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Designing Online Platforms for Offline Services: The Bigger, the Better?

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Empowered by information technologies, online platforms enable service providers to offer customized services that Chinese consumers have increasingly desired. Despite its tremendous value-creation potential, offering customized services encourages greater opportunism from the service providers. While reputation-based mechanisms have been proposed to foster trust, their effectiveness is limited by the disadvantageous initial state of the Chinese industries. To address this problem, we propose a novel platform design where, from its inception, the platform deliberately limits the number of service providers below a certain threshold, even if they are homogenous. Without imposing this threshold, the competition among the service providers may lead to a unique equilibrium under which all the service providers shirk. In contrast, by imposing the threshold, the platform may induce a welfare-enhancing equilibrium where (i) the service providers on the platform enjoy higher capacity utilization than those outside and are motivated to exert effort by future concerns, and (ii) customers prefer service providers on the platform and are willing to pay a premium. We evaluate the implications of our proposed approach on platform profitability, specifically by comparing different payment schemes. We generalize the model regarding imperfect monitoring signals and the entry and exit of service providers. Our work sheds new light on how platform design can help reduce market frictions in economic exchanges and potentially influence the evolution of industries.

Key words: offline-to-online platform; opportunism; incentive design; provider-restriction strategy

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1. Introduction

In this paper, we study how an online platform can mitigate the opportunistic behavior of service providers. Online platforms have recently emerged in China, as in the US, to transform many traditional service industries, including remodeling, home services, moving, wedding planning, car repair, and many others. The business model of these online platforms is often called Offline-to-Online, or O2O, in that online platforms connect buyers and service providers that previously transacted offline (Furr and Zhu 2016, Li, Shen, and Bart 2018, Zhu, Chen, Chen, and Lin 2017). Enabled by technological advances, such as smart phones, online platforms offer new ways to reduce market frictions (Chatain and Zemsky 2011, Gans and Stern 2010, Obloj and Zemsky 2015, Rawley and Simcoe 2010, Yao 1988) and, in turn, create economic value (Boudreau and Hagiu 2009, Gans 2012, Hagiu 2014, Hagiu and Wright 2015, Parker, Van Alstyne, and Choudary 2016). Platforms reduce search and matching costs so that buyers and service providers can more easily find and interact with each other (Arnosti, Johari, and Kanoria 2018, Halaburda and Oberholzer-Gee 2014, Halaburda, Piskorski, and Yildirim 2018, Kanoria and Saban 2017, Li and Netessine 2018). Reputation-based mechanisms, such as user feedback and certification (Cabral and Hortaçsu 2010, Cui, Li, and Zhang 2018, Elfenbein, Fisman, and McManus 2015, Jin and Kato 2007, Zhang and Zhu 2010), are also widely adopted. By linking the outcomes and awards over time these mechanisms are capable of expanding the set of equilibrium outcomes and may further reduce the information asymmetry between the two sides.

Unlike in the US, Chinese service industries have suffered from much more severe opportunism, another type of market friction, which motivates our model here. This salient feature of the Chinese service sector can be partially attributable to a disadvantageous initial state of the economy. Starting from a centrally planned economy, China has gradually transitioned toward a market economy, encouraging the entry of private firms to meet the increasing consumer demand. In many industries entrepreneurs quickly rushed in, resulting in over-capacity and excessive competition. While these industries may evolve toward consolidation, the evolution process often takes many years or decades (Klepper 2002). Before industry consolidation, the presence of fierce competition makes it difficult for individual service providers to foresee stable future orders. The resulting uncertainty and diminishing prospects cause the service providers to behave as if they care more about the short term than the long term; they heavily discount the future in economic terms. If the service providers get a job in the current period, they have incentives to make more profit now by using inferior inputs and exerting less effort, which likely results in lower service quality and further diminishes prospects. Such opportunistic behavior is particularly difficult to control in China because its underdeveloped legal infrastructure exacerbates the inevitable incompleteness of contracts (Khanna 2018, Obloj and Zemsky 2015). The prevalence of the opportunistic behavior also implies that reputation-based mechanisms are likely to fail to foster trust and to enhance the social welfare before the industry consolidates and the exchange system stabilizes. As such, the system may be trapped in an inferior equilibrium despite the reputation-based mechanisms.

The issue of opportunism is especially difficult to address for services characterized by high customization and low transaction frequency (upper-left cell in Table 1). For example, home remodeling or wedding planning need to be tailored to the specific needs of each customer, and people tend to undertake major remodeling once or undergo only a small number of weddings. When services are more or less standardized, such as the sale of tissue paper, there is not much room for opportunistic behavior, because little sales effort is involved and the outcome is straightforward

Table 1 Industry categorization

	Low-frequency	High-frequency
Customized	• Remodeling or renovation • Wedding planning • Postpartum care • Immigration	• Housekeeping • Babysitting and child care
Standardized	• Immunization • Personal tax preparation	• Online retailing • Food delivery • Ride sharing

to assess. When the transaction frequency is high, such as for ridesharing and food delivery, a good/poor reputation can build up relatively quickly based on transaction history. However, when the process of providing a service involves a significant amount of customization, severe opportunism is likely to rise. For example, a wedding planner may not work as hard as necessary to prepare food of the quality she advertised; at the same time, it is extremely challenging to specify in a contract how wholeheartedly food items are to be prepared. Moreover, when the transaction frequency is relatively low, reputation building occurs over time, because many work outcomes are required before it can be determined whether the service provider is reputable, thus increasing the incentive to shirk in early transactions (Cabral and Hortaçsu 2004, 2010, Diamond 1989).[1] In these high customization and low transaction frequency industries, the effectiveness of a reputation-based mechanism also is significantly reduced by the prevalence of fake reviews (Luca and Zervas 2016, Mayzlin, Dover, and Chevalier 2014), the lack of social trust (Nee, Holm, and Opper 2018, Wu, Firth, and Rui 2014), as well as the flexible, but less specialized, nature of the Chinese workforce which fluidly enters and exits industries (Li 2013, Wang, Huang, and Rozelle 2017).

As Chinese consumers become more sophisticated, they have begun to upgrade their consumption, which presents a wonderful market opportunity. But due to potential opportunism characterized above, the supply side has been unable to meet the growing demand for high-quality services, especially for those with high customization and low frequency. In this study, we propose a novel approach in which the platform addresses the opportunism problem by playing a more proactive coordination role.

Our approach builds on the basic economic insight of the reputation-based mechanism that regulates current period behavior via future prospects. In the reputation-based mechanism, whenever a service provider delivers a low-quality service outcome, he suffers from diminishing prospects and might be suspended from trading for a certain amount of time or even forever. This interplay

[1] Infrequent life events are likely to require customization, while frequent ones are often characterized by standardization. As a result, the off-diagonal cells in Table 1 may have fewer entries than the diagonal ones.

between the past and the future enlarges the equilibrium set despite that the observed outcomes in the past can be unrelated to the present or future outcomes. As such, while shirking and obtaining only the reservation utility remains an equilibrium, the resulting repeated game may also sustain an equilibrium in which the service providers exert welfare-improving effort and enjoy a premium in the future. The attainment of this equilibrium, however, relies on the key condition that future prospects are sufficiently bright. This condition may be violated when excessive competition among service providers weakens future concerns by reducing the expected utilization of their capacity. Our approach addresses the violation of this condition. We propose that while in a market economy competition cannot be cut back overnight by a social planner, the platform can create an environment within which competition is mitigated. Specifically, the platform can reduce competition among a subgroup of the service providers by accepting only a subset of service providers and directing customer flow to them. That is, the platform deliberately limits the network size on the service provider side. We term this approach the provider-restriction strategy.

Using the provider-restriction strategy, the platform may discipline the service providers by suspending a service provider whenever he delivers a low-quality outcome, the same as in the reputation-based mechanism. But different from the reputation-based mechanism, by abating competition among service providers upon the inception of the platform, the provider-restriction strategy offers them a greater prospect and premium pay for work well done. By doing so, the provider-restriction strategy further expands the set of equilibrium outcomes. We demonstrate that when the reputation-based mechanism fails to induce the effort, the provider-restriction strategy may support a welfare-enhancing equilibrium—it is in the service providers' best interest to join the platform and exert effort; anticipating this desirable behavior on the platform, customers are wise to prefer service providers on the platform. In this equilibrium, the service providers outside the platform are still suppliers in the overall system, but the service providers on the platform capture a disproportionally larger share of demand compared to those outside the platform.

After developing the above key insight, we conducted various analyses that produce a number of interesting results. Due to the proliferation of the equilibria, we discuss how a proactive platform employing the provider-restriction strategy may avoid the severe welfare loss during the industry consolidation periods (i.e., reputation-building periods) and coordinate the system to achieve a better equilibrium in spite of unfavorable features that plague the Chinese industries. Moreover, we demonstrate an inverted-U shape relationship between platform profit and the number of service providers when the platform charges service providers commission fees. This relationship is due to the tradeoff associated with the network size on the service provider sidehaving more service providers on the platform increases revenue streams, but the competition among service providers limits future prospects and makes incentive alignment difficult, decreasing the maximum commission fees that the platform can charge. We further compare different payment schemes, namely commission fees versus entry fees, and show how entry fees allow the platform to extract rents ex ante and to fend off fraudulent re-entry. Finally, we generalize the model by changing the degree to which the outcome can signal effort and by permitting entry and exit of service providers. These analyses demonstrate the robustness of the key results, while also generating new findings on the optimal structure of the suspension policy.

Although entrepreneurs using platform-based business models may often be pressured by capital to pursue size, bigger is not always better due to the existence of market frictions. While our exploration of this tension was motivated by the salient features of the Chinese service sector, the findings and the proposed mechanisms can be relevant in other contexts or other countries, as well. For example, Boudreau (2008, 2012) show that, despite beneficial network effects, a greater number of application software developers on a given platform is associated with a lower level of product improvement activities from the developers, thereby implying an intermediate optimal platform size. Also, consistent with this idea is an anecdote at Alibaba in China. Initially, there was a debate between a senior executive and local operational personnel regarding moving plastics injection molders onto Alibaba's e-commerce platform. The local operational personnel planned to bring all four hundred injection molding plants online because a larger size could demonstrate the success of the platform. Nevertheless, the executive chose to precommit to a threshold of 40 and helped those who joined obtain more business orders. Over one year, more than half of the off-platform molders perished, while those on the platform prospered, thanks to the traffic-directing effect of the platform. As such, the platform effectively accelerated the industry consolidation process and helped eliminate redundant capacity, a fundamental phenomenon that has hindered the economic development in China.[2]

2. Literature and Contributions

Our paper builds on and contributes to several streams of literature. First, we add to the literature on market frictions and platform strategy. As recognized by prior strategy literature, the examination of market frictions provides an important perspective to design firm strategy (Chatain and Zemsky 2011, Gans and Stern 2010, Obloj and Zemsky 2015, Rawley and Simcoe 2010, Yao 1988). Echoing this insight and extending earlier platform research focusing on two-sided pricing strategies (Armstrong 2006, Caillaud and Jullien 2003, Rochet and Tirole 2006), the recent platform literature highlights reducing market frictions as one of the economic foundations for platforms to create value (Boudreau and Hagiu 2009, Gans 2012, Hagiu 2014, Hagiu and Wright 2015, Parker

[2] http://www.gov.cn/zwgk/2013-10/15/content_2507143.htm

et al. 2016). For example, Hagiu (2011) and Hagiu (2014) suggest that platforms (e.g., Nintendo as a video game console maker) can mitigate the "lemons market failure" and curb excessive competition by excluding low-quality platform users (e.g., third-party game developers). This literature calls for "more systematic study" of various non-price strategic governance instruments that platforms can employ to mitigate market frictions and regulate economic activities (Boudreau and Hagiu 2009, page 187). Our paper responds to this call by examining a strategy whereby online platforms can address opportunism by controlling excessive competition.

Second, our work is related to the seminal study by Hagiu and Wright (2018), who demonstrate that online platforms not only connect offline service providers with customers, but also, more importantly, motivate service providers to exert effort. In their model, both the platform and the service providers need to make non-contractible investments, which creates a double-sided moral hazard; meanwhile, the platform also needs to decide whether to control certain transferable decisions itself or leave them to service providers. The interaction between the double-sided moral hazard and the allocation of the right to control transferable decisions generates a number of important results. Different from the model in Hagiu and Wright (2018), our model investigates the situation where the service providers behave opportunistically in the short run because the long-run opportunities are diminished by competition. To address this problem, we show that the platform can limit network size on the service provider side, effectively increasing expected profits in the future (carrot), and then use the potential loss (stick) of such future opportunities to motivate service providers.

Third, we add to prior work that examines the moral hazard problem in online platforms. Relevant here are the studies by Dellarocas (2005) and Cabral and Hortaçsu (2010, 2004), who examine how eBay addresses the problem of sellers' moral hazard using reputation-based mechanisms, where service providers with bad user feedback may suffer from lower future profit. We build on the insight that the future concerns can regulate agents' current behavior. While the reputation-based mechanism is best suited for industries with high transaction frequency where stationary equilibrium can be reached quickly, we study Chinese service industries, especially those that have low transaction frequency, and analyze the proactive role that a platform can take. In such cases, to raise the social welfare as well as to make a profit, the platform can restrict the number of service providers and direct demand flow to only a subset of service providers, even if they are homogeneous. This strategy would signal a commitment to creating a welfare-enhancing equilibrium and enable rapid reputation building. As such, the platform ex post produces a differentiation advantage for the service providers on the platform over those outside even though they are ex ante homogeneous.

Fourth, we complement the literature that focuses on how platforms can mitigate the adverse selection problem, i.e., hidden types of sellers of goods or services (Cui et al. 2018, Elfenbein et al. 2015, Jin and Kato 2007). For this line of research, service providers are heterogeneous in their types, and the key is to uncover the hidden information via user feedback or third-party certification. We differ from earlier work by focusing on opportunism that results from the service providers' non-verifiable actions and outcomes. To ensure that our results are not driven by the heterogeneity of the service providers, our model considers homogenous service providers.

Last but not least, our work contributes to the burgeoning body of research pioneered by Casadesus-Masanell and Halaburda (2014) and Halaburda and Oberholzer-Gee (2014) that unpacks the conditions under which a platform should limit its network size or limit choices available to users. This research highlights that, surprisingly, platform-based ventures often suffer when they follow the conventional wisdom to grow big fast.[3] Recognizing the potential competition and coordination challenges caused by multiple choices, Casadesus-Masanell and Halaburda (2014) demonstrate that the users as a whole may fail to extract the benefit from consumption complementarities. They do so using a model that incorporates user time budgets, creating a new understanding of how a proactive platform can better leverage the network effect by limiting the choices available to users. Relatedly, the search and matching literature shows that while increasing network size will increase its thickness and benefit the cross-side network effect, it will also increase congestion and the heterogeneity of users, thus lowering the quality of matching (Arnosti et al. 2018, Halaburda et al. 2018, Kanoria and Saban 2017, Li and Netessine 2018). To avoid this drawback, it may be beneficial for network size, or the number of choices available to a given user, to be limited. Notice that instead of explicitly excluding service providers, the same equilibrium can be achieved if the platform can hide the service providers and limit the choices that a customer can see during a search. Consistent with this idea, our model provides additional support for a proactive platform that limits user choices. However, we choose to present the results using the provider-restriction strategy because in our model the service providers are homogeneous and the off-platform service providers are still assessible by customers through other channels. By considering the intertemporal behavior of service providers, we offer a different, but complementary, perspective based on opportunism and competition. While the platform needs to maintain a certain number of service providers to meet demand, the competition among service providers reduces future expectations and hinders incentive alignment. In light of this tradeoff that plagues settings like the Chinese service sector, limiting size on the service provider side is a strategy that can align incentives and motivate service providers.

[3] Related here is Hagiu's research (2011, 2014) on when platforms should exclude low-quality users, which we cover above in our discussion of the literature on market frictions and platform strategy.

3. Notations and Benchmarks

3.1. Notations

We consider an infinite time period model in which homogeneous buyers interact with homogenous service providers. Assuming homogeneous service providers allows us to isolate the impact of hidden action vis-a-vis the influence of hidden information, which drives the results in prior literature. In each period, a group of new buyers (demand) emerges and trades with the same group of service providers (supply). Each buyer or service provider is assumed to be atomless and we normalize the size and the capacity of supply to 1, and assume that the normalized demand size in period i is α_i for $i \in \mathbf{N}$, which are independently and identically distributed random variables with cumulative distribution function F and probability density function f on support [0,1]. Therefore, the expected utilization rate of a service provider is $\gamma = E[\alpha]$.

When a buyer is matched with a service provider, the service outcome can be either consummate (high outcome) or perfunctory (low outcome), and the buyer derives positive utilities S_1 and S_0 from high outcome and low outcome, respectively. The buyers prefer the high outcome and we denote $\Delta S \equiv S_1 - S_0 > 0$. For each contractual relationship the service provider can either exert a costly effort with disutility $\psi(>0)$ or shirk with disutility 0. The probabilities of high outcome are π_1 and π_0 if the service provider exerts effort or shirks, respectively. The costly effort is desirable, and we denote $\Delta\pi \equiv \pi_1 - \pi_0 > 0$. Both the exerted effort and the outcome are not verifiable in the courts and cannot be specified in the contract (or they are verifiable, but the contract is incomplete).[4] In this section, we assume that a costly effort from the service provider ensures a high outcome (i.e., $\pi_1 = 1$) to simplify the exposition. We relax this restriction in the general model.

We assume that all the parties are risk-neutral with separable utility functions. The buyer's utility is $S - t$, where S is the utility derived from the outcome and t is the monetary transfer from the buyer to the service provider; and the service provider's utility is $t - \psi$ if he chooses to exert effort and t if he chooses to shirk. Without loss of generality, the service provider's reservation utility is normalized to 0 for simple exposition. The per period discount rate of the service providers is denoted as $\delta \in (0,1)$. The notation is summarized in Table 2.

3.2. Benchmarks

We first analyze *the first-best benchmark*, which maximizes the overall welfare of the buyer and the service provider for each contractual relationship. Because $S_0 > 0$, the transaction between the buyer and the service provider is desirable when no effort is exerted. Under the first-best benchmark, the costly effort is desirable if and only if the incremental utility gain due to the effort exceeds the

[4] If the outcomes are verifiable and the payment plan is contingent on the verifiable outcomes, the main insights would continue to hold despite more involved mathematical expressions.

Table 2 Notation

i	index of period, $i \in \mathbf{N}$
α_i	normalized random demand in period i on support [0,1]
F	cumulative distribution function of α_i
f	probability density function of α_i
γ	expected utilization rate, $\gamma = E[\alpha] = \int_0^1 \alpha dF(\alpha)$
δ	per period discount rate, $\delta \in (0,1)$
$S_1(S_0)$	buyer's utility derived from high (low) outcome, $S_1 > S_0 > 0$
ΔS	difference of the utilities, $\Delta S = S_1 - S_0 > 0$
t	monetary transfer from the buyer to the service provider
ψ	service provider's disutility from exerting effort, $\psi > 0$
$\pi_1(\pi_0)$	probability of high outcome with (without) costly effort, $\pi_1 = 1$
$\Delta\pi$	difference of the high outcome probabilities, $\Delta\pi = \pi_1 - \pi_0 > 0$

disutility from the effort, i.e., $\Delta\pi\Delta S > \psi$. Below, we focus on the case that $\Delta\pi\Delta S - \psi > 0$, i.e., inducing effort is welfare-improving, because if the first-best solution involves zero effort, it can be implemented by a zero-premium contract with wage zero.

Now we analyze *the second-best benchmark* for a single-period model. If payment t is independent of outcome S, opportunism arises, and the service provider would not exert the costly effort no matter the transfer payment amount t. As a result, the second-best benchmark deviates from the first-best benchmark. To ensure the trade, the transfer payment to the service providers needs to be greater than zero, the service providers' reservation utility. Given that we assume $\alpha \leq 1$ and focus on a buyer's market with redundant capacity, the market clearing price is the service providers' reservation utility. That is, the second-best benchmark adopts the zero-premium contract that induces zero effort.

4. A Base Model for Platform

While a single-period contract fails to induce the welfare-improving effort as illustrated in Section 3.2, a platform may aggregate the observable historic outcomes and discipline shirkers even if the observed outcomes in the past are unrelated to the present or future outcomes. In this section, we introduce a rational model where delivering a low outcome today creates pessimistic prospects for the service providers. By doing so, we illustrate that working as an intermediary, the platform may foster future concerns that help induce the welfare-improving effort.

4.1. Model with Future Concerns

Consider the setting where all the service providers join the platform, which may adopt various discipline policies for low service outcomes. A low service outcome reveals the shirking behavior because the costly effort ensures a high outcome.[5] A common discipline policy is the suspension policy, e.g., if a service provider delivers a low outcome, he would be suspended from the platform for next k periods, i.e., for next k periods, either he interacts with buyers outside of the platform using the single-period contract or adopts his outside options. In both cases, he only obtains his reservation utility in each period of suspension by the platform.

Now let us study the transfer payment needed to induce the costly effort from the service providers and achieve the maximum welfare. Let t be the transfer payment that induces the costly effort. The more stringent the policy (i.e., the higher the k), the lower the transfer payment t needs to be because the service provider may suffer a greater loss of future income if he shirks. (We formalize the lower bound result in Proposition 2.) The most stringent policy would suspend the service provider for a lifetime in case a low outcome arises. We solve the minimum transfer payment needed to induce the costly effort under this case.

$$[\hat{P}_\infty] \qquad \min_t \qquad t \tag{1}$$

$$\text{subject to } \Delta\pi V \geq \psi, \tag{2}$$

where V denotes the discounted incremental future payoff between the future payoff and the reservation utility. The principal's goal (1) is to minimize her own payment to the service provider. Constraint (2) is the incentive-compatible constraint, which ensures that the agent exerts effort taking into account the future payoff.

To form a consistent rational expectation, the expected discounted incremental future payoff V must equal the incremental future payoff the service provider can secure by exerting effort in all contracts, i.e., $V = \gamma\delta(t-\psi) + \gamma\delta^2(t-\psi) + \gamma\delta^3(t-\psi) + \cdots \Rightarrow V = \frac{\delta\gamma(t-\psi)}{1-\delta}$. This enables us to quantify the equilibrium payment and expected future surplus in the following proposition.

Proposition 1. $(t, V) = \left(\frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi} + \psi, \frac{\psi}{\Delta\pi}\right)$ *induces the maximum-welfare equilibrium under the lifetime suspension policy. Furthermore, equilibrium t is decreasing in both δ and γ.*

Proposition 1 illustrates that by aggregating historic outcomes, it is possible to sustain the maximum-welfare equilibrium. The service providers earn a premium of $\frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi}$ in each contract and the threat of missing future premium ensures the costly effort. Moreover, the premium needed is decreasing in the discount rate and the expected utility rate. Now we characterize the bounds of the payment for the maximum-welfare equilibrium. We first show that $t = \frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi} + \psi$ is indeed the lower bound of the transfer payment for any maximum-welfare equilibrium for any discipline policies (i.e., not limited to the suspension schemes we have proposed).

[5] We relax this assumption later in the general model and examine the case where the outcome imperfectly reveals the behavior.

PROPOSITION 2. *If $t < \frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi} + \psi$, it is impossible to induce service provider's effort.*

Therefore, when adopting the most stringent punishment, $t = \frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi} + \psi$ is the lowest compensation the buyer needs to pay to induce the costly effort. Because the buyers have the option of choosing the zero-premium contract in Section 3.2, this leads to an upper bound of the transfer payment for any maximum-welfare equilibrium, and we quantify the condition under which the maximum-welfare equilibrium is sustainable.

PROPOSITION 3. *At a maximum-welfare equilibrium, transfer payment $t \in \left[\frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi} + \psi, \Delta\pi\Delta S\right]$. The maximum-welfare equilibrium is sustainable if and only if*

$$\Delta\pi\Delta S - \psi \geq \frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi}. \tag{3}$$

Furthermore, the maximum-welfare equilibrium offers a Pareto improvement compared to the zero-premium equilibrium.

Notice that if $\gamma = 0$ or $\delta = 0$, the right-hand side of Equation (3) becomes infinity and we essentially recover the second-best benchmark because the service providers do not worry about future profit; when γ is a positive constant and δ approaches 1, $\bar{t}$ converges to ψ and we recover the first-best solution.

While we have derived the condition that sustains the welfare-improving equilibrium in this infinite-period game, offering a zero-premium and inducing no effort from the service providers is also an equilibrium. Therefore, we have shown that when $\Delta\pi\Delta S - \psi \geq \frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi}$, at least two equilibria may arise: at one equilibrium, the buyers do not expect the service providers to provide effort in the future and cannot cost-effectively induce the effort for formulation $[P]$; therefore, the buyers offer the zero-premium contract and the service providers exert no effort. At the other equilibrium, the buyers and the service providers believe that the outcome of the current contract impacts the service providers' future income. Specifically, if the outcome is low, the service providers become untrustworthy and miss out the future premium; in contrast, a trustworthy service provider continues demanding a premium while delivering high outcomes. The solution of model $[\hat{P}_\infty]$ sustains such a belief where the service providers always exert effort and the threat of the off-equilibrium path never materializes. Therefore, the analysis on future concern suggests that the costly effort may be supplied at equilibrium, not that it is always supplied at equilibrium.[6] Additional equilibria (sandwiched by these two equilibrium) may also arise.

Proposition 3 also implies that when $\Delta\pi\Delta S - \psi \geq \frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi}$, either a passive reputation-based mechanism or a proactive platform can help sustain the desirable maximum-welfare equilibrium.

[6] See Chapter 2.6.2.1 in Tirole (1988) and the references within (Klein and Leffler 1981, Shapiro 1983). Notice that the models there examine a setting of opportunism where a buyer repeatedly purchases from the same seller.

In contrast to a passive reputation-based system, however, a platform may play a proactive role in the process of belief building and equilibrium selection—it helps the system move away from the zero-premium equilibrium and move toward the maximum-welfare equilibrium that improves the payoff of both the buyers and the service providers. Nevertheless, when $\Delta\pi\Delta S - \psi < \frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi}$, the maximum-welfare equilibrium is not attainable. Under such a case, can a platform improve the social welfare and avoid the zero-premium equilibrium? We discuss the platform design in the next subsection.

4.2. The Optimal Network Size

How many service providers should the platform recruit? At first glance, this question seems trivial because the platform needs both buyers and the service providers to enable the matching. Moreover, all the service providers are homogenous so that they are equally capable. Therefore, one would expect that the bigger the network size, the better the platform performance. Nevertheless, we illustrate that by deliberately restricting the number of service providers, the platform may induce the welfare-improving effort and achieve a higher profit.

Specifically, we assume that while a service provider participates on the platform, he can still connect with the buyers through other channels and each buyer optimally chooses which channel to use first. When the buyer randomly matches with a service provider through other channels, a single-period contract would be signed, i.e., a zero-premium contract under the setting of interest. We first analyze the buyers' behavior.

Proposition 4. *The platform's equilibrium profit is zero if the platform fails to induce the costly effort at equilibrium. Furthermore, suppose that the costly effort is induced by the platform at equilibrium, the buyer (weakly) prefers the platform over other channels.*

Proposition 4 states that ignoring other frictions, the platform is profitable only if it can induce the costly effort and improve the social welfare. If the platform can alleviate the opportunism problem and improve the social welfare, it becomes the buyers' first choice when searching for a service provider. That is, the buyers first participate on the platform and match with a service provider through other channels only if there are no idle service providers available on the platform.

Proposition 5. *There exists threshold $\hat{\beta} \in [0,1]$, such that the costly effort can be induced by the platform at equilibrium if and only if the proportion of the service providers on the platform, β, is no more than $\hat{\beta}$. Moreover,*

$$\hat{\beta} = \begin{cases} 1, & \text{if } \Delta\pi\Delta S - \psi \geq \frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi} \\ 0, & \text{if } \Delta\pi\Delta S - \psi \leq \frac{1-\delta}{\delta}\frac{\psi}{\Delta\pi} \\ \gamma^{-1}\left(\frac{1-\delta}{\delta}\left(\frac{\psi/\Delta\pi}{\Delta\pi\Delta S - \psi}\right)\right), & \text{otherwise} \end{cases},$$

where γ^{-1} is the inverse function of the expected utilization $\gamma(\beta) \equiv \frac{\int_0^1 \min\{\alpha,\beta\} dF(\alpha)}{\beta}$.

To alleviate the opportunism problem, the platform should improve the future prospects of the service providers on the platform. While the service providers have the same capability whether or not joining the platform, it turns out that they may enjoy a higher expected future utilization rate at equilibrium if the platform restricts the number of service providers. By Proposition 4, when the proportion of the service providers on the platform β is less than 100%, the expected utilization $\gamma(\beta)$ on the platform would be higher than the market average γ if the buyers believe that the costly effort can be induced by the platform at equilibrium. The improved utilization allows the platform to better address the opportunism problem and sustain the equilibrium that induces the costly effort from all the service providers on the platform because the minimum transfer payment that induces the costly effort is monotonically decreasing in the expected utilization rate by Proposition 1. Proposition 5 quantifies the threshold $\hat{\beta}$. When β is at the threshold $\hat{\beta}$, the platform needs to surrender the entire ex-post social surplus to the service providers to induce the costly effort.

Therefore, we illustrate that a platform may improve the social welfare by limiting the number of service providers when a reputation-based mechanism fails to induce the costly effort (i.e., Equation (3) is violated and $\Delta\pi\Delta S - \psi < \frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi}$).

Notice that compared to the reputation-based mechanism, the provider-restriction strategy enlarges the set of equilibrium outcomes by differentiating homogenous service providers. At the welfare-improving equilibrium, service providers on the platform enjoy higher utilities compared to those off the platform. Such differentiation might also be achieved through some reputation-building process. Let us say, at the beginning of time, when no historic performance is available, we have this group of service providers and no costly effort can be induced. After some periods, the portion of the service providers with good reputation (i.e., always delivering high outcome, purely due to luck) may be smaller than $\hat{\beta}$. At this point of time, continuing with the zero-premium contract and inducing zero effort is one equilibrium and believing service providers with good reputation deserve a premium because they will exert effort and continue offering high outcome is also an equilibrium.

Ceteris paribus, the provider-restriction strategy is more proactive in guiding and coordinating the system compared to the reputation-based mechanism. By preemptively limiting the network size on the service provider side, the platform can also avoid the reputation building-periods when costly effort cannot be induced. Therefore, a platform with a provider-restriction strategy would be most helpful for the social welfare in countries where the reputation system is lacking and for the industries where reputation building takes a long time.

Now, we quantify the maximum profit of the platform. We consider two possible scenarios: (i) the platform only charges a fixed commission ϕ for each matching, and (ii) the platform may charge entrant fees for its users in addition to the commission. Because we have focused on the economic friction and quantified the range of sustainable transfer payment in Proposition 3 without imposing operational details, given that both the buyers and the service providers have joined the platform, the maximum commission is independent of how it is charged, whether the platform collects the commission only from the service providers or from both parties. The platform may also charge the entrant fees for the buyer in each period or for the service provider when he first joins the platform. With entry fees, the maximum entry fee the platform can impose for each party depends on how the commission is collected.

We first analyze the maximum commission and the associated profit the platform can generate as a function of β, the proportion of the service providers who participate on the platform, assuming the platform does not charge an entry fee. We have the following proposition.

PROPOSITION 6. *Suppose that costly effort is induced by the platform at equilibrium, that is, $\beta \leq \hat{\beta}$. The maximum commission per transaction $\phi(\beta)$ is a decreasing function of β, the transaction volume per period $\beta\gamma(\beta)$ is an increasing function of β, and the profit of the platform is a concave function of β when $f(\beta) \geq \frac{(1-F(\beta))\int_0^\beta \alpha dF(\alpha)}{\beta\int_0^1 \min\{\alpha,\beta\} dF(\alpha)}$.*

Note that the service providers compete for jobs and the more service providers on the platform, the less likely a service provider finds a match on the platform. Proposition 6 points out that the reduced utilization rate requires a higher transfer payment from the buyers to the service providers to induce the effort (Proposition 1) because the service providers have dimmer prospects. As a result, the maximum commission $\phi(\beta)$ the platform may charge for a transaction goes down as β increases. Because the platform's profit per period is the product of three factors, $\phi(\beta) * \gamma(\beta) * \beta$, the overall profit function is concave in β under some regularity condition.

Now, we analyze the platform's profit when it imposes entry fees to the service providers *ex ante*.

PROPOSITION 7. *Suppose that the costly effort is induced by the platform at equilibrium, that is, $\beta \leq \hat{\beta}$. For each commission less than the maximum commission identified in Proposition 6, there are (various) entry fee schemes that achieve the maximum profit for given β. The platform's profit is increasing in β and maximized at $\beta = \hat{\beta}$. Specifically, the maximum profit of the platform is achieved by charging zero commission, zero entry fee to the buyers, and maximum entry fee to the service providers.*

Via an entrant fee to the homogenous service providers, the platform can capture the entire social surplus of the costly effort ex ante. Therefore, the platform would earn higher profit under entrant fee schemes compared to commission schemes. Under this case, the profit-driven platform aims to maximize the social welfare and the platform would try to get as many service providers on board as possible as long as the platform can still incentivize the service providers to exert effort.[7]

[7] In this paper, we focus on the different profitability implications of commission vs. entry fee assuming risk-neutrality. In practice, whether the platform can extract all the surplus depends on various factors such as the financial constraints

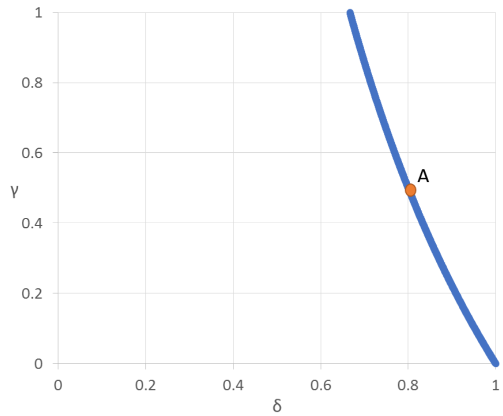

Figure 1 **The (δ, γ) combination that can sustain the welfare-improving equilibrium.**

4.3. A Numerical Illustration

Now, we illustrate how network size impacts the equilibrium behavior through one numerical example. Suppose $\Delta S = 12$, $\pi_0 = 0.75$ (so that $\Delta\pi = 0.25$), $\psi = 1$, $\delta = 0.8$, and F follows a uniform distribution on [0,1], which implies $\gamma = 0.5$.

The first-best solution induces the costly effort because the marginal gain exceeds the marginal cost, $\Delta\pi\Delta S = 3 > \psi = 1$. Under the infinite-period model, there exists exactly two equilibria: one is the zero-premium equilibrium, under which the buyer's payment equals the service provider's reservation utility and induces zero effort; the other is the welfare-improving equilibrium, under which the buyers pay a premium, $t = 3$, and the service providers exert effort for future payoff, $\Delta\pi V = 1$.

While the welfare-improving equilibrium is Pareto-improving compared to the zero-premium equilibrium by Proposition 3, for this example, the buyer's expected payoff turns out to be the same under both equilibria. The buyer is indifferent between inducing zero effort and inducing effort by paying a premium, $t = 3$. In the welfare-improving equilibrium, the service providers obtain all the surplus from the improved welfare if they do not need to pay the entry fee.

Figure 1 illustrates that the (δ, γ) combination can sustain the welfare-improving equilibrium. The costly effort can be induced at equilibrium in the northeast corner, while the zero-premium equilibrium is the unique equilibrium in the southwest corner. The parameter combination in this example is point A, which is on the boundary of the region.

Figure 2 illustrates how the platform's profit varies with the size of the service provider pool when the platform only charges commission. As the proportion of the service providers on the platform β increases, the transaction volume $\beta * \gamma(\beta)$ increases, but the maximum commission

and the risk attitude of service providers (Kaufmann and Lafontaine 1994). Future work can further examine these factors.

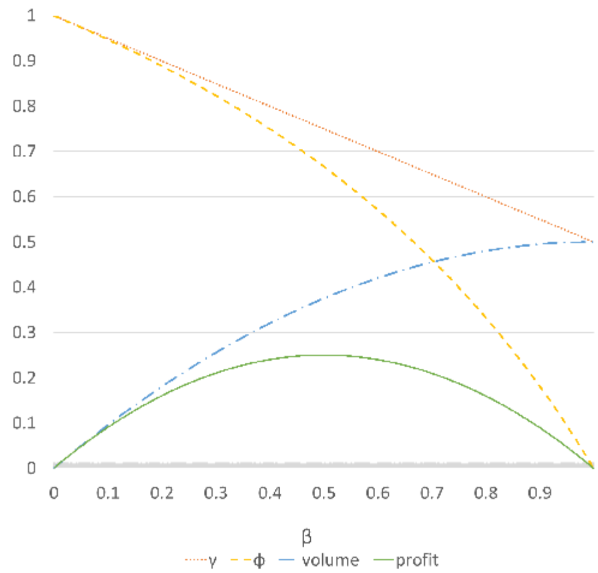

Figure 2 Platform profit and platform size.

$\phi(\beta)$ decreases. Given this relationship, the overall profit per period $\phi(\beta)*\gamma(\beta)*\beta$ is $\bigcap$-shaped, as illustrated in Figure 2. For this specific example, the maximum profit is obtained when the platform invites 50% of the service providers and captures 75% of the market share. At equilibrium, the service providers on the platform achieve a much higher utilization rate (three times) compared to those off the platform because the buyers would first check the platform to find a match.

5. A General Model for Platform

Section 4 highlights the fundamental tradeoff between incentive alignment and network size. With more service providers, the platform is more likely to satisfy customer demand, yet the competition among the service providers dims their future prospect and makes incentive alignment difficult. When the proportion of the service providers on the platform β exceeds threshold $\hat{\beta}$, the platform can no longer alleviate the opportunism problem and incentivize the service providers.

In this section, we generalize the results by considering the (i) possibility of low outcome when exerting effort, and (ii) entry and exit of the service providers. As the signal becomes less reliable, the platform may or may not rely on the threat of lifetime suspension to induce the costly effort. We derive the platform's optimal suspension policy under this case. Specifically, we denote π_1 ($\in (\pi_0, 1]$) to be the probability of high outcome with costly effort. Furthermore, in each period, η new service providers arrive and each existing service provider may leave the system with probability $\eta \in [0,1)$.[8] The platform may adopt a general suspension policy $P = \{p_i\}_0^\infty$ such that p_i is the

[8] While we have adopted an exogenous model for the entry and exit probability to simplify the exposition, the insights are readily extended to the endogenous setting when the probabilities depend on the expected payoff level.

probability of i-period suspension $(i=0,1,2\cdots)$ and $\sum_{i=0}^{\infty} p_i \leq 1$ (so that the probability of the lifetime suspension is $(1-\sum_0^{\infty} p_i)$). We call a policy $P=\{p_i\}_0^{\infty}$ *pseudo deterministic* if there exists non-negative integer k such that $p_k>0$ and $p_{k+1}=1-p_k$, i.e., a low outcome results in either a k-period suspension or a $k+1$-period suspension.

To induce the costly effort with suspension policy P, we solve the following formulation.

$$[\check{P}_P] \quad \min_{(\bar{t},\underline{t})} \quad \pi_1 \bar{t} + (1-\pi_1)\bar{t} \tag{4}$$

$$\text{subject to } \Delta\pi(V-\rho V) \geq \psi, \tag{5}$$

where $\rho=\sum_{i=0}^{\infty}\delta^i(1-\eta)^i p_i$ and V denotes the discounted incremental future payoff between the future payoff and the reservation utility. The principal's goal (4) is to minimize her expected payment to the service provider. Constraint (5) is the incentive-compatible constraint, which ensures that the agent prefers to exert effort taking into account the future payoff.

As in the base model, we assume that while a service provider participates on the platform, he can still connect with the buyers through other channels and the buyer optimally chooses which channel to use first. When the buyer randomly matches with a service provider through other channels, a single-period contract would be signed, i.e., a zero-premium contract under the setting of interest. Similar to the base model, ignoring other frictions, the platform is profitable only if it can induce the costly effort and improve the social welfare. When the costly effort is induced by the platform at equilibrium, the buyers (weakly) prefer the platform over other channels. Now we characterize the feasible region of the platform policy.

Define

$$\tilde{\beta}(\rho)=\begin{cases} 1, & \text{if } \Delta\pi\Delta S-\psi \geq \left(\frac{1-\delta(1-\eta)}{\delta(1-\eta)\gamma(1-\rho)}+1-\pi_1\right)\frac{\psi}{\Delta\pi} \\ 0, & \text{if } \Delta\pi\Delta S-\psi \leq \left(\frac{1-\delta(1-\eta)}{\delta(1-\eta)(1-\rho)}+1-\pi_1\right)\frac{\psi}{\Delta\pi} \\ \gamma^{-1}\left(\frac{1-\delta(1-\eta)}{\delta(1-\eta)(1-\rho)}\left(\frac{\psi/\Delta\pi}{\Delta\pi\Delta S-\psi-(1-\pi_1)\psi/\Delta\pi}\right)\right), & \text{otherwise} \end{cases},$$

where γ^{-1} is the inverse function of the expected utilization $\gamma(\beta)$.

Proposition 8. *There exists threshold $\check{\beta} \leq \tilde{\beta}(0) \leq \hat{\beta}$, such that the costly effort can be induced by the platform at equilibrium if and only if the proportion of the unsuspended service providers on the platform, β, is no more than $\check{\beta}$. Moreover, if $\beta=\check{\beta}$, there exists a unique suspension policy that induces the costly effort at equilibrium, and this suspension policy is either a lifetime suspension policy or a pseudo deterministic policy.*

Proposition 8 parallels Proposition 5 and characterizes the threshold structure. When the outcome is an imperfect signal of effort and service providers may exit the system, it becomes hard to induce effort and the threshold becomes smaller. Proposition 8 also points out that it suffices to consider two possible scenarios of the suspension policy: in the first scenario, when the signal is still rather accurate, the platform still limits the network size and remains selective among the service providers (even though all of the service providers are homogeneous) and the platform excludes a service provider whenever a low outcome is observed; in the second case, when the signal is rather inaccurate, the platform would allow all the service providers on board, and adopt a pseudo deterministic suspension policy instead of a lifetime suspension policy, i.e., a low outcome results in either a k-period suspension or a $k+1$-period suspension for some non-negative integer k.[9] That is, the platform uses a less harsh suspension policy to compensate for the overkill caused by the imperfect signal.

Now, we quantify the profit of the platform when the platform may charge both the commission and the entry fee. We analyze the maximum profit the platform can generate.

PROPOSITION 9. *Suppose that the costly effort is induced by the platform at equilibrium, $\beta \le \check{\beta}$. The platform's profit is increasing in β and maximized at $\beta = \check{\beta}$. Specifically, the maximum profit of the platform is achieved by charging zero commission, zero entry fee to the buyers, and maximum entry fee to the service providers.*

Once again, when the platform charges the maximum entry fee, the incentive of the platform is aligned with the social welfare and the platform would try to get as many service providers on board as possible as long as the platform can still incentivize the service providers to exert effort. When service providers may enter and exit the system, it is possible that some service provider may try to game the system by shirking and re-entering as a new service provider. Because the maximum entry fee captures the service provider's entire surplus, the service provider has no incentive to exit and re-enter as a new service provider (which would provide a strictly lower payoff when the suspension policy is pseudo deterministic) or create duplicate accounts. Therefore, an entry fee scheme not only helps better align the incentive of the platform and enhances its profit, it also reduces the incentive of potential fraud.

6. Conclusions

Online platforms are an important innovation that connects offline service providers with consumers. Empowered by advanced information technologies, online platforms can more readily ascertain customers' specific needs, allowing service providers to offer customized services that Chinese consumers have increasingly desired. Despite its tremendous value-creation potential, offering customized services encourages greater opportunism from the service providers, because of the

[9] If we adopt a continuous time model, it suffices to consider only deterministic policies, i.e., following a low outcome, the service provider is suspended either for a lifetime or some constant time t.

incompleteness of the explicit contracts. To better realize the value creation potential of customized services, online platforms need to proactively manage the opportunism problem, in addition to reducing search and matching frictions between service providers and customers.

Building on the existing reputation literature, we first develop a benchmark model where the platform removes a service provider whenever a low-quality service outcome occurs. While a welfare enhancing equilibrium may exist in that future concerns motivate the effort of service providers, its existence relies on the condition that future concerns are sufficiently strong. Unfortunately, this condition probably is often violated in China where excessive competition on the supply side weakens future prospects. To solve the excessive competition problem, we propose a novel design in which the platform, from its inception, deliberately restricts the number of service providers below a certain threshold, while still excluding service providers when they deliver low-quality outcomes. Doing so increases the expected profits of service providers on the platform, motivating them to exert effort from the onset of participation. This platform design supports a welfare-enhancing equilibrium where the service providers are paid a premium for exerting effort, and where more customers are willing to pay for the premium and actually prefer service providers on this platform to those available elsewhere. Although a reputation-based mechanism that does not limit network size may reach the same equilibrium at the stationary state, the progress toward this stationary state may be slow or even stagnant in the Chinese context, leading to welfare loss during reputation-building periods. The welfare loss problem is particularly salient when transaction frequency is low.

We analyze the implications of our proposed approach on platform profitability, specifically by comparing different participation payment schemes, namely a platform commission or an entry fee. If the platform only charges a commission, the total potential profits of the platform take an inverted U-shape relation with respect the number of service providers, driven by an underlying tradeoff. Specifically, even though recruiting a great number of service providers increases platform revenue, it also leads to fiercer competition, which, in turn, decreases service providers' future profits and thus demands a lower commission on the platform. Given this inverted-U shape relationship, the profitability of the platform peaks below the threshold beyond which the welfare-improving equilibrium is no longer sustainable. If, however, the platform is able to charge service providers an entry fee, it can yield all the ex-post rents to service providers (i.e., charging zero commission), but extract all the surplus ex ante in the form of entry fees. In this case, the total profit of the platform is maximized at the threshold.

We generalize the model by considering the cases where outcome is an imperfect signal of service provider effort and where service providers can enter and exit the platform. In these cases, it becomes harder to motivate the service providers, necessitating a stricter limit to the number of active service providers allowed on the platform. Furthermore, since, due to the imperfect signal, service providers may be penalized even if they exert effort, the platform may need to adopt a more general suspension policy where service providers are excluded for a pseudo-determined number of periods before they are allowed to again serve customers on the platform. Notice that pretending to be a new entrant may circumvent and defeat the platform's disciplining plan. To prevent this possibility, we show that an entry fee can discourage fraudulent re-entry, since service providers must pay an entry fee each time they re-enter.

Our study sheds new light onto the relationship between market frictions and firm strategy (Chatain and Zemsky 2011, Gans and Stern 2010, Obloj and Zemsky 2015, Rawley and Simcoe 2010, Yao 1988). Recent platform research recognizes that online platforms can work as a novel organizational form that coordinates economic activities and reduces market frictions (Boudreau and Hagiu 2009, Gans 2012, Hagiu 2014, Hagiu and Wright 2015, Parker et al. 2016). Adding to this literature, we propose a novel platform design that can create value by reducing opportunism. In essence, the platform proactively manages excessive competition that increases the challenges of aligning incentives.

Our research adds to the work by Hagiu and Wright (2018) that describes how online platforms not only play the familiar role of matchmakers and but also motivate service providers to exert effort. While Hagiu and Wright (2018) examine the double-sided moral hazard and the allocation of decision rights, we highlight the situation where excessive competition makes it harder to incentivize service providers. To mitigate this problem, we show that the platform can limit network size on the service provider side, effectively increasing expected profits in the future, and then use the potential loss of future opportunities as a means to motivate service providers.

We also expand the work on reputation-based mechanisms where the threat of losing future profits can influence service providers' current behavior (Cabral and Hortaçsu 2010, Dellarocas 2005). We examine a setting where the low transaction frequency and initial conditions hinder the effectiveness of reputation building. Our approach suggests the platform can restrict demand flow to only a subset of service providers, even if they are homogeneous. This restriction signals a commitment to creating a welfare-enhancing equilibrium and enables rapid reputation building. The platform differentiates the service providers on the platform from those outside even though all these individual service providers are ex ante the same.

Our work complements the platform literature that focuses on the adverse selection problem among heterogeneous goods or services providers (Cui et al. 2018, Elfenbein et al. 2015, Jin and Kato 2007). It has been argued that to mitigate this problem, the platform needs to uncover hidden information about service providers via user feedback or third-party certification. Our study differs from previous work by proposing a platform design that addresses service providers' opportunism in terms of effort exerting, even if service providers are homogeneous.

Our work contributes to the growing body of research on the conditions under which a platform needs to limit its size or limit choice (Casadesus-Masanell and Halaburda 2014, Halaburda and Oberholzer-Gee 2014). Casadesus-Masanell and Halaburda (2014) show that the allocation of time across different choices by each user may cause the failure for the users as a whole to benefit from consumption complementaries. This problem can be solved when the platform proactively limits the choices available to individual users. The search and matching literature recognizes that, although a larger network will increase thickness and enhance cross-side network effects, it will also reduce the quality of matching between platform users on the two sides (Arnosti et al. 2018, Halaburda et al. 2018, Kanoria and Saban 2017, Li and Netessine 2018). We investigate a different tradeoff based on opportunism and competition. Although the platform needs to maintain a certain number of service providers to meet demand, the competition among these service providers reduces future profits and harms incentive alignment. Because of this tradeoff, limiting size on the service provider side is a tool to motivate service providers to exert effort.

Our study generates several practical and policy implications. Contrary to the accepted wisdom that platforms should rapidly increase their size, the unique characteristics of certain Chinese service sectors may require a platform strategy that limits the network size on the service provider side. Ignoring this natural limit may result in the failure of a venture, if entrepreneurs, sometimes pressed by venture capitalists, single-mindedly pursue growth. This may help explain the quick rise and fall of many Chinese O2O startups.[10] In terms of limiting the network size, the platform plays a role akin to a central planner, but it does so via an intermediate governance form between the firm and the state, specifically without being an owner of the service providers (the firm) or taking on the role of the government (the state) (Boudreau and Hagiu 2009). Somewhat paradoxically, a mechanism that mimics the centrally planned economy serves to enable the efficient functioning of decentralized economic exchange. Moreover, since service providers outside the platform have lower performance, over time they are more likely to exit the industry. The platform thus helps eliminate redundant capacity in Chinese industries, a key objective of the Chinese government. It is important to note that, in our setting, while the platform can limit access to its platform, off-platform service providers still are suppliers in the system. That is, the platform limits suppliers on the platform, not suppliers in the system. The platform chooses to limit provider access to foster reputation building and move the system towards a better equilibrium. This platform model differs from the approach where the government creates rents by limiting competition and reducing overall

[10] https://www.forbes.com/sites/ywang/2016/04/21/o2o-leads-chinese-startups-boom-and-bust-cycle/#2d8266cc7858

supply in the system and grants these rents to privileged groups in exchange for their cooperation, an approach that harms the long-term economic development in many developing countries (North et al. 2007).

We acknowledge several limitations, which may lead to future research opportunities. In order to tease apart opportunism, we assume service providers to be homogeneous, which ensures that our results are not driven by user heterogeneity as in prior work. Future research can relax this assumption, examining the interaction of heterogeneous type and hidden effort. To focus on the difference between on and off the platform, we assume a monopoly platform; future research can investigate the competitive interaction between an entrant platform and an incumbent one. We also assume exogenous demand and a buyer's market, with these assumptions justified based on the historical conditions in China. While this approach allows us to highlight the key mechanism, underlying demand will also change over time. In this light, the essence of our approach is to maintain a certain degree of asymmetry regarding the two sides of the two-sided platform. Future research can examine how the platform can dynamically manage the relative size of one side vis-à-vis the other. To facilitate the characterization of model conditions, we situated our model within the Chinese service sector; future work can extend our model to other sectors or other economies that suffer from similar opportunism problems while incorporating their own unique institutional characteristics.

Appendix: Proofs

To consolidate the proofs, we establish the results when the probability of high outcome with costly effort $\pi_1 \in (\pi_0, 1]$, $\eta \in [0,1)$ service providers to enter and exit the system in each period, and general suspension policy $P = \{p_i\}_0^\infty$ such that p_i is probability of i-period suspension ($i = 0, 1, 2 \cdots$) and $\sum_{i=0}^\infty p_i \le 1$ (so that the probability of the lifetime suspension is $(1 - \sum_{i=0}^\infty p_i)$). For the base model results in Section 4, we check the expressions when $\pi_1 = 1$ and $\eta = 0$.

Lemma 1. *$(t, V) = \left(\frac{1-\delta(1-\eta)(1-\gamma(1-\rho)(1-\pi_1))}{\delta(1-\eta)\gamma(1-\rho)}\frac{\psi}{\Delta\pi} + \psi, \frac{\psi}{\Delta\pi(1-\rho)}\right)$ is the minimum payment scheme that induces the costly effort. Furthermore, equilibrium t is decreasing in both δ and γ, and increasing in both η and ρ.*

Proof of Lemma 1. At equilibrium, the expected future payoff V must equal the payoff the service provider can secure by exerting effort in all contracts. Notice when $\delta < 1$, V is bounded; therefore, $V = \delta(1-\eta)(1-\gamma)V + \delta(1-\eta)\gamma\,(t + \pi_1 V + (1-\pi_1)\rho V - \psi) \Rightarrow V = \frac{\delta(1-\eta)\gamma(t-\psi)}{1-\delta(1-\eta)(1-\gamma(1-\rho)(1-\pi_1))}$.

By the incentive compatibility constraint, $\Delta\pi(1-\rho)V \ge \psi$. Therefore, at the minimum payment scheme, $(t, V) = \left(\frac{1-\delta(1-\eta)(1-\gamma(1-\rho)(1-\pi_1))}{\delta(1-\eta)\gamma(1-\rho)}\frac{\psi}{\Delta\pi} + \psi, \frac{\psi}{\Delta\pi(1-\rho)}\right)$. t is decreasing in both δ and γ and increasing in both η and ρ.

Propositions 1-3 are established for the base model with $\pi_1 = 1$ and $\eta = 0$.

PROPOSITION 1. $(t,V) = \left(\frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi} + \psi, \frac{\psi}{\Delta\pi}\right)$ *induces the maximum-welfare equilibrium under the lifetime suspension policy. Furthermore, equilibrium t is decreasing in both δ and γ.*

Proof of Proposition 1. Under the lifetime suspension policy, $\rho = 0$. By Lemma 1, when $\pi_1 = 1$ and $\eta = 0$, the equilibrium solution $(t,V) = \left(\frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi} + \psi, \frac{\psi}{\Delta\pi}\right)$, and we know $\bar{t}$ is decreasing in both δ and γ.

PROPOSITION 2. *If $t < \frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi} + \psi$, it is impossible to induce service provider's effort.*

Proof of Proposition 2 If $t < \frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi} + \psi$, the future benefit is strictly bounded from above by $\gamma\delta(t-\psi) + \gamma\delta^2(t-\psi) + \cdots = \delta\gamma\frac{t-\psi}{1-\delta} = \frac{\psi}{\Delta\pi}$. Thus, the benefit of exerting effort is strictly bounded from above by $\Delta\pi\frac{\psi}{\Delta\pi} = \psi$. That is, it is impossible to induce service provider's effort.

PROPOSITION 3. *At a maximum-welfare equilibrium, transfer payment $t \in \left[\frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi} + \psi, \Delta\pi\Delta S\right]$. The maximum-welfare equilibrium is sustainable if and only if*

$$\Delta\pi\Delta S - \psi \geq \frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi}. \tag{6}$$

Furthermore, the maximum-welfare equilibrium offers a Pareto improvement compared to the zero-premium equilibrium.

Proof of Proposition 3 Because the buyers can always offer a zero-premium contract and induce no effort, the maximum transfer payment from the buyers is $\Delta\pi\Delta S$. Therefore, at a maximum-welfare equilibrium, transfer payment $t \in \left[\frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi} + \psi, \Delta\pi\Delta S\right]$ by Proposition 2.

Therefore, the maximum-welfare equilibrium is sustainable if and only if $\Delta\pi\Delta S - \psi \geq \frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi}$. That is, the maximum-welfare equilibrium is sustainable if and only if the gain of the social welfare is no less than the rent surrendered to the service provider.

The maximum-welfare equilibrium (weakly) improves the service providers' utilities because they only obtain the reservation utility in the zero-premium equilibrium. Furthermore, the maximum-welfare equilibrium (weakly) improves the buyers' utilities because the buyers can opt for the zero-premium contract but choose not to do so. Therefore, the maximum-welfare equilibrium offers a Pareto improvement compared to the zero-premium equilibrium.

PROPOSITION 4. *Suppose that the costly effort is induced by the platform at equilibrium, the buyers (weakly) prefer the platform over other channels. Furthermore, the platform's equilibrium profit is zero if the platform fails to induce the costly effort at equilibrium.*

Proof of Proposition 4 Suppose that the platform fails to induce the costly effort at equilibrium. The maximum a buyer would be willing to pay is the service provider' reservation utility given that she can also match with some service provider through other channels. The minimum a service provider is willing to accept is also his reservation utility. Therefore, the platform's equilibrium profit is zero. Suppose that the costly effort is induced by the platform at equilibrium, it must be the case that matched buyers are (weakly) better off under the contract on the platform over the zero-premium contract at equilibrium. Therefore, the buyers (weakly) prefer the platform over other channels.

LEMMA 2. *Suppose that the costly effort is induced by the platform at equilibrium, the equilibrium number of the service providers on the platform β satisfies $\eta(1-\beta) \geq (1-\pi_1)\beta(1-\eta)$ under the lifetime suspension policy.*

Proof of Lemma 2 Suppose that the costly effort is induced by the platform. In each period, the total remaining number of the service providers in the system who are suspended is

$$
\begin{aligned}
&(1-\pi_1)\beta(1-\eta)(1-p_0) + (1-\pi_1)\beta(1-\eta)^2(1-p_0-p_1) + \cdots \\
=&(1-\pi_1)\beta \sum_{i=1}^{\infty}\left((1-\eta)^i\left(1-\sum_{j=0}^{i-1}p_j\right)\right) \\
=&(1-\pi_1)\beta\left(\sum_{i=1}^{\infty}(1-\eta)^i - \sum_{i=1}^{\infty}(1-\eta)^i\left(\sum_{j=0}^{i-1}p_j\right)\right) \\
=&(1-\pi_1)\beta\left(\sum_{i=1}^{\infty}(1-\eta)^i - \sum_{j=0}^{\infty}p_j\left(\sum_{i=j+1}^{\infty}(1-\eta)^i\right)\right) \\
=&(1-\pi_1)\beta\left(\sum_{i=1}^{\infty}(1-\eta)^i\right)\left(1-\sum_{j=0}^{\infty}(1-\eta)^j p_j\right)
\end{aligned}
$$

which needs to be no more than $1-\beta$ to ensure that the equilibrium number of the service providers on the platform can be β. Therefore, $\eta(1-\beta) \geq (1-\pi_1)\beta(1-\eta)\left(1-\sum_{j=0}^{\infty}(1-\eta)^j p_j\right)$. Under the lifetime suspension, $p_i = 0$ for all i, and $\eta(1-\beta) \geq (1-\pi_1)\beta(1-\eta)$.

Recall

$$
\tilde{\beta}(\rho) = \begin{cases} 1, & \text{if} \Delta\pi\Delta S - \psi \geq \left(\frac{1-\delta(1-\eta)}{\delta(1-\eta)\gamma(1-\rho)} + 1 - \pi_1\right)\frac{\psi}{\Delta\pi} \\ 0, & \text{if} \Delta\pi\Delta S - \psi \leq \left(\frac{1-\delta(1-\eta)}{\delta(1-\eta)(1-\rho)} + 1 - \pi_1\right)\frac{\psi}{\Delta\pi} \\ \gamma^{-1}\left(\frac{1-\delta(1-\eta)}{\delta(1-\eta)(1-\rho)}\left(\frac{\psi/\Delta\pi}{\Delta\pi\Delta S - \psi - (1-\pi_1)\psi/\Delta\pi}\right)\right), & \text{otherwise} \end{cases},
$$

where γ^{-1} is the inverse function of the expected utilization $\gamma(\beta)$.

LEMMA 3. *Suppose $\eta(1-\tilde{\beta}(0)) \geq (1-\pi_1)\tilde{\beta}(0)(1-\eta)$, the costly effort can be induced by the platform at equilibrium if and only if the proportion of the service providers on the platform, β, is no more than $\tilde{\beta}(0)$.*

Proof of Lemma 3 By Lemma 1, the minimum payment to induce the costly effort is $t = \frac{1-\delta(1-\eta)(1-\gamma(1-\rho)(1-\pi_1))}{\delta(1-\eta)\gamma(1-\rho)}\frac{\psi}{\Delta\pi}+\psi$. The buyer would prefer to induce the effort if and only if $\Delta\pi\Delta S-\psi \geq t-\psi$, that is,

$$\Delta\pi\Delta S-\psi \geq \frac{1-\delta(1-\eta)(1-\gamma(1-\rho)(1-\pi_1))}{\delta(1-\eta)\gamma(1-\rho)}\frac{\psi}{\Delta\pi} = \left(\frac{1-\delta(1-\eta)}{\delta(1-\eta)\gamma(1-\rho)}+1-\pi_1\right)\frac{\psi}{\Delta\pi}.$$

When $\Delta\pi\Delta S-\psi \in \left[\left(\frac{1-\delta(1-\eta)}{\delta(1-\eta)(1-\rho)}+1-\pi_1\right)\frac{\psi}{\Delta\pi}, \left(\frac{1-\delta(1-\eta)}{\delta(1-\eta)\gamma(1-\rho)}+1-\pi_1\right)\frac{\psi}{\Delta\pi}\right]$, the above inequality is equivalent to $\gamma \geq \frac{1-\delta(1-\eta)}{\delta(1-\eta)(1-\rho)}\left(\frac{\psi/\Delta\pi}{\Delta\pi\Delta S-\psi-(1-\pi_1)\psi/\Delta\pi}\right)$.

Given proportion β of the service providers are accessible via the platform, the expected utilization rate of the service providers on the platform is $\gamma(\beta) \equiv \frac{\int_0^1 \min\{\alpha,\beta\}dF(\alpha)}{\beta}$, which is a continuous function of β, monotonously decreasing from 1 to γ as β increases from 0 to 1. By Lemma 1 and Proposition 4, the platform may induce the costly effort from all the service providers on the platform at equilibrium if and only if a suspension policy with ρ and participation β supports $\Delta\pi\Delta S-\psi \geq \left(\frac{1-\delta(1-\eta)}{\delta(1-\eta)\gamma(\beta)(1-\rho)}+1-\pi_1\right)\frac{\psi}{\Delta\pi}$. Furthermore, the minimum ρ, which is zero, is obtained under a lifetime suspension policy, which maps into the maximum β. Therefore, Lemma 2 implies that if $\eta(1-\tilde{\beta}(0)) \geq (1-\pi_1)\tilde{\beta}(0)(1-\eta)$, the costly effort can be induced by the platform at equilibrium if and only if the proportion of the service providers on the platform, β, is no more than $\tilde{\beta}(0)$.

Propositions 5-7 are established for the base model with $\pi_1 = 1$ and $\eta = 0$.

Proposition 5. *There exists threshold $\hat{\beta} \in [0,1]$, such that the costly effort can be induced by the platform at equilibrium if and only if the proportion of the service providers on the platform, β, is no more than $\hat{\beta}$. Moreover,*

$$\hat{\beta} = \begin{cases} 1, & \text{if} \Delta\pi\Delta S-\psi \geq \frac{1-\delta}{\delta\gamma}\frac{\psi}{\Delta\pi} \\ 0, & \text{if} \Delta\pi\Delta S-\psi \leq \frac{1-\delta}{\delta}\frac{\psi}{\Delta\pi} \\ \gamma^{-1}\left(\frac{1-\delta}{\delta}\left(\frac{\psi/\Delta\pi}{\Delta\pi\Delta S-\psi}\right)\right), & \text{otherwise} \end{cases},$$

where γ^{-1} is the inverse function of the expected utilization $\gamma(\beta) \equiv \frac{\int_0^1 \min \alpha,\beta dF(\alpha)}{\beta}$.

Proof of Proposition 5 When $\pi_1 = 1$ and $\eta = 0$, $\eta(1-\tilde{\beta}(0)) \geq (1-\pi_1)\tilde{\beta}(0)(1-\eta)$. Therefore, the costly effort can be induced by the platform at equilibrium if and only if the proportion of the service providers on the platform, β, is no more than $\tilde{\beta}(0)$ by Lemma 3. Plugging in $\pi_1 = 1$, $\eta = 0$, and $\rho = 0$ in the expression of $\tilde{\beta}$ results in the statement.

Proposition 6. *Suppose that the costly effort is induced by the platform at equilibrium, that is, $\beta \leq \hat{\beta}$. The maximum commission per transaction $\phi(\beta)$ is a decreasing function of β, the transaction volume per period $\beta\gamma(\beta)$ is an increasing function of β, and the profit of the platform is a concave function of β when $f(\beta) \geq \frac{(1-F(\beta))\int_0^\beta \alpha dF(\alpha)}{\beta\int_0^1 \min\{\alpha,\beta\}dF(\alpha)}$.*

Proof of Proposition 6 Suppose that the costly effort is induced by the platform at equilibrium, with β proportion of the service providers on the platform. The buyers' maximum willingness to pay is $(\Delta\pi\Delta S)$, and the minimum transfer payment to the service providers is $t=\frac{1-\delta}{\delta\gamma(\beta)}\frac{\psi}{\Delta\pi}+\psi$ by Proposition 2. Hence, the maximum commission per transaction $\phi(\beta)$ is $\left(\Delta\pi\Delta S-\psi-\frac{1-\delta}{\delta\gamma(\beta)}\frac{\psi}{\Delta\pi}\right)$, the difference of these two terms, which is a decreasing function of β because the first term is independent of β and the second term is increasing in β (minimum transfer payment t is decreasing in $\gamma(\beta)$, which is decreasing in β). The transaction volume per period is $\beta\gamma(\beta)=\int_0^1\min\{\alpha,\beta\}dF(\alpha)$, which is an increasing function of β.

The per period profit of the platform is, hence, $\left(\int_0^1\min\{\alpha,\beta\}dF(\alpha)\right)\left(\Delta\pi\Delta S-\psi-\frac{1-\delta}{\delta\gamma(\beta)}\frac{\psi}{\Delta\pi}\right)$. Notice that $\left(\int_0^1\min\{\alpha,\beta\}dF(\alpha)\right)'_\beta=1-F(\beta)>0$ for $\beta<1$, $\left(\int_0^1\min\{\alpha,\beta\}dF(\alpha)\right)''_\beta=-f(\beta)\le 0$, $\left(\Delta\pi\Delta S-\psi-\frac{1-\delta}{\delta\gamma(\beta)}\frac{\psi}{\Delta\pi}\right)'_\beta=-\frac{(1-\delta)\psi}{\delta\Delta\pi}\left(\frac{1}{\gamma(\beta)}\right)'_\beta=-\frac{(1-\delta)\psi}{\delta\Delta\pi}\frac{\int_0^\beta\alpha dF(\alpha)}{\left(\int_0^1\min\{\alpha,\beta\}dF(\alpha)\right)^2}<0$ for $\beta>0$, and $\left(\Delta\pi\Delta S-\psi-\frac{1-\delta}{\delta\gamma(\beta)}\frac{\psi}{\Delta\pi}\right)''_\beta=-\frac{(1-\delta)\psi}{\delta\Delta\pi}\frac{1}{\left(\int_0^1\min\{\alpha,\beta\}dF(\alpha)\right)^2}\left(\beta f(\beta)-\frac{2(1-F(\beta))\int_0^\beta\alpha dF(\alpha)}{\int_0^1\min\{\alpha,\beta\}dF(\alpha)}\right)$. Because $\left(\int_0^1\min\{\alpha,\beta\}dF(\alpha)\right)''_\beta\le 0$ and $\left(\Delta\pi\Delta S-\psi-\frac{1-\delta}{\delta\gamma(\beta)}\frac{\psi}{\Delta\pi}\right)\ge 0$, the platform profit is concave in β if

$$
\begin{aligned}
&(1-F(\beta))\frac{(1-\delta)\psi}{\delta\Delta\pi}\frac{\int_0^\beta\alpha dF(\alpha)}{\left(\int_0^1\min\{\alpha,\beta\}dF(\alpha)\right)^2}\\
&+\beta\gamma(\beta)\frac{(1-\delta)\psi}{\delta\Delta\pi}\frac{1}{\left(\int_0^1\min\{\alpha,\beta\}dF(\alpha)\right)^2}\left(\beta f(\beta)-\frac{2\,(1-F(\beta))\int_0^\beta\alpha dF(\alpha)}{\int_0^1\min\{\alpha,\beta\}dF(\alpha)}\right)\ge 0\\
\Leftrightarrow&(1-F(\beta))\left(\int_0^\beta\alpha dF(\alpha)\right)+\beta\gamma(\beta)\left(\beta f(\beta)-\frac{2\,(1-F(\beta))\int_0^\beta\alpha dF(\alpha)}{\int_0^1\min\{\alpha,\beta\}dF(\alpha)}\right)\ge 0\\
\Leftrightarrow&f(\beta)\ge\frac{(1-F(\beta))\int_0^\beta\alpha dF(\alpha)}{\beta\int_0^1\min\{\alpha,\beta\}dF(\alpha)}.
\end{aligned}
$$

PROPOSITION 7. *Suppose that the costly effort is induced by the platform at equilibrium, that is, $\beta\le\hat\beta$. For each commission amount no more than the maximum commission identified in Proposition 6, there are (various) entry fee schemes that achieve the maximum profit for given β. The platform's profit is increasing in β and maximized at $\beta=\hat\beta$. Specifically, the maximum profit of the platform is achieved by charging zero commission, zero entry fee to the buyers, and maximum entry fee to the service providers.*

Proof of Proposition 7 When $\beta\le\hat\beta$ and the commission amount is no more than the maximum commission identified in Proposition 6, the platform can induce costly effort from the service providers on the platform. Moreover, by using an entrant fee, the platform can ensure a zero surplus for both the buyers and the service providers, and thus fully capture the social welfare gain. Therefore, the maximum profit of the platform is obtained at $\beta=\hat\beta$, under which we adopt zero commission and zero entrant fee to the buyers to induce the costly effort from the service providers.

LEMMA 4. *The costly effort can be induced by the platform at equilibrium with the proportion of the service providers on the platform* β *if and only if there exists policy* P *such that* $\Delta\pi\Delta S - \psi \geq \left(\frac{1-\delta(1-\eta)}{\delta(1-\eta)\gamma(\beta)(1-\rho)} + 1 - \pi_1\right)\frac{\psi}{\Delta\pi}$ *and* $\eta(1-\beta) \geq (1-\pi_1)\beta(1-\eta)\left(1 - \sum_{j=0}^{\infty}(1-\eta)^j p_j\right)$*, where* $\rho = \sum_{i=0}^{\infty}\delta^i(1-\eta)^i p_i$.

Proof of Lemma 4 Suppose the costly effort can be induced by the platform at equilibrium with the proportion of the service providers on the platform β. By the proof of Lemma 3, $\Delta\pi\Delta S - \psi \geq \left(\frac{1-\delta(1-\eta)}{\delta(1-\eta)\gamma(\beta)(1-\rho)} + 1 - \pi_1\right)\frac{\psi}{\Delta\pi}$. By the proof of Lemma 2, $\eta(1-\beta) \geq (1-\pi_1)\beta(1-\eta)\left(1 - \sum_{j=0}^{\infty}(1-\eta)^j p_j\right)$.

Furthermore, when both inequalities are satisfied by some policy P, an effort-inducing equilibrium with the proportion of the service providers on the platform β can be sustained by the payment scheme calculated in Lemma 1.

PROPOSITION 8. *There exists threshold* $\check{\beta} \leq \tilde{\beta}(0) \leq \hat{\beta}$*, such that the costly effort can be induced by the platform at equilibrium if and only if the proportion of the unsuspended service providers on the platform,* β*, is no more than* $\check{\beta}$*. Moreover, if* $\beta = \check{\beta} > 0$*, there exists a unique suspension policy that induces the costly effort at equilibrium, and this suspension policy is either a lifetime suspension policy or a pseudo deterministic policy.*

Proof of Proposition 8 Suppose that by policy P, the costly effort can be induced at equilibrium with the proportion of the service providers on the platform β'. The costly effort can also be induced at equilibrium by policy P with the proportion of the service providers on the platform β'' for all $\beta'' < \beta'$. Define

$$\check{\beta} = \max\{0, \sup\{\beta|\text{there exists } P \text{ satisfying the two inequalities in Lemma 4}\}\},$$

i.e., the maximum β under which the platform can induce costly effort at equilibrium.

Note that $\hat{\beta}(\rho)$ can be written as

$$\max\{0, \sup\{\beta|\text{there exists } P \text{ satisfying the first inequality in Lemma 4}\}\}$$

by Proposition 5. Moreover, as ρ increases, the first inequality becomes harder to satisfy. Therefore, $\check{\beta} \leq \tilde{\beta}(0)$.

Setting $\rho = 0$, consider the value of $\tilde{\beta}(\rho)$. If $\tilde{\beta}(0) = 0$, it is impossible to induce costly effort from service providers on platform and $\check{\beta} = 0$. Now, we consider the case $\tilde{\beta}(0) > 0$. There are two possible cases.

If condition $\eta(1-\tilde{\beta}(0)) \geq (1-\pi_1)\tilde{\beta}(0)(1-\eta)$ holds, then $\check{\beta} = \tilde{\beta}(0)$ and at boundary $\check{\beta}$, this suspension policy must be the lifetime suspension policy to ensure $\rho = 0$ and costly effort can be induced by the platform at equilibrium at $\check{\beta}$.

If condition $\eta(1-\tilde{\beta}(0)) \geq (1-\pi_1)\tilde{\beta}(0)(1-\eta)$ fails, costly effort cannot be induced by the platform at equilibrium at $\tilde{\beta}(0)$. Now we increase the value of ρ continuously. For each ρ, we calculate $\tilde{\beta}(\rho)$ and consider the following parametric formulation.

$$[M] \quad \max_P \quad M = \sum_{j=0}^{\infty} (1-\eta)^j p_j \tag{7}$$

$$\text{subject to} \sum_{i=0}^{\infty} \delta^i (1-\eta)^i p_i \leq \rho, \tag{8}$$

$$\sum_{i=0}^{\infty} p_i \leq 1, \tag{9}$$

$$p_i \geq 0 \text{ for all } i. \tag{10}$$

For a given ρ, if the optimal objective function value M is such that $\eta(1-\beta(\rho)) \geq (1-\pi_1)\beta(\rho)(1-\eta)(1-M)$, at equilibrium, the platform can induce costly effort with $\beta(\rho)$ as the proportion of the service providers on the platform by the implementing the optimal solution to $[M]$ as the suspension policy. Furthermore, as ρ increases, $\beta(\rho)$ continuously decreases to zero and M continuously increases (but bounded by 1). Therefore, $\check{\beta}$ is the threshold β such that the inequality $\eta(1-\beta(\rho)) \geq (1-\pi_1)\beta(\rho)(1-\eta)(1-M)$ becomes equality.

Now, we show that if condition $\eta(1-\tilde{\beta}(0)) \geq (1-\pi_1)\tilde{\beta}(0)(1-\eta)$ fails, the optimal solution to $[M]$ is a pseudo deterministic policy; and thus, the suspension policy at $\check{\beta}$ is a pseudo deterministic policy. We prove by contradiction. For given $\rho > 0$, we first show that $\sum_{i=1}^{\infty} p_i = 1$ at the optimal solution. Suppose that $\sum_{i=1}^{\infty} p_i < 1$, if $\sum_{i=0}^{\infty} \delta^i (1-\eta)^i p_i < \rho$, we can strictly increase the value of M, which contradicts the optimality of M. Therefore, $\sum_{i=0}^{\infty} \delta^i (1-\eta)^i p_i = \rho > 0$, and we can pick some $p_k > 0$ for $k \geq 0$. Now, we construct solution $\{p'_i\}_0^{\infty}$ such that $p'_i = p_i$ for all $i \neq k$ or $k+1$ and $p'_k = p_k - \delta(1-\eta)\epsilon$ and $p'_{k+1} = p_{k+1} + \epsilon$. It is easy to verify that when ϵ is a small positive number (say, smaller than p_k), the solution $\{p'_i\}_0^{\infty}$ is feasible and leads to a larger objective value. Therefore, we have reached a contradiction, and $\sum_{i=1}^{\infty} p_i = 1$ at the optimal solution. Now suppose that $p_j, p_k \in (0,1)$ and $k - j > 1$. Now, we construct solution $\{p'_i\}_0^{\infty}$. If $k - j > 2$, we set $p'_i = p_i$ for all $i \neq j$ or $j+1$ or $k-1$ or k, $p'_j = p_j - \delta(1-\eta)\epsilon$, $p'_{j+1} = p_{j+1} + \epsilon$, $p'_{k-1} = p_{k-1} + \delta(1-\eta)\epsilon$, $p'_k = p_k - \epsilon$; If $k - j > 2$, we set $p'_i = p_i$ for all $i \neq j$ or $j+1$ or $k-1$ or k, $p'_j = p_j - \delta(1-\eta)\epsilon$, $p'_{j+1} = p_{j+1} + \epsilon$, $p'_{k-1} = p_{k-1} + \delta(1-\eta)\epsilon$, $p'_k = p_k - \epsilon$; if $k - j = 2$, we set $p'_i = p_i$ for all $i \neq j$ or $j+1 = k-1$ or k, $p'_j = p_j - \delta(1-\eta)\epsilon$, $p'_{j+1} = p'_{k-1} = p_{j+1} + \epsilon + \delta(1-\eta)\epsilon$, $p'_k = p_k - \epsilon$. It is easy to verify that when ϵ is a small positive number, the solution $\{p'_i\}_0^{\infty}$ is feasible and leads to a larger objective value. Therefore, we have reached a contradiction and the optimal solution to $[M]$ is a pseudo deterministic policy when condition $\eta(1-\tilde{\beta}(0)) \geq (1-\pi_1)\tilde{\beta}(0)(1-\eta)$ fails.

Therefore, if $\beta = \check{\beta} > 0$, there exists a unique suspension policy that induces the costly effort at equilibrium. This suspension policy is either a lifetime suspension policy or a pseudo deterministic policy.

PROPOSITION 9. *Suppose that the costly effort is induced by the platform at equilibrium, that is, $\beta \leq \check{\beta}$. The platform's profit is increasing in β and maximized at $\beta = \check{\beta}$. Specifically, the maximum profit of the platform is achieved by charging zero commission, zero entry fee to the buyers and maximum entry fee to the service providers.*

Proof of Proposition 9 The first part of the statement follows the proof of Proposition 7. That is, the maximum profit of the platform is achieved by charging zero commission, zero entry fee to the buyers, and maximum entry fee to the service providers. Notice that under this scheme, after a low outcome, if the service provider exits and re-enters the platform, his expected utility is zero, while his expected utility for staying on the platform and undergoing the suspension is $\rho V \geq 0$. Therefore, he has no incentive to shirk and re-enter. Furthermore, the expected payoff of creating additional accounts is zero. Therefore, the maximum commission scheme also eliminates the service providers' incentive to create duplicate accounts.

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