Two-sided Adverse Selection and Bilateral Reviews in the Sharing Economy

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Abstract

Online peer-to-peer platforms match service providers with consumers. Both providers and consumers derive heterogeneous payoffs depending on whom they are matched with. To ensure that providers and consumers identify the most valuable matches, many of these platforms elicit relevant information from and also disclose the information to the market participants by adopting bilateral review schemes. Although the bilateral review scheme has its own merits in reducing information asymmetry and possibly enabling better matches, its impact on the various stakeholders in online peer-to-peer platforms remains unexplored. We show that, in equilibrium, the bilateral review scheme intensifies price competition among service providers to attract low-cost consumers and consequently reduces the platform's profit. Interestingly, service providers may be better off with more intense price competition and lower prices when the proportion of low-cost consumers is sufficiently high. More importantly, we find that social welfare is not always higher under the bilateral review scheme compared to either the unilateral review scheme or no reviews. Our findings demonstrate that even though the bilateral review scheme eliminates the information asymmetry and adverse selection on both sides of the market, it does not necessarily enhance market efficiency when competing providers strategically respond to reviews by adjusting their prices.

Keywords: *sharing economy, bilateral reviews, competition, analytical modeling, economics of IS*

Introduction

The sharing economy has enjoyed a steep growth during the last decade, driven mostly by online peer-to-peer platforms. These platforms have emerged for a wide range of services such as transportation (e.g., Uber, Lyft), accommodation (e.g., Airbnb), labor contracting (e.g., TaskRabbit, Upwork) and consumer loans (e.g., Lending Club, Prosper) (Einav et al. 2016). A primary objective of such platforms is to facilitate proper matches between service providers (hereafter, providers) and service seekers (hereafter, consumers) because both providers and consumers could derive different payoffs depending on whom they are matched with (Romanyuk 2017). To meet this objective, many of these platforms elicit and disclose information about market participants by adopting a bilateral review scheme (Ke et al. 2017). Unlike the more prevalent

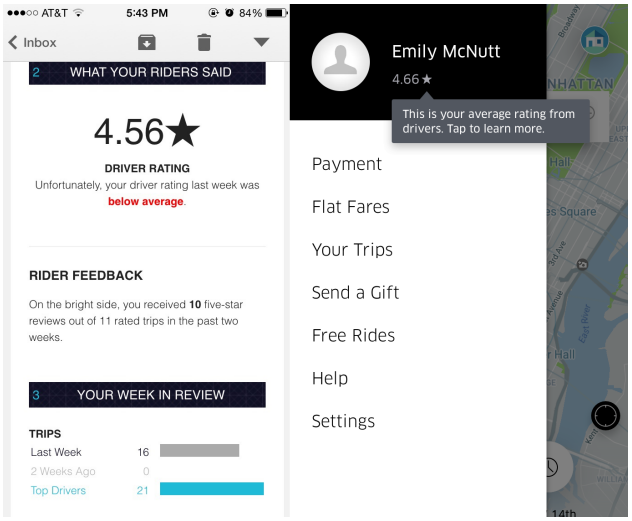

Figure 1. Uber (a sharing economy platform for transportation services) uses a bilateral rating scheme where a star rating for drivers (on the left) and a star rating for riders (on the right) are given after each transaction.

unilateral review scheme in which only consumers provide reviews about providers, many peer-to-peer platforms also allow a provider to write reviews about a consumer. For instance, in Airbnb, a potential guest can observe reviews about a host to assess the quality of the host's service before deciding whether to submit a request to a specific host. Each host, in turn, can observe the reviews about a guest to assess how easy/costly it is to serve her before deciding whether to accept the guest's request.

The need for a bilateral review scheme in a peer-to-peer platform stems from an important distinction between peer-to-peer contexts and marketplaces where unilateral review schemes are adopted. Consider the Amazon marketplace, which employs a unilateral review scheme where consumers rate sellers' products. In this marketplace, a seller's cost of serving a consumer does not vary across consumers. Therefore, sellers do not have any preference regarding the consumers they serve.[1] Essentially, only consumers have a preference for sellers and a choice regarding from which seller to buy becomes a key issue in traditional marketplaces. In such a context, a unilateral review (product and/or seller) scheme is sufficient to help consumers mitigate their uncertainty about product quality and fit (Hong and Pavlou 2014; Kwark et al. 2014). In contrast, providers in peer-to-peer sharing platforms incur different costs depending on the type of consumers they serve, and they can choose to serve or not serve a consumer. For instance, in Airbnb, providers incur less cost to serve consumers who are responsible and follow the rules of the property, referred to as low-cost consumers (Jin et al. 2017), compared to misbehaving consumers, referred to as high-cost consumers, who could damage the property and increase the provider's cost. Moreover, providers can vary with respect to the quality of their service, which also affects their cost. For example, a luxury property has higher maintenance and cleaning costs compared to a simple property, like a regular apartment. When providers incur heterogeneous costs to serve to different segments of consumers, they would desire to have information about a consumer's type before engaging in a transaction. Similar to Airbnb, in Uber, a driver has an option to filter out the requests from consumers with poor reviews (Ke et al. 2017). Since both providers and consumers derive heterogeneous payoffs depending on whom they are matched with, a bilateral review scheme may become less desirable in the peer-to-peer markets. Figures 1 and 2 illustrate the ratings in Uber and Airbnb respectively.

The main premise of a review scheme, whether unilateral or bilateral, is that it mitigates the information asymmetry among market participants. Information asymmetry between consumers and sellers may have detrimental effects on the market and may lead to a market failure due to adverse selection (Akerlof 1978). The impact of one-sided information asymmetry and adverse selection has been extensively studied in the

[1]Moreover, the laws and regulations force sellers in these marketplaces not to discriminate against certain consumers.

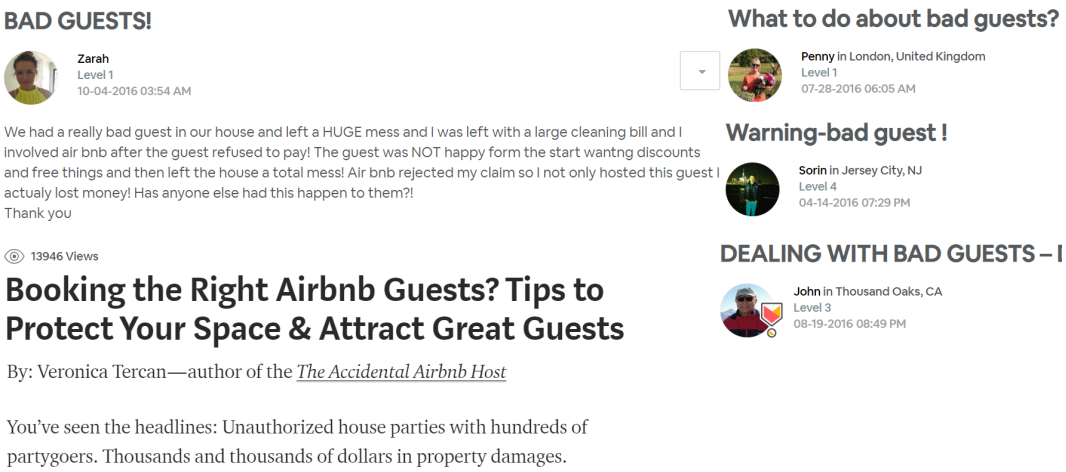

Figure 2. AirBnB (a sharing economy platform for accommodation) hosts discuss what to do with bad guests in online forums. One host claims that she lost money due to high cleaning cost. Another article mentions how to attract great guests to avoid property damages.

literature in domains ranging from insurance, health care, to labor markets (Cutler and Reber 1998; Finkelstein and Poterba 2004; Greenwald 1986). However, the two-sided information asymmetry and adverse selection has received little attention. The emergence of the sharing economy has highlighted the significance of two-sided adverse selection issue. In this paper, we study the strategic implications of a bilateral review scheme on various stakeholders in online peer-to-peer marketplaces to provide insights into sharing platforms. We perform the analysis by developing a game theoretical model of a platform that matches consumers of heterogeneous serving costs and providers of varying qualities.

Our analysis reveals several interesting findings that have important implications for the platform, providers, consumers, and the society. We show that the bilateral review scheme intensifies the price competition among service providers as they lower their prices in equilibrium to attract the low-cost consumers. Intensified price competition, in turn, reduces the platform's profit. Interestingly, service providers may be better off with more intense price competition and lower prices when the proportion of low-cost consumers are sufficiently high. These results are driven by the fact that under the bilateral review scheme cost to serve is revealed, thereby enabling service providers to attract low-cost consumers with reduced prices to diminish their cost to serve. More importantly, we find that social welfare is not always higher under the bilateral review scheme, compared to the unilateral scheme or no reviews. Hence, our findings demonstrate that the bilateral review scheme, which reduces the information asymmetry and adverse selection between market participants, does not necessarily enhance market efficiency when providers strategically respond to information in reviews by adjusting their prices.

Prior Literature and Contributions

This paper primarily contributes to the growing literature on peer-to-peer markets (Einav et al. 2016; Jin et al. 2017; Ke et al. 2017; Tadelis 2016) and to the vast literature on adverse selection. While the literature on peer-to-peer markets has examined operational and strategic aspects such as platform competition, our work relates specifically to the impact of bilateral reviews in peer-to-peer markets. Ke et al. (2017) show that bilateral ratings facilitate customer segmentation based on the cost to serve them and may result in higher market prices. In their model, consumers search and individually apply to providers, which leads to several inefficiencies due to search frictions and rejections by service providers. In contrast, we consider a scenario in which the online peer-to-peer platform matches providers with consumers to eliminate the search frictions and other inefficiencies. Thus, our study highlights the role of bilateral ratings when market efficiency is determined solely by consumer valuation and cost to serve consumers. Jin et al. (2017) show that bilateral ratings may lead to over-selective behavior of providers in which they turn down many con-

sumers, thus resulting in a decline in service quality. Jin et al. (2017) also considers a setting in which the platform sets the price of each transaction. Our paper differs from this in that service providers strategically choose their prices in our model, which is consistent with online peer-to-peer platforms such as Airbnb, Turo, TaskRabbit, etc.

Our work contributes to the literature on two-sided adverse selection. Soberman (1999) introduces the term "double adverse selection" in the context of product warranties, and states that when double adverse selection exists, buyers do not know the seller's product quality, and sellers do not know the buyer's type (preference). He examines product warranties as both a screening and a signalling mechanism. Gale (2001) studies two-sided adverse selection in the context of a labor market that has high-skilled and low-skilled workers, and workers have preferred and non-preferred firms. The primary objective is to characterize the equilibrium paths in such a market. Our definition of two-sided adverse selection varies slightly from the above two definitions in that both providers and consumers have heterogeneous types and they realize heterogeneous payoffs when matched with different types. Second, we focus on the effects of adverse selection on society and market participants, as opposed to the earlier studies' focus on the characterization of the equilibrium. As established by Akerlof (1978), adverse selection of consumers may lead to market failure and diminish social welfare. We examine whether the detrimental effects of adverse selection are more severe when it is two-sided. More importantly, the peer-to-peer context we consider in this paper has several distinctive characteristics not examined by the traditional literature on adverse selection. For instance, in our context, the supply is finite, causing the provider-side price competition to be fundamentally different in high demand and low demand scenarios, whereas the prior literature has assumed that all demand can be met by suppliers. Furthermore, unlike in peer-to-peer markets, the notion of a platform that matches providers with consumers does not exist in traditional markets.

Our study is also related to the literature on information disclosure in matching markets. There exists a long-standing debate in this stream of work on whether, and to what degree, information disclosure is beneficial in matching markets. Tadelis and Zettelmeyer (2015) shows that information disclosure helps in matching heterogeneous buyers to sellers of varying quality. Romanyuk (2017) reveals that full information disclosure is inefficient due to excessive rejections by sellers in matching platforms. He also concludes that a simple policy with partial disclosure restores the efficiency when the platform observes the preferences of sellers. Hoppe et al. (2009) shows that information disclosure leads to wasteful signaling which offsets the benefits of improved matching. Einav et al. (2016) points out that the trade-off between eliciting dispersed information and minimizing transaction costs in online peer-to-peer markets is important to keep the users happy. In contrast to many models in this stream of literature, we abstract away from platform's information disclosure policy (i.e., whether to disclosure partial or full information, whether to aggregate or disperse information, etc.) in order to focus on the impact of the bilateral review scheme, which has already been adopted by many peer-to-peer platforms, on various stakeholders.

Finally, our study relates to the literature on the use and manipulation of online reviews by firms for pricing strategies (Dellarocas 2006; Kwark et al. 2017; Li 2017; Li et al. 2011). Li et al. (2011) concludes that online product reviews influence firms' pricing decisions for products with repeated purchases. Kwark et al. (2017) show that retailers can use the upstream pricing scheme as a strategic tool to benefit from online product reviews. Li (2017) identifies conditions under which revealing average ratings is more profitable than not revealing them. Tunc et al. (2017) examine how aggregation of online reviews affects the upstream price competition depending on factors such as review precision and the extent of differentiation. In contrast, we consider the strategic implications of the bilateral review scheme in peer-to-peer markets to reduce the asymmetry of information between service providers and consumers to facilitate better matching. Specifically, we focus on the impact of disclosing a consumer's type (i.e., the cost of serving the consumer) to providers on price competition among providers and subsequent matching decisions by the sharing platform.

Model

We consider an online peer-to-peer sharing platform (R) that has M competing providers, who are indexed by j, and N consumers, who are indexed by i. Provider j sets price p_j for his service and the platform charges

a commission equal to α fraction of the price for each matched transaction. The platform deploys an online review system that provides information about the providers and consumers. Consumers, each of whom has unit demand, use provider reviews to decide which provider to seek the service from. Similarly, providers use consumer reviews to choose which type of consumers they prefer to serve. Finally, the platform matches providers with consumers based on the preferences on both sides.

Provider j has a service quality of q_j, which is a *vertical quality* in the sense that all consumers prefer more of service quality to less, *ceteris paribus*. We assume, for expositional clarity, that a service quality takes a value of either *high* or *low*, i.e., $q_j \in \{q_H, q_L\}$. The proportion of high-quality providers is denoted by ρ. For providers, consumers are heterogeneous in terms of the cost to serve them. The consumer i has type θ^i which takes a value of either high or low, i.e., $\theta^i \in \{\theta^H, \theta^L\}$, $\theta^H > \theta^L$. The proportion of low type consumers in the market is represented by γ. We assume, for analytical tractability, that the proportions of low type consumers and high-quality providers are common knowledge. We also point out that a service provider can only serve one consumer at a given time.

Provider j incurs a cost to serve a consumer i, denoted as $c_{i,j}$. A provider incurs a higher cost to serve a high-cost consumer than a low-cost consumer. Moreover, a provider's cost to serve is higher when the service is of higher quality (Ke et al. 2017). Therefore, we assume that provider j's cost to serve consumer i is given by $c_{i,j} = \theta^i q_j$. We assume that $\theta^H < 1$ so that no provider would turn away any consumer, even the high-cost ones. Consumer i's net utility from being served by provider j is given by $U_{i,j} = q_j - p_j$. Provider j's net profit from serving consumer i is given by $\pi_{i,j} = (1-\alpha)p_j - \theta^i q_j$.

The game proceeds as follows. In stage 1, providers simultaneously set their prices, either p_L or p_H. In stage 2, consumers submit their preference to the platform (i.e. either high or low quality provider) based on their expected net utility. Consumers prefer a high-quality service provider if $q_H - p_H \geq q_L - p_L$, and a low-quality service provider, otherwise.[2] Since consumer utility does not depend on the consumer type, both low-cost and high-cost consumers will prefer the same provider that offers a higher net utility. In stage 3, providers submit their preferred consumer type (i.e. low-cost or high-cost consumer). Since all providers incur a lower cost serving a low-cost type than a high-cost type, all providers prefer the low-cost type. In stage 4, the platform matches providers and consumers based on their preferences. We note that when the consumer type is unknown, the provider's preference is meaningless. Analogously, when the provider type is unknown, the consumer preference is based only on prices. The matching procedure depends on whether the platform and the players have knowledge about provider type and/or consumer type. Depending on the platform's knowledge, we distinguish three cases: no review, unilateral review scheme, and bilateral review scheme. The matching process in each of these cases works as follows. In the no review case, neither providers nor consumers know the type of the other player. Consumers' pre-purchase expected net utility depends on the expected quality minus the price. Since the expected quality is the same for every provider, consumers will prefer the low-priced provider. On the other hand, providers do not know the consumer type, therefore they have no preference. Then, the platform randomly picks a consumer of any type and matches her with the preferred (low-priced) provider, until the preferred providers are fully matched. After that, consumers are matched with the non-preferred (high-priced) provider. In the unilateral review scheme, the platform and the consumers know the provider type, but the consumer type is unknown to them. Therefore, while consumers provide their preference based on their net utility, providers prefer any consumer (no matter what her cost type is).[3] Then, the platform chooses a random consumer and matches her with her preference. When a service provider of the preferred type is no longer available, the platform matches the consumer with the other service provider type without violating the incentive compatibility constraints.[4] In the bilateral review scheme, every player knows the types of all providers and consumers. since all providers prefer low-cost consumers, the platform chooses a low-cost consumer randomly and matches her with her preference. Similarly, when the service provider type that a low-cost consumer prefers is no longer available, then the platform matches her with the other service provider type. After all low-cost consumers are matched, the platform repeats the same steps for high-cost consumers until either all high-cost consumers are matched

[2]We assume that when $q_H - p_H = q_L - p_L$, consumers will prefer a high-quality provider.

[3]An alternative unilateral review scheme is one in which providers know the consumer type but the consumers do not know the provider type. We do not examine this alternative in this paper.

[4]We note that even when a consumer is matched with the other service provider type, equilibrium prices are set such that it would not violate consumer's incentive compatibility constraint.

or there are no more service providers available.

We point out that the matching scheme seeks to accommodate the preferences of both providers and consumers conditional on the information available to the platform. We adopt this matching process in the main model in order to highlight the impact of two-sided adverse selection on the social welfare and mitigate the role of matching process (e.g., any social inefficiency caused by matching process) on the impact. Moreover, accommodating the providers' and consumers' preferences could be beneficial to the two-sided platform over a long run.

We can illustrate the matching procedure using an example. Assume that $q_H = 10, q_L = 4, p_H = 8, p_L = 3, N = 80, M = 60, \gamma = \rho = 0.5$. First, we consider the no reviews case. In the second stage, since there are no reviews for service providers, consumers would prefer the low-priced provider (i.e., low-quality providers). On the other hand, providers have no preference for consumers since the low-cost consumers cannot be differentiated from the high-cost consumers. In the final stage, the platform randomly matches consumers with the preferred (low-quality) providers. When the low-quality providers are fully matched, 20 remaining consumers are randomly matched with the non-preferred (high-quality) providers. In this scenario, all low-quality providers are matched and 20 high-quality providers are not matched. Moreover, 10 low-cost and 10 high-cost consumers are not matched.

Second, suppose the platform uses the bilateral review system for the same set of parameters. In the second stage, consumers prefer the high-quality providers since $U_H > U_L$ and submit their preference to the platform. In stage 3, service providers prefer the low cost consumers since bilateral reviews enables them to differentiate between low and high cost consumers. In stage 4, the platform considers the preferred types of providers (i.e., high-quality), and consumers (i.e., low cost). The platform matches 30 high-quality service providers with 30 low-cost consumers. Due to high demand, several low-cost consumers are not matched with their preferred provider. Then, the platform matches the remaining low-cost consumers with 10 low-quality providers. Finally, 20 remaining low-quality providers are matched with 20 high-cost consumers. In this setting, all low cost consumers are matched, and 20 high-cost consumers are not matched with any providers.

Now, assume the platform uses the unilateral review system for the same example. In stage 2, consumers prefer the high-quality providers as before since $U_H > U_L$. In stage 3, providers cannot differentiate consumers since there are no ratings associated with consumers. Therefore, providers do not have any preference for the consumer type. In stage 4, the platform prioritizes high-quality providers since they are preferred by consumers. The platform matches 30 high-quality providers with consumers randomly. Since the proportion of low-cost consumers is 0.5, 15 low-cost and 15 high-cost consumers are matched with high-quality providers. Then, the platform matches 30 low-quality providers with the remaining consumers randomly. Therefore, 15 low-cost and 15 high-cost consumers will be matched with low-quality providers. In the unilateral ratings scheme, 10 low-cost consumers are not matched along with 10 high-cost consumers. Hence, the platform is not able to match a certain proportion of low-cost consumers, which leads to inefficiencies in the market due to higher serving cost associated with matched high-cost consumers.

We consider two demand scenarios: high and low. In the high demand scenario, the total number of consumers is greater than the total number of providers, and the number of low-cost consumers is greater than the number of providers of any type. On the other hand, in the low demand scenario, the total number of consumers is smaller than the number of providers of any type.[5] The probability of high demand scenario is ϕ_H and the probability of low demand scenario is $\phi_L = 1 - \phi_H$. The parameters are depicted in figures 4 and 5 in the appendix.

[5]Clearly, other demand scenarios are possible, e.g., the total number of consumers is greater than the total number of providers, but the number of low-cost consumers is less than the total number of providers. We do not consider such scenarios in this paper for brevity and expositional clarity.

Equilibria under No Review, Unilateral Review and Bilateral Review Schemes

We first derive the equilibrium in each review scheme: no review, unilateral review, and bilateral review. We then compare the equilibrium outcomes under these schemes to assess the impacts of the review systems on various variables of interest.

No Review

In the no review scheme, neither providers nor the platform can differentiate the low-cost consumers from the high-cost consumers. Therefore, providers have no preference for the consumer type. Provider j's expected cost to serve a consumer is $\mathbb{E}[c_j] = (\gamma\theta^L + (1-\gamma)\theta^H)q_j$. In addition, consumers as well as the platform cannot distinguish between the provider types. Consumer i's expected net utility from provider j is $\mathbb{E}[U_{i,j}] = \mathbb{E}[q] - p_j$, where the expected quality is $\mathbb{E}[q] = \rho q_H + (1-\rho)q_L$. Clearly, all consumers will prefer the low-priced provider since the expected quality is the same across all service providers. The expected demand for provider j, $\mathbb{E}[D_j]$, depends on several factors such as the demand scenario, the number of consumers, the number of providers, and the prices. Consider the low-demand scenario. Recall that in the low-demand scenario, the total number of consumers is less than the number of low-quality providers as well as the number of high-quality providers. In the no review scheme, higher-priced providers would have no demand, and not all lower-priced providers would realize a positive demand. That is, if $p_L < p_H$, $\mathbb{E}[D_L] = \frac{N_L}{M(1-\rho)}$, and $\mathbb{E}[D_H] = 0$. Similarly, if $p_L > p_H$, then $\mathbb{E}[D_L] = 0$, and $\mathbb{E}[D_H] = \frac{N_L}{M\rho}$. In the high-demand scenario, the expected demand for all providers is equal to 1.

We obtain the equilibrium prices by simultaneously solving the following maximization problems for providers, where we use the superscript NR to denote the no review case, $*$ in the superscript to denote the equilibrium quantity, and the subscript H or L to indicate the high and low-quality service providers, respectively.

$$\begin{aligned} p_H^{NR*} &= \underset{p_H}{\operatorname{argmax}}\, \mathbb{E}[D_H]((1-\alpha)p_H - q_H(\gamma\theta^L + (1-\gamma)\theta^H)) \\ p_L^{NR*} &= \underset{p_L}{\operatorname{argmax}}\, \mathbb{E}[D_L]((1-\alpha)p_L - q_L(\gamma\theta^L + (1-\gamma)\theta^H)) \end{aligned} \tag{1}$$

Lemma 1. *In the absence of any reviews, the equilibrium prices in the high-demand and low-demand scenarios are as follows:*

	p_H^{NR*}	p_L^{NR*}
High Demand	$\rho q_H + (1-\rho)q_L$	$\rho q_H + (1-\rho)q_L$
Low Demand	$\frac{q_H(\gamma\theta^L+(1-\gamma)\theta^H)}{1-\alpha}$	$\frac{q_H(\gamma\theta^L+(1-\gamma)\theta^H)}{1-\alpha}$

Proof: All proofs are in the appendix unless indicated otherwise.

Lemma 1 characterizes the equilibrium prices for high- and low-quality service providers in the no reviews scheme. In the high-demand scenario, neither provider type has an incentive to compete on prices since their capacity will be fully satisfied. Therefore, they set a price equal to the expected quality.[6] In the low-demand scenario, providers compete on prices to attract consumers. Notice that the higher-priced provider does not realize any demand. Therefore, both types of providers engage in a Bertrand-like price competition. The lowest price that a high-quality provider would set is one that would cover his expected cost after adjusting for commission, $\frac{\mathbb{E}[c_H]}{1-\alpha}$. Similarly, the lowest price that a low-quality provider would set is $\frac{\mathbb{E}[c_L]}{1-\alpha}$. Note that $\frac{\mathbb{E}[c_L]}{1-\alpha} < \frac{\mathbb{E}[c_H]}{1-\alpha}$. However, if the low-quality provider sets a lower price than the high-quality provider, then the consumers would infer that the lower-priced provider is of low quality. In that case, even though the consumers do not observe the provider ratings, they can still infer the provider quality from the prices. Consequently, a low-quality provider can attract a positive demand by signaling he is of low quality only by setting a price that is less than $\frac{\mathbb{E}[c_H]}{1-\alpha} - (q_H - q_L)$. However, at these prices, the low-quality provider does not

[6] We assume that $(1-\alpha)\,\mathbb{E}[q_H] > \mathbb{E}[c_H]$, otherwise providers would exit the market, since they get negative payoffs.

make a profit. Therefore, the low-quality provider would mimic the high-quality provider and set the same price as the high-quality provider, i.e., $\frac{\mathbb{E}[c_H]}{1-\alpha}$.

If $\mathbb{E}[q] < p_j^{NR*}$, then in the low-demand scenario, the market would break down because the consumer's expected valuation is less than the price charged by providers. This is consistent with the well-established result that adverse selection could lead to market failure in traditional markets. We note that in the traditional adverse selection literature, it is assumed that there is no constraint on the supply and thus the demand never exceeds the supply. This is analogous to the low-demand scenario in our model. Lemma 1 shows an additional result that in the high-demand scenario where the demand exceeds the supply, the market does not break down because the price does not exceed the consumers' expected valuation. Thus, Lemma 1 suggests that the undesirable impact of adverse selection depends on whether or not the supply can meet the demand.

Unilateral Review Scheme

In the unilateral review scheme, we consider that every provider's type (i.e. high-quality, low-quality) is truthfully revealed. However, service providers and the platform cannot differentiate between the low-cost and high-cost consumers. Therefore, provider j's expected cost to serve is $\mathbb{E}[c_j] = (\gamma\theta^L + (1-\gamma)\theta^H)q_j$, as in the no reviews scheme. The expected demand function for provider j, $\mathbb{E}[D_j]$, depends on several factors, such as the number of consumers, and the difference in the net utilities obtained from the providers, i.e. $q_H - p_H$ and $q_L - p_L$. Consider the low-demand scenario. If $q_H - p_H > q_L - p_L$, then $\mathbb{E}[D_H] = \frac{N_L}{M\rho}$, and $\mathbb{E}[D_L] = 0$. If $q_H - p_H \leq q_L - p_L$, then $\mathbb{E}[D_L] = \frac{N_L}{M(1-\rho)}$, $\mathbb{E}[D_H] = 0$. In the high-demand scenario, the expected demand is equal to 1 for all providers. We obtain equilibrium prices by simultaneously solving the following providers' maximization problems.

$$\begin{aligned} p_H^{UR*} &= \underset{p_H}{\operatorname{argmax}}\, \mathbb{E}[D_H]((1-\alpha)p_H - q_H(\gamma\theta^L + (1-\gamma)\theta^H)) \\ p_L^{UR*} &= \underset{p_L}{\operatorname{argmax}}\, \mathbb{E}[D_L]((1-\alpha)p_L - q_L(\gamma\theta^L + (1-\gamma)\theta^H)) \end{aligned} \tag{2}$$

Lemma 2. *In the unilateral review scheme, the equilibrium prices in the high-demand and low-demand scenarios are as follows:*

	p_H^{UR*}	p_L^{UR*}
High Demand	q_H	q_L
Low Demand	$q_H - q_L + \frac{q_L(\gamma\theta^L+(1-\gamma)\theta^H)}{1-\alpha}$	$\frac{q_L(\gamma\theta^L+(1-\gamma)\theta^H)}{1-\alpha}$

Lemma 2 characterizes the equilibrium prices for high- and low-quality service providers when consumers can observe ratings of providers. In the high-demand scenario, no provider has an incentive to compete on prices since the providers are guaranteed to get demand and their price has no impact on which consumer type will be assigned to them and hence the expected cost. Therefore, they set a price equal to their quality. In response to the equilibrium prices, all consumers prefer high-quality providers. However, there is no incremental payoff of being the preferred provider, since the match with a low-cost consumer is random and both provider types will have full demand. In the low-demand scenario, providers compete on prices to attract consumers. Notice that a provider with a lower net utility, $q_J - p_J$, does not realize any demand. Therefore, both types engage in a Bertrand-like price competition. The lowest price that a low-quality provider would set is one that covers his expected cost, $\frac{\mathbb{E}[c_L]}{1-\alpha}$. Similarly, the lowest price a high-quality provider would set is $\frac{\mathbb{E}[c_H]}{1-\alpha}$. Note $q_H - \frac{\mathbb{E}[c_H]}{1-\alpha} > q_L - \frac{\mathbb{E}[c_L]}{1-\alpha}$. Therefore, a low-quality provider does not realize any demand even at its lowest possible price. As a result, the high-quality provider sets the price, $q_H - q_L + \frac{\mathbb{E}[c_L]}{1-\alpha}$ and gets the full demand.

Lemma 2 shows that, both in low-demand and high-demand scenarios, the high-quality providers set a price that cover their expected cost to serve and the consumers' valuation is greater than the price they pay. Therefore, the market does not break down in the unilateral review scheme regardless of the demand

scenario. This finding is consistent with the result in the prior literature (e.g., Akerlof (1978)) that the market breakdown caused by adverse selection or information asymmetry between the sellers and consumers can be eliminated or mitigated by eliminating the information asymmetry. Additionally, Lemma 2 shows that, in our context, eliminating the information asymmetry on the consumer side by revealing the provider type is sufficient to eliminate the market breakdown caused by adverse selection even though the adverse selection is two-sided.

Bilateral Review Scheme

In the bilateral review scheme, we consider that both service providers' and consumers' types are truthfully revealed. Therefore, service providers always prefer the low-cost consumers. On the other hand, the low-cost consumers prefer the high-quality providers if and only if $q_H - p_H \geq q_L - p_L$. Consequently, the expected demand, provider profit, and the optimization model solved by the providers depend on whether or not $q_H - p_H \geq q_L - p_L$. Let us consider, for illustrative purposes, that high-quality service providers are preferred by low-cost consumers in the high-demand scenario. Then, the platform will match the low-cost consumers with high-quality service providers. However, since there are more low-cost consumers than high-quality service providers, some fraction of the low-cost consumers will be matched with low-quality service providers with probability $\frac{N_H\gamma - M\rho}{M(1-\rho)}$. Then, the simultaneous maximization problems for the service providers in the high-demand scenario can be written as below.

$$\begin{aligned} p_H^{BR*} &= \underset{p_H}{\text{argmax}}\ (1-\alpha)p_H - q_H\theta^L \text{ subject to } q_H - p_H \geq q_L - p_L \\ p_L^{BR*} &= \underset{p_L}{\text{argmax}}\ (1-\alpha)p_L - q_L(\tfrac{N_H\gamma - M\rho}{M(1-\rho)}\theta^L + (1 - \tfrac{N_H\gamma - M\rho}{M(1-\rho)})\theta^H) \text{ subject to } q_H - p_H \geq q_L - p_L \end{aligned} \tag{3}$$

(or)

$$\begin{aligned} p_H^{BR*} &= \underset{p_H}{\text{argmax}}\ (1-\alpha)p_H - q_H(\tfrac{N_H\gamma - M(1-\rho)}{M\rho}\theta^L + (1 - \tfrac{N_H\gamma - M(1-\rho)}{M\rho})\theta^H) \text{ s.t. } q_H - p_H < q_L - p_L \\ p_L^{BR*} &= \underset{p_L}{\text{argmax}}\ (1-\alpha)p_L - q_L\theta^L \text{ subject to } q_H - p_H < q_L - p_L \end{aligned} \tag{4}$$

First, we find the conditions under which $q_H - p_H \geq q_L - p_L$. Then, we get expressions for the expected cost to serve for each provider, $\mathbb{E}[c_j]$, and expected demand functions, $\mathbb{E}[D_j]$. Finally, we solve for the equilibrium prices and find the expected profit of service providers as well as the platform's profit. The following lemma summarizes the equilibrium prices in the bilateral review scheme.

Lemma 3. *In the bilateral review scheme, the equilibrium prices in the high-demand and low-demand scenarios are as follows:*

	p_H^{BR*}	p_L^{BR*}
High Demand	$q_H - \frac{q_L(M-N_H\gamma)(\theta^H-\theta^L)}{M(1-\alpha)(1-\rho)}$	q_L *if* $0 \leq \rho \leq \frac{q_H}{q_H+q_L}$
	q_H	$q_L - \frac{q_H(M-N_H\gamma)(\theta^H-\theta^L)}{M(1-\alpha)\rho}$ *if* $\frac{q_H}{q_H+q_L} < \rho \leq 1$
Low Demand	$q_H - q_L + \frac{q_L(\gamma\theta^L+(1-\gamma)\theta^H)}{1-\alpha}$	$\frac{q_L(\gamma\theta^L+(1-\gamma)\theta^H)}{1-\alpha}$

In the high demand scenario, even though every provider is guaranteed to get a consumer, providers compete for the low-cost consumers in order to maximize their profits.[7] We find that if the proportion of high-quality providers is sufficiently large (low), then the low-quality (high-quality) providers compete aggressively to ensure that they get only low-cost consumers. We note that in the high-demand scenario, there are a sufficient number of low-cost consumers that each provider type would get some of these consumers. The high-quality providers lower the price to less than their quality and ensure matching with low-cost consumers only when the proportion of high-quality providers is sufficiently low, i.e., when $0 \leq \rho \leq \frac{q_H}{q_H+q_L}$. The reason behind

[7]We note that in equilibrium providers set a price such that the payoff from serving to a high-cost consumers is non negative. Therefore, they would not turn down a consumer of any type.

this finding is the intricate nature of the competition between providers as explained below. Suppose the high-quality providers compete aggressively to ensure matching with low-cost consumers. As the proportion of high-quality service providers increases, the number of low-cost consumers available to low-quality providers decreases. This causes the low-quality providers to compete aggressively for the low-cost consumers and reduce their prices, which, in turn, forces the high-quality providers to decrease their prices also in order to maintain their competitive advantage over low-quality providers. Therefore, as the proportion of high-quality service providers increases, the attractiveness of the strategy of competing for low-cost consumers decreases for the high-quality providers. When the proportion of high-quality providers crosses a threshold, the high-quality providers find it profitable to switch to a strategy of not competing for low-cost consumers and charge a price equal to their quality. On the contrary, the low-quality service providers follow a strategy that is the opposite of that of high-quality providers, i.e., they decrease their prices and attract the low-cost consumers when the proportion of high-quality service providers is sufficiently high, i.e., when $\frac{q_H}{q_H+q_L} < \rho \leq 1$.

In the low-demand scenario, both types of service providers have incentives to lower their prices to attract any type of consumer. However, since the prices are set such that $\pi_j = (1-\alpha)p_j - \mathbb{E}(c_j) \geq 0$, the prices can be as low as the serving cost divided by $1-\alpha$, which gives the high-quality service providers an edge in the price competition, since $q_H - \frac{\mathbb{E}(c_H)}{1-\alpha} \geq q_L - \frac{\mathbb{E}(c_L)}{1-\alpha}$. Consequently, in equilibrium $p_L^* = \frac{\mathbb{E}(c_L)}{1-\alpha}$ and $p_H^* = q_H - q_L + \frac{\mathbb{E}(c_L)}{1-\alpha}$ such that both consumer types prefer the high-quality service providers.

Implications of Unilateral and Bilateral Reviews Schemes for Social Welfare

In this section, we compare the social welfare under no review, unilateral review, and bilateral review schemes.

Proposition 1. *The social welfare in the unilateral review scheme is greater than that in the no review scheme.*

Proposition 1 demonstrates that eliminating the adverse selection suffered by consumers improves social welfare. This is consistent with the well-documented result, shown initially by the seminal study of Akerlof (1978) which also demonstrated that adverse selection suffered by consumers can potentially lead to a market failure. Although our context is different and more general than that used by Akerlof (1978) and studies that followed it, the result holds in our context as well attesting to the robustness of this finding.

The intuition behind our result is the following. The social welfare is equal to the expected quality minus the expected cost to serve in our context. When there are no reviews about the providers, consumers can not infer the qualities or prefer specific providers. Consequently, they are randomly matched with a provider. In the unilateral review scheme, consumers observe the qualities of providers and decide accordingly. The high-quality providers set the prices such that they are preferred in equilibrium, which increases their demand and the expected quality that the consumers enjoy. On the other hand, since there are more high-quality providers that are matched with consumers under the unilateral reviews, the total cost to serve also increases when compared to the no reviews case. Note that service cost is calculated by the product of consumer type and the provider quality. However, the increase in the expected quality is higher than the increase in the cost to serve because providers find it profitable to serve any consumer. As a result, the increase in the service cost is lower than the increase in the expected quality, the social welfare under the unilateral reviews to be greater than that in the no reviews case.

Proposition 2. *The social welfare in the bilateral review scheme is lower than that in the unilateral review scheme when the proportion of high-quality service providers is sufficiently high, i.e.* $\frac{q_H}{q_H+q_L} < \rho$, *and the proportion of low-cost consumers is sufficiently low, i.e.* $\gamma < \frac{M(1-\rho)(q_H-q_L)}{q_H(N_H-M\rho)-q_L M(1-\rho)}$.

Interestingly, we find that eliminating the adverse selection suffered by providers in addition to that suffered by consumers does not necessarily improve the social welfare compared to when only the consumer-side adverse selection is eliminated. This is surprising because the bilateral review scheme overcomes the problem of information asymmetries on both sides - between service providers and consumers - and therefore, one would expect that it would reduce the market inefficiencies and imperfect matches. However, social welfare

in the bilateral review scheme is lower than that in the unilateral review scheme when the proportion of high-quality service providers is sufficiently high and the proportion of low-cost consumers is sufficiently low.

A closer examination of the two equilibria under the unilateral review scheme and bilateral review scheme reveals that the equilibria in the two schemes in the low-demand scenario are identical. These findings have two implications: (i) once the adverse selection suffered by the consumer side is eliminated, eliminating the adverse selection on the seller side does not add to the social welfare if the demand is low or there is adequate supply to meet the demand. It highlights the role of consumer-side adverse selection in contexts examined by the bulk of prior literature where supply is assumed to be large enough to meet the demand. (ii) The surprising outcome regarding the impact of bilateral scheme on the social welfare is solely driven by the high-demand scenario. Furthermore, in the high-demand scenario, the expected quality in the equilibrium is the same between the two review schemes. Therefore, the difference in the social welfare in the two schemes is only determined by the misfit cost, or in our context, the cost to serve consumers.

The intuition behind Proposition 2 is twofold. First, when the proportion of high-quality service providers is sufficiently high, recall from Lemma 3 that while low-quality providers get only low-cost consumers, some high-quality providers end up with high-cost consumers under the bilateral review scheme, because high-quality providers do not find it profitable to go after the low-cost consumers. On the other hand, under the unilateral review scheme, the low-cost consumers are randomly split between high-quality and low-quality providers. Second, when the proportion of low-cost consumers is sufficiently low, a high (low) number of high-cost (low-cost) consumers would be assigned to high-quality providers, compared to the unilateral review scheme. While the cost for low-quality providers reduces, the serving cost for high-quality providers increases under the bilateral review scheme. As a result, the social welfare decreases in the bilateral review scheme compared to the unilateral review scheme under the conditions stated in Proposition 2.

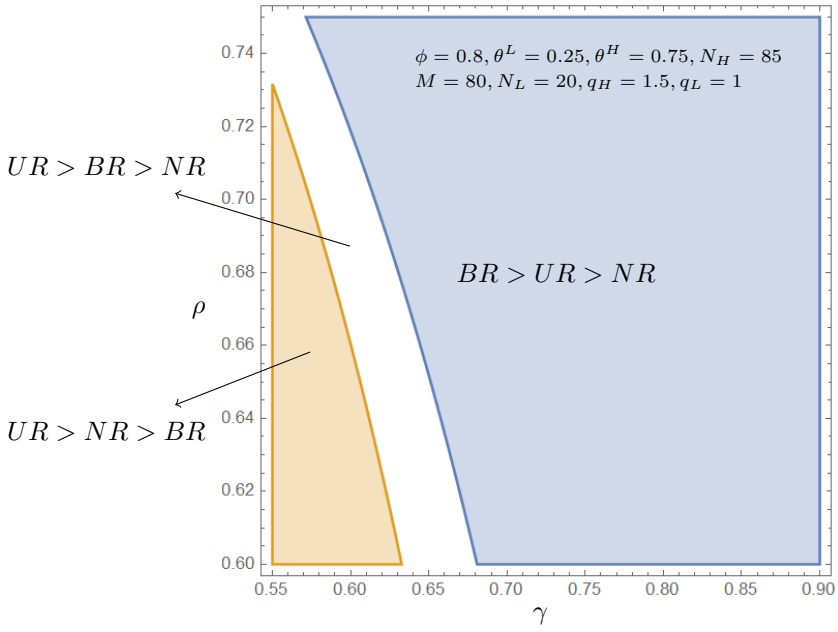

Figure 3. Social welfare comparison of all three review schemes.

Figure 3 illustrates Proposition 2 and also compares the social welfare under the three schemes. In particular, it shows that the bilateral review scheme can hurt the social welfare even when compared to no review scheme when both ρ and γ are small. These results challenge the intuitive reasoning for the social welfare implications of two-sided adverse selection. One might argue that the negative effect of adverse selection on society may be more severe when it is two-sided. Therefore, removing the asymmetry of information on both sides using the bilateral review scheme should improve the social welfare more than removing the

asymmetry of information on one side using the unilateral review scheme. However, we show that it is not necessarily the case when providers strategically respond to available information about consumer types. In summary, when the proportion of high-quality providers is sufficiently high, the high-quality providers set higher prices such that they are no longer preferred by the consumers. Moreover, the proportion of low-cost consumers in the market is another critical factor. Specifically, when the proportion of low-cost consumers is sufficiently low, the reduced cost to serve for low-quality providers does not offset the increased serving cost for high-quality providers. These two factors combined suggest that the implications of two-sided adverse selection for social welfare may not be as severe as those of one-sided (consumer-side) adverse selection.

Implications for Platform, Providers, and Consumers

In this section, we compare unilateral review and bilateral review schemes from the platform's, providers' and consumers' perspectives.

Proposition 3. *The platform's revenue is lower in the bilateral review scheme than in the unilateral review scheme.*

The platform's revenue is directly proportional to the average price charged to a consumer, or the intensity of price competition under a review scheme. In the bilateral review scheme, the price competition is more intense since service providers lower their prices in equilibrium to attract low-cost consumers and to reduce their cost to serve. On the other hand, the lack of information about consumer type prevents the providers from engaging in an intense price competition for low-cost consumers. Therefore, although the bilateral review scheme reduces the asymmetry of information between providers and consumers, the platform may not necessarily prefer this more efficient review scheme as it hurts the platform's bottom line.

Proposition 4. *Provider's total profit is higher in the bilateral review scheme than in the unilateral scheme when the proportion of low-cost consumers is sufficiently high. More formally,* $\pi^{BR*} > \pi^{UR*}$ *if and only if* $\gamma^* < \gamma \leq 1$*, where*

$$\gamma^* = \begin{cases} \frac{M\rho(q_L(2-\rho)-q_H(1-\rho))}{q_L(N_H-M(1-\rho)^2)-q_H M(1-\rho)\rho} & \text{if } 0 \leq \rho < \frac{q_H}{q_H+q_L} \\ \frac{M(1-\rho)(q_H(1+\rho)-q_L\rho)}{q_H(N_H-M\rho^2)-q_L M(1-\rho)\rho} & \text{otherwise} \end{cases}$$

Although the bilateral review scheme intensifies the price competition among providers, when the proportion of low-cost consumers is sufficiently high, providers are better off even with low prices due to reduced serving costs. More specifically, when the number of low-cost consumers is high enough, reduced cost to serve consumers offsets the losses due to intensified competition and lower prices. In other words, we find that competition for low-cost consumers makes providers better off when there are more low-cost consumers in the market. Otherwise, i.e., when the proportion of low-cost consumers is sufficiently low, providers are worse off in the bilateral review scheme, similar to the platform.

Proposition 5. *Consumer surplus is greater in the bilateral review scheme than in the unilateral review scheme.*

Interestingly, consumers enjoy a greater surplus when their types are revealed to the providers. When consumer types are presented to the providers by bilateral reviews scheme, providers lower their prices in equilibrium to attract low-cost consumers. Due to intensified price competition and lower prices, consumers benefit more in the bilateral review scheme.

Managerial Implications and Future Work

Our study has implications for practicing managers and researchers. From an academic researcher perspective, the study examines a less-explored variation of the well-known adverse selection problem. The traditional adverse selection problem is one-sided. The information asymmetry we consider in this paper is a two-sided adverse selection problem, which has not received much attention in the literature even though it has been recognized. It is well-known that adverse selection leads to diminished social welfare and possibly market failure. One would expect that these detrimental impacts of adverse selection would be more

severe under two-sided adverse selection than under one-sided adverse selection. Consequently, the conventional wisdom would be that the bilateral review system would mitigate the two-sided adverse selection problem more than the unilateral review system. However, our findings show that this need not be the case.

From a practitioner perspective, we find that the online platform has little incentive to adopt the bilateral review scheme on its own if the platform uses a matching algorithm that maximizes social welfare. However, providers may demand from the online platform to adopt the bilateral review scheme when the proportion of low-cost consumers is sufficiently high. Clearly, the matching algorithm used by the platform has significant implications on the impacts of the review system. While a platform could justify the algorithm that matches the social welfare as somewhat neutral that balances the interests of all parties, this algorithm may not provide much incentives to the platform to make the player types transparent to everyone. On the other hand, it is conceivable that a different algorithm could provide such information disclosure incentives. Therefore, identifying an appropriate matching algorithm that benefits every player becomes important in online peer-to-peer markets.

Future studies can extend this paper in several directions to provide additional insights about bilateral reviews in the sharing economy. For instance, a future research direction would be to analyze a marketplace that the platform uses a matching procedure that maximizes its own expected profit as opposed to the expected social welfare. In another extension, researchers would consider that the ratings do not reveal the provider quality or the consumer type perfectly. Moreover, we assume that the providers charge one price to consumers and the platform takes a fraction of that price as commission. In practice, providers may charge multiple prices. For example, in Airbnb, hosts may charge a price and a separate cleaning fee. Furthermore, it is possible that the providers could charge a deposit which could be refunded if the consumer behaved responsibly. An analysis of such pricing schemes would provide much richer insights into the impacts of information asymmetry in peer-to-peer markets.

Another future direction would be to investigate two competing platforms with different review schemes. One possible scenario is that one of the platforms uses bilateral review scheme and the other uses unilateral review scheme. There may be several interesting findings when analyzing such a marketplace. For instance, providers who may be multihoming between the platforms would prefer the platform with unilateral review scheme since they may set higher prices. On the other hand, consumers would prefer the platform with bilateral review scheme due to intensified price competition and reduced prices. At the same time, some privacy-sensitive and high-cost consumers may choose to use the platform where they are not rated. An analysis of the competing platforms may provide many rich insights and it would be a potential fruitful research direction for the future. One other future research direction may be to endogeneize the quality decision of service providers. We acknowledge that when service providers choose their quality given the information strategy of the online sharing platform, there would potentially be several fruitful insights into the impact of bilateral reviews on the social welfare.

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Appendix

Positions of parameters in high and low demand scenarios

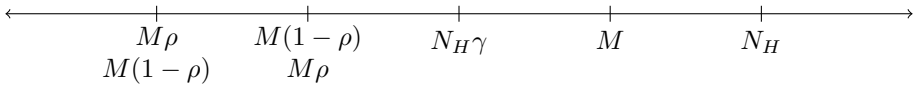

Figure 4. Positions of parameters in high demand scenario.

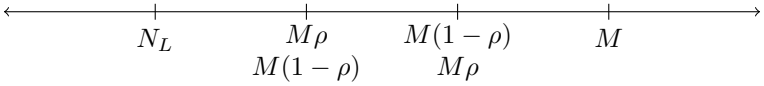

Figure 5. Positions of parameters in low demand scenario.

Proof of Lemma 1

High-demand Scenario: Consider a low-quality service provider. There are three possible cases. 1) When $p_L < p_H$, all consumers apply to low-quality service providers. However, since the low-cost consumers can not be differentiated from the high-cost consumers, low-quality service providers will randomly be matched with any type of consumers. Then, the probability that a match with a low-cost consumer will be γ and a match with a high-cost consumer will be $(1-\gamma)$. 2) When $p_L = p_H$, consumers will be have a preference and randomly matched with any type of service providers. Again, low-quality service providers will be randomly matched with consumers. Therefore, the probability to serve a low-cost consumer will be γ and to serve a high-cost consumer will be $(1-\gamma)$. 3) When $p_L > p_H$, consumers prefer high-quality service providers.

Then, high-quality service providers will be the preferred provider, and will be matched with consumers with a priority. The remaining consumers will be randomly matched with the low-quality service provider. Once again, the probability to serve a low-cost consumer will be γ and to serve a high-cost consumer will be $(1-\gamma)$. In all three possible cases, the expected cost to serve to a consumer will be the same. Therefore, there is no incentive to lower the price, i.e. $p_L^* = \mathbb{E}(q)$. A similar logic applies to high-quality service providers. Then, the equilibrium outputs will be, $p_L^* = p_H^* = \mathbb{E}(q) = \rho q_H + (1-\rho)q_L$.

Low-demand Scenario: Since there are no rating information for the service providers, consumers are willing to pay at most $\mathbb{E}(q)$. Consumers decide their preference based on the prices. Since price is the only decision variable for the consumers and it is the low-demand case, service providers engage in Bertrand-like competition. However, since the expected cost for the high quality service providers is higher than low quality service provider, $p_H^* = \frac{\mathbb{E}(c_H)}{1-\alpha}$. Low quality service provider can set a price lower than $\frac{\mathbb{E}(c_H)}{1-\alpha}$. However, when low quality service providers set a price lower than $\frac{\mathbb{E}(c_H)}{1-\alpha}$, consumers can infer that the low priced providers are of low quality. Because, high quality would never set a price lower than $\frac{\mathbb{E}(c_H)}{1-\alpha}$. In that case, consumers would apply to high quality service provider even with a higher price. Therefore, it is not profitable for low quality service providers to set a price lower than $\frac{\mathbb{E}(c_H)}{1-\alpha}$, i.e. $p_L^* = \frac{\mathbb{E}(c_H)}{1-\alpha}$. Then, the equilibrium prices will be $p_H^* = p_L^* = \frac{\mathbb{E}(c_H)}{1-\alpha} = \frac{q_H(\gamma\theta^L + (1-\gamma)\theta^H)}{1-\alpha}$.

Proof of Lemma 2

High Demand Scenario: In high demand scenario, both service providers will have full demand. Therefore, service providers have incentive to lower their prices only to attract low-cost consumers. However, in unilateral ratings, low-cost consumers can not be distinguished from high-cost consumers since there are no ratings for the consumers. Then, both service providers do not have any incentive to lower their prices in high demand scenario under unilateral ratings. Then, the equilibrium prices are given as $p_H^{UR*} = q_H, p_L^{UR*} = q_L$.

Low-demand Scenario: There exists a pure strategy Nash equilibrium in low demand scenario. Fix $p_H \in [\frac{\mathbb{E}(c_H)}{1-\alpha}, q_H]$. When $q_H - p_H \geq q_L - p_L$, all consumers prefer high quality service providers. However, it is not certain that a demand will be realized even for high quality service providers due to low demand. There is a probability β_3 that a consumer will be matched with a high quality service provider, $\beta_3 = \frac{N_H}{M\rho}$. Due to low demand, high quality service providers will prefer any type of consumers, since no matter the cost to serve to them is, it is always better to serve a consumer than not to serve a consumer. Then, $\pi_H(p_H) = \beta_3((1-\alpha)p_H - \mathbb{E}(c_H))$, where $\mathbb{E}(c_H) = \gamma\theta^L q_H + (1-\gamma)\theta^H q_H$. When $q_H - p_H < q_L - p_L$, all consumers prefer low quality service provider, so $\pi_H(p_H) = 0$. Therefore, it is always more profitable to set $p_H \leq q_H - q_L + p_L$. Moreover, it is always possible to find a price $\frac{\mathbb{E}(c_H)}{1-\alpha} < p_H \leq q_H - q_L + p_L$, $\forall p_L \in [\frac{\mathbb{E}(c_L)}{1-\alpha}, q_L]$. Then, in equilibrium $p_L^* = \frac{\mathbb{E}(c_L)}{1-\alpha}$ and $p_H^* = q_H - q_L + \frac{\mathbb{E}(c_L)}{1-\alpha}$, as ϵ approaches to zero.

Proof of Proposition 1

Social welfare is calculated as the summation of the service provider's profit and the consumer surplus. The price does not have an impact on the social welfare, since the price consumers pay goes to service providers and they neutralize each other in the social welfare calculations. Therefore, social welfare is calculated as the quality of the service net the provider's service costs.

High demand scenario:
$W^{NR*} = M\rho q_H + M(1-\rho)q_L - M\rho(\gamma\theta^L q_H + (1-\gamma)\theta^H q_H) - M(1-\rho)(\gamma\theta^L q_L + (1-\gamma)\theta^H q_L)$
$W^{UR*} = M\rho q_H + M(1-\rho)q_L - M\rho(\gamma\theta^L q_H + (1-\gamma)\theta^H q_H) - M(1-\rho)(\gamma\theta^L q_L + (1-\gamma)\theta^H q_L)$

In high demand scenario, social welfare is equal in the two review schemes.

Low demand scenario:
$W^{NR*} = N\rho q_H + N(1-\rho)q_L - N\rho(\gamma\theta^L q_H + (1-\gamma)\theta^H q_H) - N(1-\rho)(\gamma\theta^L q_L + (1-\gamma)\theta^H q_L)$
$W^{UR*} = Nq_H - N(\gamma\theta^L q_H + (1-\gamma)\theta^H q_H)$

A comparison of the social welfare between the two review schemes is as follows.

$$W^{UR*} > W^{NR*}$$
$$N(1-\rho)q_H - N(1-\rho)(\gamma\theta^L q_H + (1-\gamma)\theta^H q_H) > N(1-\rho)q_L - N(1-\rho)(\gamma\theta^L q_L + (1-\gamma)\theta^H q_L) \tag{5}$$

It is clear that the social welfare in unilateral reviews is greater than the social welfare in no reviews.

Proof of Proposition 2

High demand scenario - Bilateral Reviews: There are two possibilities. (i) When $\frac{q_H}{q_H+q_L} < \rho < 1$, low cost consumers prefer low-quality service providers. Therefore, the serving cost for the low quality service providers is $\gamma_L q_L$, whereas the serving cost for the high quality service providers is $\beta_2\gamma_L q_H + (1-\beta_2)\gamma_H q_H$. (ii) When $0 < \rho < \frac{q_H}{q_H+q_L}$, then low cost consumers prefer high quality providers. As a result, their cost to serve is $\gamma_L q_H$ and the cost to serve for low quality service providers is $\beta_1\gamma_L q_L + (1-\beta_1)\gamma_H q_L$. In both cases, the service quality is $m\rho q_H + m(1-\rho)q_L$. Then, the social welfare in high demand scenario under bilateral reviews is calculated as follows.

$$W^{BR*} = \begin{cases} M\rho q_H + M(1-\rho)q_L - M\rho(\theta^L q_H) - M(1-\rho)(\beta_1\theta^L q_L + (1-\beta_1)\theta^H q_L) & \text{if } 0 \le \rho < \frac{q_H}{q_H+q_L} \\ M\rho q_H + M(1-\rho)q_L - M\rho(\beta_2\theta^L q_H + (1-\beta_2)\theta^H q_H) - M(1-\rho)(\theta^L q_L) & \text{if } \frac{q_H}{q_H+q_L} \le \rho \le 1 \end{cases} \tag{6}$$

High demand scenario - Unilateral Reviews: Due to high demand, all service providers fulfill their capacities. Therefore, the service quality is $M\rho q_H + M(1-\rho)q_L$. Since there are no reviews for consumers, the service providers can not differentiate between the low cost and high cost consumers. Therefore, consumers are randomly matched with service providers. Then, the cost to serve is $M\rho(\gamma\theta^L q_H + (1-\gamma)\theta^H q_H) + M(1-\rho)(\gamma\theta^L q_L + (1-\gamma)\theta^H q_L)$. Then, $W^{UR*} = M\rho q_H + M(1-\rho)q_L - M\rho(\gamma\theta^L q_H + (1-\gamma)\theta^H q_H) - M(1-\rho)(\gamma\theta^L q_L + (1-\gamma)\theta^H q_L)$ in high demand.

Low demand scenario - Bilateral Reviews: In low demand scenario, high quality service providers capture all the demand. However, some of high quality service providers do not serve any consumers. Therefore, the service quality will be $N_L q_H$. Some proportion of high quality service providers will be matched with high cost consumers. The cost to serve the consumers is $N(\gamma\theta^L q_H + (1-\gamma)\theta^H q_H)$. Then, $W^{BR*} = N_L q_H - N_L(\gamma\theta^L q_H + (1-\gamma)\theta^H q_H)$ in low demand.

Low demand scenario - Unilateral Reviews: High quality service providers will be preferred by the consumers as before. Then, the service quality is $N_L q_H$. Since there are no reviews for consumers, service providers can not differentiate the consumer type. Then, the cost to serve is calculated as $N_L(\gamma\theta^L q_H + (1-\gamma)\theta^H q_H)$. Finally, $W^{UR*} = N_L q_H - N_L(\gamma\theta^L q_H + (1-\gamma)\theta^H q_H)$ in low demand.

Comparison of social welfare: Notice that in low demand scenario, $W^{UR*} = W^{BR*}$. We compare the welfare in high demand scenario as below.

When $0 \le \rho < \frac{q_H}{q_H+q_L}$

$$W^{BR*} > W^{UR*}$$
$$M\rho(\gamma\theta^L q_H + (1-\gamma)\theta^H q_H) + M(1-\rho)(\gamma\theta^L q_L + (1-\gamma)\theta^H q_L) > M\rho\theta^L q_H + M(1-\rho)(\beta_1\theta^L q_L + (1-\beta_1)\theta^H q_L)$$
$$\frac{\rho(1-\gamma)M(q_H - q_L) + q_L N_H\gamma - q_L M\rho}{M} > 0 \tag{7}$$

This always holds since $N_H\gamma > M\rho$. When $0 \le \rho < \frac{q_H}{q_H+q_L}$, $W^{BR*} > W^{UR*}$.

When $\frac{q_H}{q_H+q_L} \leq \rho \leq 1$

$$\begin{aligned} W^{BR*} &> W^{UR*} \\ \rho(\gamma\theta^L q_H + (1-\gamma)\theta^H q_H) + (1-\rho)(\gamma\theta^L q_L + (1-\gamma)\theta^H q_L) &> \rho(\beta_2\theta^L q_H + (1-\beta_2)\theta^H q_H) + (1-\rho)\theta^L q_L \\ \gamma &> \frac{M(1-\rho)(q_H - q_L)}{q_H(N_H - M\rho) - q_L M(1-\rho)} \end{aligned} \tag{8}$$

Then, $W^{BR*} > W^{UR*}$ only when $\frac{q_H}{q_H+q_L} \leq \rho \leq 1$ and $\gamma > \frac{M(1-\rho)(q_H-q_L)}{q_H(N_H-M\rho)-q_L M(1-\rho)}$. On the other side, $W^{UR*} > W^{BR*}$ only when $\frac{q_H}{q_H+q_L} \leq \rho \leq 1$ and $\gamma < \frac{M(1-\rho)(q_H-q_L)}{q_H(N_H-M\rho)-q_L M(1-\rho)}$.

Proof of Proposition 3

Platform profit under bilateral ratings in high demand scenario can be calculated as below.

$$\pi_R^{BR*} = \alpha M(\rho p_H^{BR*} + (1-\rho)p_L^{BR*}) \tag{9}$$

When we plug the equilibrium prices in the formula above, we calculate the platform profit under bilateral ratings in high demand scenario as shown below.

$$\pi_R^{BR*} = \begin{cases} \alpha(M\rho q_H + M(1-\rho)q_L - \frac{(M-N_H\gamma)\rho q_L(\theta^H-\theta^L)}{(1-\alpha)(1-\rho)}) & \text{if } 0 \leq \rho < \frac{q_H}{q_H+q_L} \\ \alpha(M\rho q_H + M(1-\rho)q_L - \frac{(M-N_H\gamma)(1-\rho)q_H(\theta^H-\theta^L)}{(1-\alpha)\rho}) & \text{if } \frac{q_H}{q_H+q_L} \leq \rho \leq 1 \end{cases} \tag{10}$$

In low demand scenario, the platform profit is given below.

$$\pi_R^{BR*} = \alpha N_L(q_H - q_L + \frac{q_L(\gamma\theta^L + (1-\gamma)\theta^H)}{1-\alpha}) \tag{11}$$

In unilateral ratings, the platform profit in high demand scenario is given below.

$$\pi_R^{UR*} = \alpha M(\rho q_H + (1-\rho)q_L) \tag{12}$$

Similarly, the platform profit in low demand scenario under unilateral ratings are given below.

$$\pi_R^{UR*} = \alpha N_L(q_H - q_L + \frac{q_L(\gamma\theta^L + (1-\gamma)\theta^H)}{1-\alpha}) \tag{13}$$

Then, one can observe that in low demand scenario, the platform profit is the same under both review schemes. However, in high demand scenario, the platform profit in unilateral reviews is always higher than the platform profit in bilateral reviews. The proof is straight-forward when we compare $\pi_R^{BR*} - \pi_R^{UR*} = -\frac{(M-N_H\gamma)\rho q_L(\theta^H-\theta^L)}{(1-\alpha)(1-\rho)} < 0$, since $M > N_H\gamma, \theta^H > \theta^L, 0 \leq \rho < \frac{q_H}{q_H+q_L}$ and $0 < \alpha < 1-\theta^H < 1$. The same comparison also yields the same result when $\frac{q_H}{q_H+q_L} \leq \rho \leq 1$, since $\pi_R^{BR*} - \pi_R^{UR*} = -\frac{(M-N_H\gamma)(1-\rho)q_H(\theta^H-\theta^L)}{(1-\alpha)\rho} < 0$.