commission rates, and demand under each technology adoption strategy, we find that, compared to traditional services without technology, improved services with technology have lower prices and transaction commission rates, along with higher service demand, somewhat similar to the findings of Zhang *et al*. (2022) and Hagspiel *et al*. (2020). Notably, under partial technology adoption, the price of traditional services is higher than in the scenario where no technology is adopted at all.

Second, our model evaluates the platform's strategic decisions regarding technology adoption. We show that when operating costs are low, the platform tends to partially adopt digital technology. When costs fall within a moderate range, full adoption becomes more attractive. However, when costs are either high or in another moderate range, the platform may forgo adoption altogether. While Flatt (2024) argues that cost reduction is the primary motivation for technology adoption, our findings emphasize that cost savings alone are not sufficient to justify adoption. Platforms must weigh the benefits of technological enhancement against the direct and indirect costs it imposes on consumers and providers.

Third, we examine the implications of technology adoption for consumer surplus, provider surplus, and social welfare, offering policy-relevant insights. According to Propositions 3, 4, and 5, digital technology adoption does not always improve outcomes across all stakeholders. When operating costs are low, partial adoption benefits both consumers and providers and maximizes social welfare. When costs are moderate, full adoption becomes more favorable. Conversely, when operating costs are high, no adoption may yield the greatest benefits for both users and society.

7.2 Managerial Insights

Our analysis yields several managerial and practical insights.

First, when setting prices and commissions, platform managers should be aware that the coexistence of traditional services and improved services in the partial adoption scenario can lead to internal competition. In such cases, prices for traditional services should be set higher than improved services and those in scenarios without any digital technology. Additionally, to mitigate the negative impacts of internal competition, managers should consider a differentiated commission structure, adjusting both the transaction and technology commission rates (e.g., α, β). This approach allows the platform to maintain provider participation and profitability across varying levels of technology adoption.

Second, the platform's optimal technology strategy is highly dependent on its operating cost structure. Managers should recognize that digital technology is not universally beneficial. The decision to adopt must carefully consider the trade-off between marginal efficiency gains and the associated investment and consumer learning costs (e.g., $C(k)$, f). When operating costs are low and consumer acceptance is heterogeneous, partial adoption may serve as a viable transitional strategy. When operating costs are relatively high, full adoption is justified only if it brings substantial process efficiencies and enhances customer experience.

Finally, our findings carry important implications for policymakers. Policymakers should consider encouraging platforms with low or moderate operating costs to adopt digital technologies. Moreover, although partial adoption may benefit both consumers and providers, it may reduce overall social welfare if the platform fails to benefit. Therefore, targeted subsidies or other policy instruments could be introduced to incentivize partial adoption where it aligns with broader welfare objectives.

7.3 Limitations and Future Research

Although this study makes several contributions to the literature, it has some limitations that can be explored in further research.

First, our model assumes symmetric information among consumers, providers, and the platform when analyzing technology adoption strategies. In reality, platforms often face information asymmetry regarding consumer preferences (such as dissatisfaction levels or technology acceptance) and provider characteristics (such as service costs or willingness to adopt technology). Such asymmetries can significantly affect participation decisions on both sides of the market and, consequently, influence the platform's strategic choices. Future research should therefore examine platform technology adoption decisions under conditions of information asymmetry.

Second, we develop a game model to analyze the strategy choices of two-sided platforms and use numerical simulations to verify the reliability of the results. However, the lack of actual data may result in findings that do not fully align with reality. Therefore, in future research, we will consider collecting actual data and conducting empirical studies to address the limitations of the current methodology.

Third, this study treats digital technology as a homogeneous category without distinguishing the differential impacts of various technologies. In practice, different digital innovations can affect stakeholders differently. For instance, AI may primarily reduce consumer dissatisfaction and lower provider service costs, whereas blockchain technology may enhance trust and transparency. Future work could investigate platform adoption strategies by differentiating between specific digital technologies and their distinct effects on consumers, providers, and the platform.

ACKNOWLEDGEMENTS

This work was supported by the Research Start-up Foundation of Chaohu University [grant number KYQD-2025059] and the National Natural Science Foundation of China [grant numbers 72131006, 72171073].

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APPENDIX 1: THRESHOLD VALUE

Table A.1 Expressions for thresholds.

Index	Expression
c_1	$\dfrac{n\big(vk(n\rho+\omega)-f(1+n(1-\lambda-\varphi))\big)-2\sqrt{C(k)nk(n\rho+\omega)\big((1+n(1-\lambda-\varphi))-k(n\rho+\omega)\big)(1+n(1-\lambda-\varphi))}}{n\big(k(n\rho+\omega)-\delta k(1+n(1-\lambda-\varphi))\big)}$
c_2	$\dfrac{f}{\delta k}$
c_3	$\dfrac{1}{n\big(k(n\rho+\omega)-\delta k(1+n(1-\lambda-\varphi))(2-k\delta)\big)}\Big(n\big(vk(n\rho+\omega)-(f-fk\delta+kv\delta)(1+n(1-\lambda-\varphi))\big)$ $-\sqrt{n\big((1+n(1-\lambda-\varphi))-k(n\rho+\omega)\big)(1+n(1-\lambda-\varphi))\Big(n(f-kv\delta)^2+4C(k)\big(k(n\rho+\omega)-k(1+n(1-\lambda-\varphi))\delta(2-}$
c_4	$\dfrac{v\big(1+n(1-\lambda-\varphi)-k(n\rho+\omega)-\sqrt{1-k\rho}(1+n(1-\lambda-\varphi))\big)+\sqrt{1-k\rho}f(1+n(1-\lambda-\varphi))}{1+n(1-\lambda-\varphi)-k(n\rho+\omega)-(1-\delta k)\sqrt{1-k\rho}(1+n(1-\lambda-\varphi))}$
c_5	$\dfrac{v\big(1+n(1-\lambda-\varphi)-k(n\rho+\omega)-\sqrt{1-k\omega}(1+n(1-\lambda-\varphi))\big)+\sqrt{1-k\omega}f(1+n(1-\lambda-\varphi))}{1+n(1-\lambda-\varphi)-k(n\rho+\omega)-(1-\delta k)\sqrt{1-k\omega}(1+n(1-\lambda-\varphi))}$
c_6	$\dfrac{X+k(n\rho+\omega)(1+n(1-\lambda-\varphi))\big((1+n(1-\lambda-\varphi))-k(n\rho+\omega)\big)\sqrt{Y}}{Z}$, where $X=n\Big(f(1+n(1-\lambda-\varphi))^2\Big(2k(n\rho+\omega)\Big(-k^2(n\rho+\omega)^2-k\delta(1+n(1-\lambda-\varphi))^2+k(n\rho+\omega)\Big(1+(1+n(1-\lambda-\varphi))-k\delta\big(1-(1+n(1-\lambda-\varphi))\big)\Big)\Big)+k(2\omega+n(\rho-\omega))\big(2k^2\delta(n\rho+\omega)(1+n(1-\lambda-\varphi))-k\delta(1+n(1-\lambda-\varphi))^2-k^2(n\rho+\omega)^2\big)\Big)+vk^2(n\rho+\omega)^2\Big(2\big(1+(1+n(1-\lambda-\varphi))\big)\big(k^2(n\rho+\omega)^2+k\delta(1+n(1-\lambda-\varphi))^2-k(n\rho+\omega)(1+n(1-\lambda-\varphi))\big)-2k(n\rho+\omega)(1+n(1-\lambda-\varphi))\big(1+k\delta(1+n(1-\lambda-\varphi))\big)+k(2\omega+n(\rho-\omega))(1+n(1-\lambda-\varphi))^2(1-k\delta)\Big)\Big)$, $Y=n\Big(n\big(2k(n\rho+\omega)-k(1+n(1-\lambda-\varphi))(2\omega+n(\rho-\omega))\big)^2(k\delta v-f)^2-8C(k)\big(k(n\rho+\omega)-k\delta(1+n(1-\lambda-\varphi))\big)\Big(2k^3(n\rho+\omega)^3\big(1+(1+n(1-\lambda-\varphi))\big)+2k^2\delta(n\rho+\omega)(1+n(1-\lambda-\varphi))^3-2k^2(n\rho+\omega)^2(1+n(1-\lambda-\varphi))\Big(2+(1+n(1-\lambda-\varphi))-k\delta\big(1-(1+n(1-\lambda-\varphi))\big)\Big)+k(1+n(1-\lambda-\varphi))^2(2\omega+n(\rho-\omega))\big(k(n\rho+\omega)+k\delta(1+n(1-\lambda-\varphi))-2k^2\delta(n\rho+\omega)\big)\Big)\Big)$, and $Z=kn\big(n\rho+\omega-\delta(1+n(1-\lambda-\varphi))\big)\Big(2k^3(n\rho+\omega)^3\big(1+(1+n(1-\lambda-\varphi))\big)-2k^2(n\rho+\omega)^2(1+n(1-\lambda-\varphi))\Big(2+(1+n(1-\lambda-\varphi))-k\delta\big(1-(1+n(1-\lambda-\varphi))\big)\Big)+k^2(1+n(1-\lambda-\varphi))^3\delta(n(\rho-\omega)+2\omega)+k^2(n\rho+\omega)(1+n(1-\lambda-\varphi))^2\big(2\delta(1+n(1-\lambda-\varphi))+(1-2k\delta)(n\rho+(2-n)\omega)\big)\Big)$

Table A.1 Expressions for thresholds (con't)

Index	Expression
c_7	$\frac{Q+(1+n(1-\lambda-\varphi))\left((1+n(1-\lambda-\varphi))-k(n\rho+\omega)\right)\sqrt{W}}{E}$, where $Q = n\Big(-2fk(n\rho+\omega)(1+n(1-\lambda-\varphi))^2(1-k\delta) + (f(1-k\delta) + k\delta v)(1+n(1-\lambda-\varphi))^2\left(2(1+(1+n(1-\lambda-\varphi))-k\omega)-kn(\rho-\omega)\right) + v\Big(2k^2(n\rho+\omega)^2\left(1+(1+n(1-\lambda-\varphi))\right) - 2k(n\rho+\omega)(1+n(1-\lambda-\varphi))\left(2+(1+n(1-\lambda-\varphi))+k\delta(1+n(1-\lambda-\varphi))\right) + k(1+n(1-\lambda-\varphi))^2(2\omega+n(\rho-\omega))\Big)\Big)$, $W = 2n\Big(-2nk(n\rho+\omega)\left(1+(1+n(1-\lambda-\varphi))\right)(f-k\delta v)^2 + \Big(n\left(1+(1+n(1-\lambda-\varphi))\right)(f-k\delta v)^2 - 4Kk\delta(1+n(1-\lambda-\varphi))^2(2-k\delta)\Big)\left(2(1+(1+n(1-\lambda-\varphi))-k\omega)-kn(\rho-\omega)\right) - 4K\Big(2k^2(n\rho+\omega)^2\left(1+(1+n(1-\lambda-\varphi))\right) - 2k(n\rho+\omega)(1+n(1-\lambda-\varphi))\left(2+(1+n(1-\lambda-\varphi))(1+2k\delta-k^2\delta^2)\right) + k(1+n(1-\lambda-\varphi))^2(2\omega+n(\rho-\omega))\Big)\Big)$, and $E = n\Big(2k^2(n\rho+\omega)^2\left(1+(1+n(1-\lambda-\varphi))\right) - 2k(n\rho+\omega)(1+n(1-\lambda-\varphi))\left(2+(1+n(1-\lambda-\varphi))(1+2k\delta-k^2\delta^2)\right) + k(1+n(1-\lambda-\varphi))^2\Big(2\omega+n(\rho-\omega)+\delta(2-k\delta)\left(2(1+(1+n(1-\lambda-\varphi))-k\omega)-kn(\rho-\omega)\right)\Big)\Big)$
c_8	$\frac{n\tau\left(vk(n\rho\tau+\omega) - f\left(1-n(\lambda-\tau(1-\varphi))\right)\right) - 2\sqrt{n\tau k(n\rho\tau+\omega)\left(1-n(\lambda-\tau(1-\varphi))\right)\left(1-n(\lambda-\tau(1-\varphi))-k(n\rho\tau+\omega\right.}}{n\tau\left(k(n\rho\tau+\omega)-k\delta\left(1-n(\lambda-\tau(1-\varphi))\right)\right)}$
c_9	$\frac{1}{-n\tau\left(n(1-\tau-k\rho)+k\delta(2-k\delta)\left(1-n(\lambda-\tau(1-\varphi))\right)-k\omega\right)}\Big(n\tau\left(n(\lambda-\tau(1-\varphi))(f+(v-f)k\delta)-f(1-k\delta)\right. - v\left(n(1-\tau-k\rho)+k(\delta-\omega)\right)\Big) - \sqrt{n\tau\left(1-n(\lambda-\tau(1-\varphi))\right)(1+n(1-\lambda-k\rho-\tau\varphi)-k\omega)\left(n\tau(f-kv\delta)^2-4K\left(n(1-\tau-k\rho)+k\delta(2-k\delta)\left(1-n(\lambda-\right.\right.\right.}$

APPENDIX 2: EQUILIBRIUM OUTCOMES IN EACH SCENARIO

Equilibrium outcomes in scenario B. Given the consumer utility function in scenario B, $U_T = v - x - p_T + \lambda N$, the service demand is derived as $D = v - p_T + \lambda N$. Similarly, from the provider utility function, the service supply is determined as $N = n\left((1-\alpha)p_T + \varphi D\right)$. By equating supply and demand, we obtain $D = \frac{n(1-\alpha)p_T}{1-n\varphi}$ and $N = \frac{v-p_T}{1-\lambda}$, and the service price $p_T = \frac{v-nv\varphi}{1+n\left((1-\lambda)(1-\alpha)-\varphi\right)}$. Substituting D, N, and p_T into the platform's profit function $\max_{\alpha} \pi = D(\alpha p_T - c)$ and taking the first-order derivative with respect to the commission rate α, the equilibrium commission rate is obtained as $\alpha_T^{B*} = \frac{(1+n(1-\lambda-\varphi))(v+c)}{v(2+n(1-\lambda-2\varphi))+n(1-\lambda)c}$. Then, we obtain the equilibrium outcomes in scenario B, as shown in Table 2.

Equilibrium outcomes in scenario P. In scenario P, consumer utility from traditional services is given by $U_T = v - x - p_T + \lambda N$ and from improved services by $U_I = v - f - (1-\rho k)x - p_I + \lambda N$. Consumers will choose to purchase traditional services when $U_T > U_I$ and $U_T > 0$ and improved services when $U_I > U_T$ and $U_I > 0$. Therefore, the total service demand in scenario P is $D = \frac{v-f-p_I+\lambda N}{1-\rho k}$, where the demand for traditional services is $D_T = \frac{f-p_T+p_I}{\rho k}$, the demand for improved services is $D_I = \frac{v-f-p_I+\lambda N}{1-\rho k} - \frac{f-p_T+p_I}{\rho k}$.

On the supply side, based on the provider utility for traditional and improved services, the total service supply in scenario P is $N = n\frac{(1-\alpha-\beta)p_I+\varphi D}{1-\omega k}$, where the supply of traditional services is $N_T = n\frac{(1-\alpha)p_T-(1-\alpha-\beta)p_I}{\omega k}$, the supply of improved services is $N_I = n\frac{(1-\alpha-\beta)p_I+\varphi D}{1-\omega k} - n\frac{(1-\alpha)p_T-(1-\alpha-\beta)p_I}{\omega k}$.

Given $D_T = N_T$ and $D_I = N_I$, we derive $D_T = \frac{f-p_T+p_I}{k\rho}$ and $D_I = \frac{n(1-\alpha-\beta)p_I}{1-\omega k-n\varphi} - \frac{f-p_T+p_I}{k\rho}$, $p_T = \frac{\omega f\left(n(1-\alpha-\beta)(1-\rho k-\lambda)+(1-\omega k-n\varphi)\right)+\left(\omega+n\rho(1-\alpha-\beta)\right)(1-\omega k-n\varphi)(v-f)}{\left(n(1-\alpha-\beta)(1-\rho k-\lambda)+(1-\omega k-n\varphi)\right)(n\rho(1-\alpha)+\omega)}$ and $p_I = \frac{(1-\omega k-n\varphi)(v-f)}{n(1-\alpha-\beta)(1-\rho k-\lambda)+(1-\omega k-n\varphi)}$. Substituting these into the platform's profit function $\max_{\alpha,(\alpha+\beta)} \pi = D_T(\alpha p_T - c) + D_I\left((\alpha+\beta)p_I - (1-\delta k)c\right) - C(k)$, and taking the first-order derivative with respect to α and $(\alpha+\beta)$, we obtain the equilibrium outcomes in scenario P, as shown in Table 3.

Equilibrium outcomes in scenario F. In scenario F, the utility functions for consumers and providers are given by $U_I = v - f - (1-\rho k)x - p_I + \lambda N$ and $V_I = (1-\alpha-\beta)p_I + \varphi D - (1-\omega k)y$, respectively. From these, we derive the service demand as $D = \frac{v-f-p_I+\lambda N}{1-\rho k}$ and the service supply as $N = n\frac{(1-\alpha-\beta)p_I+\varphi D}{1-\omega k}$. Given that demand equals supply ($D = N$), we have $D = \frac{n(1-\alpha-\beta)p_I}{1-\omega k-n\varphi}$, $N = \frac{v-f-p_I}{1-\rho k-\lambda}$, and $p_I = \frac{(v-f)(1-n\varphi-k\omega)}{1-n\varphi-k\omega+n(1-\lambda-k\rho)(1-\alpha-\beta)}$. Substituting these into the platform's profit function $\max_{(\alpha+\beta)} \pi = D\left((\alpha+\beta)p_I - (1-\delta k)c\right) - C(k)$, and taking the first-order derivative with respect to $(\alpha+\beta)$, we derive the equilibrium outcomes in scenario F, as shown in Table 4.

Equilibrium outcomes in the extended model. Based on the utility function in the primary model and following a solution process analogous to that used in the main analysis, we derive the demand and supply outcomes under scenarios B, P, and F. Let $D = \tau N$ represent the relationship between demand and supply. For each scenario, we first determine the price expression. By substituting these prices into the platform's profit function and taking the first-order derivative with respect to the commission rate, we obtain the equilibrium commission rate. Substituting this rate back into the price expression yields the equilibrium price, which subsequently allows us to determine the corresponding equilibrium demand and platform profit. Then, we obtained the equilibrium outcomes, as shown in Table A.2.

Table A.2 Equilibrium outcomes under scenarios B, P, and F in the extended model.

Scenario	Index	Expression
B	α_T^{B*}	$\frac{(c+v)\left(1-n\left(\lambda-\tau(1-\varphi)\right)\right)}{v\left(2-n(\lambda-\tau+2\tau\varphi)\right)-cn(\lambda-\tau)}$
	p_T^{B*}	$\frac{v\left(2-n(\lambda-\tau+2\tau\varphi)\right)-cn(\lambda-\tau)}{2\left(1-n\left(\lambda-\tau(1-\varphi)\right)\right)}$
	$D_T^{B*}(N_T^{B*})$	$\frac{(v-c)n\tau}{2\left(1-n\left(\lambda-\tau(1-\varphi)\right)\right)}$
	π^{B*}	$\frac{(v-c)^2 n\tau}{4\left(1-n\left(\lambda-\tau(1-\varphi)\right)\right)}$
P	α_T^{P*}	$(-(c+v)(n\rho\tau+\omega)\left(1-n\left(\lambda-\tau(1-k\rho-\varphi)\right)-k\omega\right)) /(n^2\rho\tau\left((v+c)\left(\lambda-\tau(1-k\rho)\right)+\tau\varphi(2v+k\delta c)\right) + v\omega\left((2\varphi+3k\rho)n\tau-2(1-k\omega)\right)+fn\rho(\tau-n\tau^2\varphi) + (\lambda-\tau)\left(v+f+c(1-k\delta)\right)n\omega-n\left(2v-ck(\omega-\delta)\right)\rho\tau)$
	$(\alpha+\beta)_I^{P*}$	$\frac{\left(v-f+c(1-k\delta)\right)(1+n(\tau(1-k\rho-\varphi)-\lambda)-k\omega)}{(v-f)(2+n(\tau(1-k\rho-2\varphi)-\lambda)-2k\omega)+cn(1-k\delta)\left((1-k\rho)\tau-\lambda\right)}$
	p_I^{P*}	$\frac{(v-f)(2+n(\tau(1-k\rho-2\varphi)-\lambda)-2k\omega)+cn(1-k\delta)\left((1-k\rho)\tau-\lambda\right)}{2(1+n(\tau(1-k\rho-\varphi)-\lambda)-k\omega)}$
	p_T^{P*}	$\frac{f(n\rho\tau+2\omega)+ckn\delta\rho\tau}{2(n\rho\tau+\omega)} + \frac{(v-f)(2+n(\tau(1-k\rho-2\varphi)-\lambda)-2k\omega)+cn(1-k\delta)\left((1-k\rho)\tau-\lambda\right)}{2(1+n(\tau(1-k\rho-\varphi)-\lambda)-k\omega)}$

Table A.2 Equilibrium outcomes under scenarios B, P, and F in the extended model (con't)

Scenario	Index	Expression
	$D_T^{P*}+D_I^{P*}$ $(N_T^{P*}+N_T^{P*})$	$\frac{n(v-f-c(1-k\delta))\tau}{2(1+n(\tau(1-k\rho-\varphi)-\lambda)-k\omega)}$
	$D_T^{P*}(N_T^{P*})$	$\frac{n(f-ck\delta)\tau}{2k(n\rho\tau+\omega)}$
	$D_I^{P*}(N_I^{P*})$	$\frac{n(v-f-c(1-k\delta))\tau}{2(1+n(\tau(1-k\rho-\varphi)-\lambda)-k\omega)}-\frac{n(f-ck\delta)\tau}{2k(n\rho\tau+\omega)}$
	π^{P*}	$\frac{1}{4k(n\rho\tau+\omega)(1+n(\tau(1-k\rho-\varphi)-\lambda)-k\omega)}\Big(n\tau\Big((f-ck\delta)^2\Big(1-n\big(\lambda-\tau(1-\varphi)\big)\Big)+k(v-c)\big(v-c-2(f-ck\delta)\big)(n\rho\tau+\omega)\Big)\Big)-C(k)$
F	$(\alpha+\beta)_I^{F*}$	$\frac{(v-f+c(1-k\delta))(1+n(1-\lambda-k\rho-\tau\varphi)-k\omega)}{(v-f)(2+n(1-\lambda-k\rho-2\tau\varphi)-2k\omega)+cn(1-k\delta)(1-\lambda-k\rho)}$
	p_I^{F*}	$\frac{(v-f)(2+n(1-\lambda-k\rho-2\tau\varphi)-2k\omega)+cn(1-k\delta)(1-\lambda-k\rho)}{2(1+n(1-\lambda-k\rho-\tau\varphi)-k\omega)}$
	D_I^{F*}	$\frac{n(v-f-c(1-k\delta))\tau}{2(1+n(1-\lambda-k\rho-\tau\varphi)-k\omega)}$
	π^{F*}	$\frac{n(v-f-(1-\delta k)c)^2\tau}{4(1+n(1-\lambda-k\rho-\tau\varphi)-k\omega)}-C(k)$

APPENDIX 3: PROOF OF PROPOSITIONS

Proof of Proposition 1. By analyzing and comparing the equilibrium outcomes in scenarios B, P, and F, we have $p_T^{P*}>p_T^{B*}>p_I^{P*}=p_I^{F*}$, $\alpha_T^{P*}>\alpha_T^{B*}$, $(\alpha+\beta)_I^{P*}=(\alpha+\beta)_I^{F*}$, and $D_T^{P*}+D_I^{P*}=D_I^{F*}>D_T^{B*}>D_T^{P*}$.

Proof of Proposition 2. In scenario P, the equilibrium demand for traditional services is given by $D_T^{P*}=\frac{n(f-\delta kc)}{2k(n\rho+\omega)}$. If the condition $c<c_2$ holds, then $D_T^{P*}>0$ and $\pi^{P*}\neq\pi^{F*}$. Note that the functions of this threshold and the other thresholds are summarized in Table A.1. Under this condition, the platform has three technology adoption strategies available: Forgoing adoption, partial adoption, and full adoption. However, if $c\geq c_2$, then $\pi^{P*}=\pi^{F*}$, leaving the platform with only two strategic options: forgoing adoption or full adoption.

When $c<c_2$, by comparing the equilibrium profits in scenarios P and F, we find that $\pi^{P*}>\pi^{F*}$. The comparison of profits between scenarios B and P reveals that when $c<c_1$, $\pi^{P*}>\pi^{B*}$. Otherwise, $\pi^{B*}>\pi^{P*}$.

When $c\geq c_2$, comparing the platform's profits in scenarios B and F, we find that when $c<c_3$, $\pi^{F*}>\pi^{B*}$. Otherwise, $\pi^{B*}>\pi^{F*}$.

Proof of Proposition 3. When $c<c_2$, by comparing consumer surplus in scenarios P and F, we find that $CS^{P*}>CS^{F*}$. Similarly, comparing consumer surplus between scenarios B and P, we find that $CS^{P*}>CS^{B*}$. When $c\geq c_2$, comparing consumer surplus in scenarios B and F, we observe that when $c<c_4$, $CS^{F*}>CS^{B*}$. Otherwise, $CS^{B*}>CS^{F*}$.

Proof of Proposition 4. When $c<c_2$, by comparing provider surplus in scenarios P and F, we find that $PS^{P*}>PS^{F*}$. Additionally, comparing provider surplus between scenarios B and P reveals that $PS^{P*}>PS^{B*}$. When $c\geq c_2$, comparing provider surplus in scenarios B and F, we find that when $c<c_5$, $PS^{F*}>PS^{B*}$. Otherwise, $PS^{B*}>PS^{F*}$.

Proof of Proposition 5. When $c<c_2$, by comparing social welfare in scenarios P and F, we find that $SW^{P*}>SW^{F*}$. Similarly, comparing social welfare between scenarios B and P, we find that when $c<c_6$, $SW^{P*}>SW^{B*}$. When $c\geq c_2$, comparing social welfare in scenarios B and F, we find that when $c<c_7$, $SW^{F*}>SW^{B*}$. Otherwise, $SW^{B*}>SW^{F*}$.

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