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Pricing strategies of laborer-sharing platform in two transaction modes

GUAN Shuhan, SHENG Jianchao, DU Shaofu *
School of Management, University of Science and Technology of China, Hefei 230026, China
* Corresponding author. E-mail: sdu@ustc.edu.cn

Abstract: With the advancement of Internet information technology, the laborer-sharing platform plays a crucial role in promoting the full use of human resources across the whole society. At present, multiple trading modes with different pricing strategies are adopted by the laborer-sharing platform. Considering the heterogeneity of laborers' abilities, we construct the laborer-sharing platform's profit functions under the buyer pricing strategy and laborer pricing strategy, and analyze its optimal pricing strategy in the bidding mode. First, our analysis shows that when the mismatch degree between the service of the low-type laborer and the buyer's task is close to that of the high-type laborer, the laborer pricing strategy is beneficial to the platform. Second, when the task mismatch degree of the low-type laborer is much lower than that of the high-type laborer, the platform's pricing strategy depends on the buyer's satisfaction with the completing task. Finally, we compare two transaction models: the bidding mode and the piece mode, and find that under the laborer pricing strategy, the platform's profit in the bidding mode is not always higher than that in the piece mode.

Keywords: laborer-sharing; bidding mode; piece mode; buyer pricing strategy; laborer pricing strategy
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1 Introduction

The development of Chinese economy has entered a new normal, which requires improving the supply system's quality and advancing the supply-side structural reform further. The new mode of laborer-sharing has emerged. Laborer-sharing refers to the laborer using her fragmented time to create value through an online platform. This mode enables an effective flow of labor resources, improves the adaptability of the supply structure when facing changes in demands, and helps stabilize the economy.

With the continuous increase in labor demand and the advancement in information technology, laborer-sharing platforms have developed rapidly over recent years. The emergence of laborer-sharing platforms changes the employment mode of the laborer and the enterprise, promotes the upgrade of business technologies, and stimulates the economic growth. Indeed, it is estimated that these platforms already comprise an approximately \$26 billion market[1]. It is suggested that the utilization of laborer-sharing is growing at a rate of 26% per year[2]. Furthermore, about 70 million global workers register in laborer-sharing platforms, facilitating remote forms of gig work[3]. In China, the market value of laborer-sharing is estimated at ￥90 billion, and the largest laborer-sharing platform, ZBJ.com, has got 15 million registered users.

On these laborer-sharing platforms, the bidding mode and the piece mode are the most widely adopted service pattern. The bidding mode allows the buyer to post his demand and the laborer to scramble for the bid, and the buyer chooses a proper laborer to deliver his task. The piece mode refers to a transaction mode in which the buyer chooses services by paying the laborer's remuneration based on a qualified demand, and the number of selected services depends on the buyer's demand. When the service quality is qualified, the buyer will immediately pay for the services. In these modes, the most frequently involved job is the design type, including slogan design, logo design, etc. There are two main pricing strategies adopted by laborer-sharing platforms: Buyer pricing strategy and laborer pricing strategy. On the platform, the laborer can independently decide whether to accept a task or not, resulting in a significant difference in the number and the quality of the service that can be provided. An

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appropriate pricing strategy can ensure an adequate supply and demand match and maximize the platform's profit. However, there are few studies on the pricing strategy of the laborer-sharing platform.

Our contributions are in the following three aspects. First, the pricing strategy is an essential practical issue in laborer-sharing platform research but has not been researched deeply. This study develop a pricing model for the laborer-sharing platform to analyze the platform's pricing strategy and explore the related theory on the sharing economy. Second, to the best of our knowledge, the platform's price strategy studied in the extant literature has seldom considered the buyer pricing strategy. However, this study considers the buyer pricing strategy and compares it with the traditional laborer pricing strategy. Finally, this study provides management enlightenment for the formulation of platform pricing strategy, enriches the research of platform pricing strategy theory, and has significant theoretical value and practical significance.

2 Literature review

This study relates to the sharing platform's mode and pricing strategy. The former literature mainly covers three aspects. Firstly, scholars conducted an overall analysis of the current sharing platform. Philip et al. [4] found that the sharing platforms break down the supply and demand information asymmetry barrier by connecting the resource supply and demand sides, thus providing rapid and accurate transaction information matching services and promoting resource sharing. Martin et al. [5] explored the business model of the sharing platform based on its uniqueness. Secondly, some researches specifically analyzed the supply and demand sides of the sharing platforms. For instance, Hall and Krueger[6] are the first to comprehensively analyze the factors that affect Uber (a car-sharing platform) to attract drivers to register with the platform based on the survey data. Bimpikis et al. [7] discussed the space price discrimination by the car-sharing platform from two aspects: Passenger's destination preference and driver's service provision preference. Jiang and Yang[8] explored the impact of transaction cost, transaction price, and product quality of the product-sharing platform on the enterprise and consumer. Sun et al. [9] analyzed the impact of driver's hourly income rate on labor supply from an empirical perspective. Thirdly, scholars also explored the matching, search, and other issues involved in connecting the platform's supply and demand sides. Halaburda et al. [10] demonstrated that two-way matching platforms could gain a competitive advantage by limiting the number of choices it provides to consumers while charging a higher price than the no-restriction platforms. Basu et al. [11] sought the optimal pricing of the search and authentication service offered by the online matching platform, and found that even if providing authentication service does not bring profit to the platform, it is still the optimal strategy for the platform.

This study is also closely related to the platform's pricing strategy. We consider two pricing strategies: buyer pricing strategy and laborer pricing strategy. The buyer pricing strategy in our research is similar to a pricing mechanism called "pay what you want" (PWYW) pricing. Then we review the relevant research on PWYW. Kim et al. [12] believed that although the PWYW strategy can increase the consumer's purchase intention, consumers may pay a price lower than the seller's cost or even not pay at all, which is very unfavorable to the seller. Therefore, after analyzing the factors affecting the consumer's willingness to pay, they found that PWYW can increase the seller's income. Gneezy et al. [13] used an experiment to study the price consumers are willing to pay when considering the charity into the pay-as-you-wish pricing. Schmidt et al. [14] studied PWYW pricing strategy and confirmed through experiments that the consumer's payment level increases in the enterprise marginal cost. PWYW strategy cannot completely replace traditional seller pricing strategy. Chen et al. [15] discussed how to improve the profit under the PWYW strategy and further studied the circumstances under which PWYW is superior to the traditional pricing strategy.

In our research, a laborer is a seller who sells services. Therefore, literature about seller pricing strategy also relate to our research. Hirshleifer[16] studied the pricing of goods and services exchanged between various departments within an enterprise, and how to determine these prices in order to prompt each department to take action to maximize the profit of the entire enterprise. Burdett et al. [17] analyzed a situation where the seller posts price, and then the buyer chooses the seller. They found that the matching is less efficient when there are more low-capacity sellers, with total supply held constant. Aviv and Pazgal[18] studied a seller's optimal pricing of fashion-like seasonal goods. Zhang et al. [19] showed how a seller formulates optimal intertemporal target pricing strategy to maximize profits over time while considering the impact of the pricing decision on short-term profitability, reference price formation, and long-term relationship. Caldentey et al. [20] found that a seller who does not know if the customers are myopic should price as if they are strategic.

Unlike the literature mentioned above, this study mainly explores laborer-sharing platforms' choices of two different pricing strategies: buyer pricing strategy and laborer pricing strategy. This study enriches the related research on laborer sharing and provides a theoretical basis for the healthy development of sharing platforms.

3 Problem description and parameter assumptions

We consider an online laborer-sharing platform where a buyer (he) can purchase services, and a laborer (she) can sell services. The buyer finds an appropriate laborer to meet his requirements. The laborer will decide whether to work for a buyer and satisfy the buyer's requirement or not. The sharing platform connects laborer and buyer, determines a pricing strategy, and collects a commission for each transaction. Although the platform may have multiple trading modes, such as service mode, delivery mode, bidding mode, and piece mode, we select bidding mode and piece mode, which are widely used in practice as a representative. The platform has two pricing strategies: Buyer pricing strategy (the buyer determines the price) and laborer pricing strategy (the laborer determines the price). We describe the problem from the perspectives of the laborer, the buyer, and the laborer-sharing platform, respectively. The timeline of this trade is depicted in Figure 1.

Laborer: Considering the heterogeneity of laborer's service quality, we assume that laborers in the market have two types: the high-type (H-type) laborer and low-type (L-type) laborer. The type of laborer decides her service value offered to the buyer. More specifically, to any buyer, an H-type laborer will offer a service with value h, and an L-type laborer will offer a service with value l, where $h>l>0$. An H-type laborer's cost is ch^2, and an L-type laborer's cost is cl^2, where c represents the laborer's cost efficiency. The laborer decides the transaction price in the principle of maximizing her profits.

Buyer: Buyer can derive different values from purchasing different types of services. A buyer can get the value h when trading with an H-type laborer or the value of l with an L-type laborer. The buyer makes the decision to maximize his utility. When a buyer decides the price, he would hope that the transaction price is as low as possible, and to attract the H-type laborer to participate in the task for improving the quality of the service.

Platform: The laborer-sharing platform is a service trading platform that matches buyer and laborer. When a buyer and a laborer reach a deal, the platform will collect a commission for the deal. No matter which type of laborer the buyer makes a deal with, the platform's commission for the deal is constant. A transaction's profit consists of two parts: The commission for each transaction and the probability of a buyer trading with an H-type or L-type laborer. The platform chooses between buyer pricing strategy and laborer pricing strategy, which depends on its profits. We summarize the key notations in this research in Table 1.

4 Model and analysis

4.1 Buyer pricing strategy

Since the buyer pricing strategy is less used in the piece mode, we only consider it in the bidding mode. Under the buyer pricing strategy, the buyer issues his task requirements and price, and the laborer decides whether to accept the task or not. Based on the research of Syam and Kumar[21], let x be the laborer's mismatch degree to the task, and x is a random variable that is distributed uniformly on $[0,1]$. Since the service quality of the H-type laborer is higher than that of the L-type laborer, the mismatch degree of the H-type laborer to the service is also relatively low. According to the above assumption, the utility functions of the H-type laborer and the L-type laborer are as follows:

$$\left.\begin{aligned} u_h &= p - ch^2 - x \\ u_l &= p - cl^2 - \delta x \end{aligned}\right\} \tag{1}$$

The laborer participates in the task when the utility is greater than 0, so the probability of H-type laborer participating in the task is $\Pr_h = \Pr\{u_h>0\} = p-ch^2$, and the probability of L-type laborer participating in the task is $\Pr_l = \Pr\{u_l>0\} = \frac{p-cl^2}{\delta}$. The buyer only sets a price and accepts the service from one type of laborer. Because the H-type laborer's expected price is higher than that of the L-type laborer, the buyer would prioritize the L-type laborer. Therefore, when setting a price, the buyer should ensure that the L-type laborer is willing to accept the task and strive for the H-type laborer's

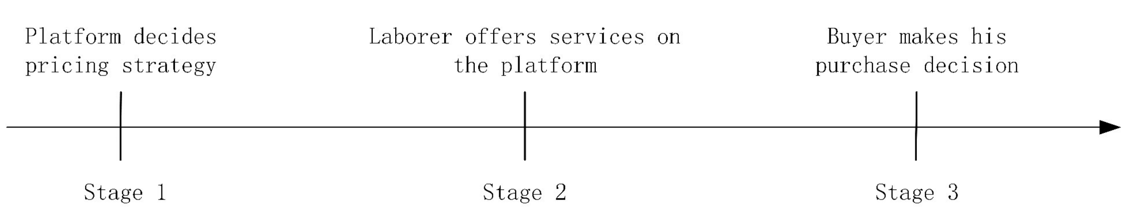

Figure 1. Timeline of the trade.

Table 1. Variable definitions.

Notations	Definitions
h	Value offered by an H-type laborer
l	Value offered by an L-type laborer
c	Laborer's cost efficiency, $c>0$
p	Selling price of per service paid by a buyer under the buyer pricing strategy
x	Laborer's mismatch degree to the task
δ	Difference between the two types of laborers in mismatch degree, $\delta>1$
r	Platform's commission under the bidding mode
p_h	Selling price of per service offered by an H-type laborer under the laborer pricing strategy
p_l	Selling price of per service offered by an L-type laborer under the laborer pricing strategy
y	Buyer's satisfaction with the service
ρ	Difference between the buyer's satisfaction in two types of services, $\rho>1$
u_h	H-type laborer's expected utility under the buyer pricing strategy
u_l	L-type laborer's expected utility under the buyer pricing strategy
b_p	Buyer's expected utility under the buyer pricing strategy
b_h	Buyer's expected utility when trading with H-type laborer under the laborer pricing strategy
b_l	Buyer's expected utility when trading with L-type laborer under the laborer pricing strategy
l_h	H-type laborer's expected profit under the laborer pricing strategy
l_l	L-type laborer's expected profit under the laborer pricing strategy
Π_B	Platform's expected profit under the buyer pricing strategy
Π_L	Platform's expected profit under the laborer pricing strategy

willingness to participate in the task to improve the quality of the task. When only the L-type laborer participates in the bidding, the buyer just trades with the L-type laborer. On the other hand, when the H-type laborer and L-type laborer participate in the bidding, the buyer would trade with the H-type laborer because of her high quality. Consequently, the buyer's utility function is

$$b(p) = (h - p - r)Pr_h Pr_l + (l - p - r)(1 - \mathrm{Pr}_h)\mathrm{Pr}_l \tag{2}$$

The optimal price of the buyer is decided by

$$p(r) = \frac{c(h^3 - h^2 l + hl^2 - l^2(1 + l)) + r - l}{2(h - l - 1)} \tag{3}$$

The profit function of the platform is

$$\Pi_B = r(\mathrm{Pr}_h \mathrm{Pr}_l + (1 - \mathrm{Pr}_h)\mathrm{Pr}_l) \tag{4}$$

Substituting the buyer's optimal price into the profit function of the platform, we can obtain the optimal commission of the platform:

$$r_b^* = \frac{1}{2}(l - c(h^3 - lh^2 + l^2 - hl^2 + l^3)) \tag{5}$$

Substituting Eq. (4) into Eq. (2), we can get

$$p^* = \frac{ch^3 - l - ch^2 l - 3cl^2 + 3chl^2 - 3cl^3}{4(h - l - 1)} \tag{6}$$

Therefore, the optimal profit of the platform is

$$\Pi_B^* = \frac{(l - c(h^3 - h^2 l + l^2 - hl^2 + l^3))^2}{8\delta(l - h + 1)} \tag{7}$$

These optimal decisions are stated as Proposition 4.1.

Proposition 4.1 Under the bidding mode, when the platform adopts the buyer pricing strategy, the optimal price is $p^* = \frac{ch^3-l-ch^2l-3cl^2+3chl^2-3cl^3}{4(h-l-1)}$, and the optimal commission is

$$r_b^* = \frac{1}{2}(l-c(h^3-lh^2+l^2-hl^2+l^3)).$$

All proofs in our research see the Appendix.

When $p^* > 0$ and $r^* > 0$, the quality difference between the service of H-type laborer and L-type laborer does not exceed 1 ($h-l<1$). The platform adopts the buyer pricing strategy under the bidding mode based on the condition that the difference in the quality of services provided by the two types of laborers is small. When the platform adopts the buyer pricing strategy, the buyer's prices for the H-type and L-type laborer are the same. Only when the two types of laborers have different qualities but not much difference can the same price attract both L-type and H-type laborers. If there is a big difference in service quality and cost between the two types of laborers, their expected prices would be a big difference. Therefore, the same price cannot simultaneously attract the two types of laborers. The buyer pricing strategy would lose its significance because it aims to purchase the services of either H-type laborer or L-type laborer, but not both.

4.2 Laborer pricing strategy

Unlike the buyer pricing strategy, the laborer pricing strategy is not only used in bidding mode, but also widely used in piece mode. Therefore, we will consider the laborer pricing strategy in both bidding mode and piece mode.

4.2.1 Case 1: Bidding mode

Under the bidding mode, when the platform applies the laborer pricing strategy, the laborer provides services and decides the service price separately. The buyer decides whether to buy services or not. Because the quality and cost of H-type and L-type laborer's service are different, the two types of laborers set their prices, respectively. Specifically, the price set by H-type laborer is p_h while the price set by L-type laborer is p_l. The platform's commission for each transaction is r. Under the bidding mode, the buyer chooses one of the services to complete a transaction. Similar to the research of Syam and Pazgal[22], we consider the buyer's satisfaction with the service y, which is a random variable distributed uniformly on $[0,1]$. Given the buyer's satisfaction with high-quality service is higher, we can get the buyer's utility function:

$$\left.\begin{aligned} b_h &= h - p_h - y, \\ b_l &= l - p_l - \rho y \end{aligned}\right\} \tag{8}$$

The buyer makes the decision by comparing the utilities of different services. In other words, for the H-type, the buyer's utility is greater than 0 and higher than that for the L-type, so the buyer would choose the H-type laborer to complete the task. Therefore, the probability of the buyer purchasing the H-type laborer's service is

$$\mathrm{Pr}_H = \mathrm{Pr}\{b_h > b_l, b_h > 0\} = \frac{p_l - l + (h - p_h)\rho}{\rho - 1}.$$

Similarly, the probability of the buyer purchasing L-type laborer's service is

$$\mathrm{Pr}_L = \mathrm{Pr}\{b_l > b_h, b_l > 0\} = \frac{p_h - p_l + l - h}{\rho - 1}.$$

The utility functions of the two types of laborers are

$$\left\{\begin{aligned} l_h &= (p_h - ch^2 - r)Pr_H \\ l_l &= (p_l - cl^2 - r)Pr_L \end{aligned}\right. \tag{9}$$

In the principle of utility maximization, the optimal price determined by a laborer is

$$\left.\begin{aligned} p_h(r) &= \frac{l(cl-1) + r + 2(h + ch^2 + r)\rho - h}{(4\rho - 1)}, \\ p_l(r) &= \frac{(ch^2 + 2l(1 + cl) + 3r - h)\rho - l}{(4\rho - 1)} \end{aligned}\right\} \tag{10}$$

Substituting Eq. (10), the profit function of the platform is

$$\Pi_L = r(\mathrm{Pr}_H + \mathrm{Pr}_L) = \frac{r(cl^2 + r + 2(h(ch-1) + r)\rho - l)}{1 - 4\rho} \tag{11}$$

To maximize the platform's profit, the optimal commission can be obtained as below:

$$r_l^* = \frac{l - cl^2 - 2h(ch-1)\rho}{2 + 4\rho} \tag{12}$$

Equation (10) is an expression about the commission. Substituting (12) into (10), we can obtain the optimal pricing decisions under the laborer pricing strategy of bidding mode.

$$\left.\begin{aligned} p_h &= \frac{l(cl-1) + 2h((3 + ch)\rho - 1)}{8\rho - 2}, \\ p_l &= \frac{cl^2\rho(1 + 8\rho) + l(\rho(3 + 8\rho) - 2)}{4\rho(1 + 4\rho) - 2} - \\ &\quad \frac{2h(ch-1)(\rho - 1)\rho}{4\rho(1 + 4\rho) - 2} \end{aligned}\right\} \tag{13}$$

Therefore, the optimal profit of the platform is

$$\Pi_L^* = \frac{(l(cl-1) + 2h(ch-1)\rho)^2}{8\rho(4\rho + 1) - 4} \tag{14}$$

Analyzing these optimal solutions, we get the following proposition:

Proposition 4.2 Under the laborer pricing strategy of bidding mode, the optimal price of laborers has a non-monotonic relationship with the service quality of competitors:

(Ⅰ) The optimal price of an H-type laborer decreases and then increases with the increase in L-type laborer's service quality.

(Ⅱ) The optimal price of an L-type laborer increases and then decreases with the increase in the H-type laborer's service quality.

Intuitively, it is believed that the service price of the laborer is only related to her service quality. However, Proposition 4.2 shows that under the bidding mode, the laborer's price is related to her service quality and affected by the service quality of the competitor. In addition, under the bidding mode, the buyer needs to choose either an H-type laborer or an L-type laborer to complete the task. Therefore, for the H-type laborer, with an increase in L-type laborer's service quality, the probability of buyer purchasing L-type laborer's service will go up, so the H-type laborer decreases her price to attract the buyer. However, when the L-type laborer's service quality is improved to a relatively high level close to that of the H-type laborer, the L-type laborer will increase service price, and the H-type laborer also needs to raise the price to distinguish them from the L-type laborer. Therefore, the H-type laborer's optimal price would decrease and then increase with changes in the L-type laborer's service quality.

Similarly, for the L-type laborer, with an increase in H-type laborer's service quality, the difference in service quality between the two types of laborers, the buyer's willingness to buy H-type laborer's service, the price of H-type laborer, and the platform's commission, will all increase. Since the platform collects the same commission for the two types of laborers, the L-type laborer will raise her price to ensure profit. While the difference between H-type and L-type laborer's service quality widens further, the two laborer's service types will be completely different, and the price gap will become large. Buyer's willingness to purchase the L-type laborer's service will be further declined, so the L-type laborer cannot increase her profit by increasing price. Moreover, the platform needs to consider the two types of laborers, so the commission cannot be set too high. When the L-type laborer's service decreases, the optimal price will decrease in the H-type laborer's service quality. Therefore, an L-type laborer's optimal price will increase first and then decrease in the H-type laborer's service quality.

4.2.2 Case 2: Piece mode

The basic setting of the laborer pricing strategy under the piece mode is similar to that under the bidding mode. Both H-type and L-type laborers provide services and determine their own service prices separately: the H-type laborer's price is p_H, and the L-type laborer's price is p_L. The buyer decides whether to buy the service and which service to buy, and the fixed commission charged by the platform for each transaction is s. Given the heterogeneity between buyers, we consider the buyer's satisfaction with the service y, which is a random variable distributed uniformly on $[0,1]$. The buyer is more satisfied with the H-type laborer's service than the L-type laborer's service. The buyer's utility function is

$$\begin{cases} b_H = h - p_H - y \\ b_L = l - p_L - \rho y \end{cases} \tag{15}$$

where b_H represents the utility when the buyer purchases the H-type laborer's service, and b_L represents the utility when the buyer purchases the L-type laborer's service. $\rho > 1$ represents the difference between the buyer's satisfaction with the two types of services.

The buyer pays for a service when the buyer's utility is greater than 0, so the probability of the buyer purchasing H-type laborer's service is $\mathrm{Pr}_H = \mathrm{Pr}\{b_H > 0\} = h - p_H$, and the probability of the buyer purchasing L-type laborer's service is $\mathrm{Pr}_H = \mathrm{Pr}\{b_L > 0\} = l - p_L$. The utility function of H-type and L-type laborers is

$$\left.\begin{aligned} l_H &= (p_H - ch^2 - s)\mathrm{Pr}_H, \\ l_L &= (p_L - cl^2 - s)\mathrm{Pr}_L \end{aligned}\right\} \tag{16}$$

In the principle of utility maximization, the optimal price determined by the laborer is

$$\left.\begin{aligned} p_H(s) &= \frac{h + ch^2 + s}{2}, \\ p_L(s) &= \frac{l + cl^2 + s}{2} \end{aligned}\right\} \tag{17}$$

Substituting Eq. (17), the platform's profit function is

$$\begin{aligned} \Pi = s(Pr_H + Pr_L) = \\ \frac{s(l - cl^2 + h(1 - ch)\rho - s(1 + \rho))}{2\rho} \end{aligned} \tag{18}$$

In the principle of utility maximization, the optimal commission determined by the platform is

$$s^* = \frac{l - cl^2 + h\rho - ch^2\rho}{2(1 + \rho)} \tag{19}$$

We can know from Equation (17) that the optimal price is an expression about the platform's commission. Substituting (19) into (17), we can obtain the optimal pricing decisions under the laborer pricing strategy of piece mode.

$$\left.\begin{aligned} p_H^* &= \frac{l - cl^2 + ch^2(2 + \rho) + h(2 + 3\rho)}{4(1 + \rho)}, \\ p_L^* &= \frac{l(3 + cl) + (h - ch^2 + 2l(1 + cl))\rho}{4(1 + \rho)} \end{aligned}\right\} \tag{20}$$

The platform's optimal profit is

$$\Pi^* = \frac{(l(cl - 1) + h(ch - 1)\rho)^2}{8\rho(1 + \rho)} \tag{21}$$

Then we analyze the platform's optimal commission.

Proposition 4.3 Under the laborer pricing strategy in the piece mode, the platform's optimal commission has a non-monotonic relationship with the service's quality. Whether for an H-type laborer or an L-type laborer's service, the platform's optimal commission will increase and then decrease in the service's quality.

Under the piece mode, the buyer pays for service when the utility is greater than zero. Both H-type laborer and L-type laborer's prices increase in the platform's commission. In addition, the laborer's price is influenced by the buyer's purchase intention: The higher his purchase intention, the higher the price he is willing to pay. Therefore, whether for H-type or L-type laborer's service quality, as the service quality increases, the buyer is more willing to purchase both types of services and pay a higher price. With a higher trade price, the platform can charge a higher commission for each transaction. The optimal commission of the platform increases with the service quality. When the quality of services is improved to a certain level, with the cost continuing to increase, the price of both the H-type and L-type laborers will go too high, and the buyer's willingness to buy will decrease. Thus, the platform needs to reduce the commission charged for each transaction to adjust the laborer's price while ensuring the buyer's willingness to purchase and guarantee the platform's profit. Then, the platform's optimal commission will decrease as the service quality increases. In the laborer pricing strategy under the piece mode, H-type and L-type laborer's service quality has the same impact on the platform's optimal commission. The platform's optimal commission will first increase and then decrease with the service quality of laborers.

5 Empirical analysis and results

5.1 Selection of strategy under the bidding mode

The above analyses determine the laborer-sharing platform's optimal decision and profit under the buyer pricing strategy and the laborer pricing strategy, respectively. Then we compare the profit of the platform under these two pricing strategies and analyze the influence of the mismatch degree of the laborer with the task and the satisfaction of the buyer with the service on the platform's selection of the optimal pricing strategy, as implied by the following proposition.

Proposition 5.1 There exist thresholds on δ and ρ such that:

①When $1<\delta<\delta_1$ and $1<\rho<\rho(\delta)$, the laborer pricing strategy is the optimal pricing strategy.

②When $1<\delta<\delta_1$ and $\rho\geq\rho(\delta)$, the buyer pricing strategy is the optimal pricing strategy.

③When $\delta\geq\delta_1$, the laborer pricing strategy is the optimal pricing strategy.

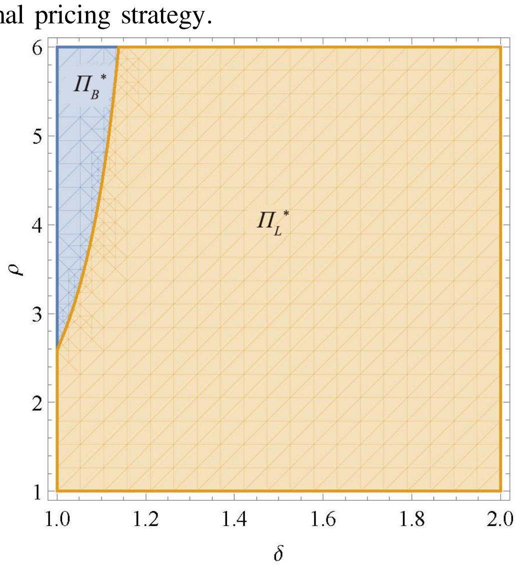

Figure 2. Profit comparison under the platform's two pricing strategies when $c=\frac{1}{10}, l=2, h=\frac{5}{2}$.

As shown in Figure 2, we consider a situation where the laborer's cost c is relatively low, and the quality of service provided by the H-type laborers and L-type laborer (h and l) are quite different. This situation is basically in line with reality. We discuss how the platform chooses the pricing strategy to ensure its maximum profit. As shown in Proposition 5.1, there are three cases: ① When δ and ρ are relatively low: The mismatch degree of service for the L-type laborer is similar to that for the H-type laborer, and the degree of buyer's satisfaction with the service provided by the L-type laborer is similar to that by the H-type laborer. In this case, when the buyer pricing strategy is adopted, the buyer will pay the same price to both the H-type laborer and the L-type laborer. The L-type laborer's service cost will be relatively low, and the probability of the L-type laborer participating in the task is higher than that of H-type laborer. Therefore, the buyer would prefer the L-type laborer's service if only considering price because her price is relatively low, causing the platform's commission to decrease. Since the platform's profit is affected by the commission, the lower the price will result in the platform's lower commission and profit. When the platform adopts the laborer pricing strategy, the buyer has a similar degree of satisfaction with the services of both H-type and L-type laborers and is willing to pay a higher price for the two types of laborers. The probability that the buyer chooses the H-type laborer to offer the service is similar to that for the L-type laborer. The platform's commission is related to both H-type and L-type laborers. When the price of H-type laborer and L-type laborer is higher, the platform's commission is higher than that under the buyer pricing strategy. As a result, the platform's profit is relatively high, and the laborer pricing strategy becomes the optimal pricing strategy.

② When δ is relatively low and ρ is relatively high: Unlike in Case ①, the buyer's satisfaction with the service provided by L-type laborer is much lower than that by H-type laborer, so the buyer prefers to choose the H-type laborer to offer service. Given that the buyer's willingness to buy L-type laborer's service declines, the L-type laborer has to ask for a lower price. Since the L-type laborer's competitiveness is weakened, the H-type laborer can raise her price, causing a big difference between the two types of laborer's price. When an L-type laborer's price is lower, the platform can only collect less commission, and the platform's profit will go lower. While under the buyer pricing strategy, the two types of laborers have similar mismatches to the task. Based on ensuring that the L-type laborer participates in the task, the buyer also expects the H-type laborer to participate, which can improve pricing to a certain extent. The platform can charge a higher percentage of commission and increase the platform's profit. Therefore, the buyer pricing strategy is better. Under such a strategy, the two types of laborers have a similar degree of mismatch to the task. The buyer expects the H-type laborer to participate in the task based on ensuring that the L-type laborer wants to participate. The price would be increased to a certain extent, and the platform can collect more commissions, which can increase the platform's profit. Therefore, the buyer pricing strategy is the optimal pricing strategy.

③ When δ is relatively high, the mismatch degree of L-type laborer to the task is much higher than that of H-type laborer, but the L-type laborer can only bring lower profit. Under the buyer pricing strategy, the buyer needs to ensure that an L-type laborer wants to participate in a specific task. The buyer's price is relatively low, so the platform collects a lower commission, thus decreasing its profit. In contrast, under the laborer pricing strategy, the H-type laborer will increase the price because of her relatively low mismatch degree to the task. The L-type laborer decides her price based on her actual situation. The platform collects a higher commission and gets higher profit than under the buyer pricing strategy. Regardless of the buyer's satisfaction with the services provided by different laborers, the commission under the laborer pricing strategy always needs to take both types of laborers into account. On the other hand, under the buyer pricing strategy, the platform only considers the L-type laborer and collects a lower commission. Therefore, the platform's profit under the buyer pricing strategy is lower than that under the laborer's pricing strategy, so the laborer's pricing strategy is optimal.

5.2 Comparison of laborer pricing strategy under different modes

In this section, we compare and analyze the laborer pricing strategy under the piece mode and the bidding mode, which leads to some significant results.

Proposition 5.2 There exists a threshold on l such that:

(ⅰ) When $0<l<l(h)$, the platform's profit under the bidding mode is better.

(ⅱ) When $l=l(h)$, there is no difference in platform's profit between the two modes.

(ⅲ) When $l(h)<l<h$, the platform's profit under the piece mode is better.

As shown in Figure 3, we consider a situation where the laborer's cost c is relatively low, and the difference between the buyer's satisfaction in two types of services ρ is relatively high. This situation is basically in line with reality. When the quality of services provided by the L-type laborer l is low, $h-l$ is large. Under the bidding mode, the buyer can only

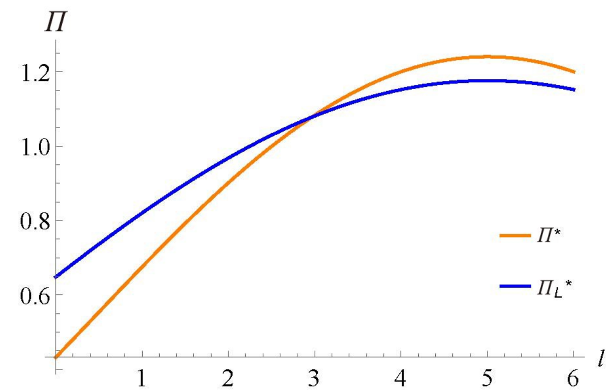

Figure 3. Comparison of the platform's profit between two transaction modes when $c=\frac{1}{10}$, $\rho=\frac{3}{2}$, $h=6$.

choose one of the two types of laborers, so the buyer prefers to trade with the H-type laborer to obtain higher service value. The platform would also consider the H-type laborer more when deciding the commission. The buyer has a strong willingness to buy service from the H-type laborer, who would decide a higher price, and the platform can charge a relatively high commission. Under the piece mode, as long as the laborer's service can make the buyer's benefit greater than zero, the buyer would make the deal. In order to attract the buyer, the L-type laborer will decide on a lower price. Since the buyer can enter the transaction with two types of laborers simultaneously and the platform charges the same commission for both types of laborers, the platform needs to consider both H-type and L-type laborers when deciding the commission. Given that the transaction price of the L-type laborer is low, the platform can only charge a relatively low commission. Therefore, the platform's profit under the bidding mode is higher than that under the piece mode.

Then we analyze the case that L-type laborer provides a relatively high quality of services. In this situation, the L-type laborer's quality of service is close to the H-type laborer. Under the bidding mode, according to Proposition 4.2, when the service quality of H-type and that the L-type laborer is similar, the price of the H-type laborer will be higher, and the buyer will be more willing to buy service from the L-type laborer. Consequently, the platform's commission tends to be lower, and its profit will also decrease. However, there is no competitive relationship between the two types of laborers under the piece mode. When the L-type laborer's quality of service is relatively high, the buyer's willingness to buy the L-type laborer's service will increase. The L-type laborer may decide on a relatively higher price, and the H-type laborer can still keep the normal price unchanged. Thus, the L-type laborer pricing tends to be closer to that of the H-type laborer, so the platform can charge a relatively high commission to increase its profit. When an L-type laborer's quality of service is relatively high, the platform's profit under the piece mode will be higher than that under the bidding mode.

6 Conclusions

Laborer sharing has emerged as a significant trend over recent years as the society pays more and more attention to the effective use of laborer resources. The advancement in mobile communication technology has further promoted the growth of the laborer-sharing platform. This study establishes a tripartite game model involving a buyer, a laborer, and a sharing platform. By mainly analyzing the buyer pricing and laborer pricing strategies under the bidding mode, this study compares two pricing strategies. Besides, this study also explores the platform's laborer pricing strategy under the piece mode and compares this strategy with the laborer pricing strategy under the bidding mode. This study provides some valuable insights for platform operations.

Under the bidding mode, the buyer pricing strategy's premise is that the quality of services provided by the two types of laborers is similar, and the same price can attract both types of laborers. This finding could help the buyer make a pricing decision in a suitable situation. Under the laborer pricing strategy, as the competitor's service quality is improved, the laborer's optimal pricing will have a non-monotonic relationship with the competitor's service quality. H-type laborer's price will first decrease and then increase with the improvement in the L-type laborer's service quality. The L-type laborer's price will first increase and then decrease with the improvement in the H-type laborer's service quality. Consistent with our findings, the laborer takes her competitor's pricing into account when she decides the price. This study also finds that when the service provided by the laborer matches the buyer's demand better and the buyer's satisfaction with the two types of laborer's services differs greatly, the buyer pricing strategy is a better choice. Otherwise the laborer pricing strategy is better. Comparing the laborer pricing strategy in the bidding mode and the piece mode, we find that when L-type laborer's service quality is low, the platform's profit is better in the bidding mode. While the L-type laborer's service quality is similar to that of the H-type laborer, the platform can profit more in the piece mode. Our findings may help the platform to decide the pricing strategy.

This study only considers the mechanism design of the platform. In the future, the incentive effect of government policies on laborer sharing will be explored, and how the platforms and governments jointly encourage and guide the supply side to share laborers and the demand side to adopt shared laborers will be analyzed. In addition, since the trust between the supply and demand parties affects labor matching efficiency, the impact of false and invalid comments on laborer-sharing platforms on their pricing strategy will also be considered in the future.

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Conflict of interest

The authors declare no conflict of interest.

Author information

GUAN Shuhan is currently a master student under the supervision of Prof. Du Shaofu at the Department of Management Science and Engineering, University of Science and Technology of China. Her research interests focus on behavior operation.

DU Shaofu (corresponding author) received his PhD degree in management from University of Science and Technology of China (USTC). He is currently a professor at the USTC. His research interests focus on supply chain management, behavior operation, and low carbon operation.

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两种交易模式下共享劳动力平台的定价策略

管舒涵,盛健超,杜少甫*
中国科学技术大学管理学院,安徽合肥 230026
*通讯作者. E-mail:sdu@ ustc. edu. cn

摘要:随着互联网信息技术的快速发展,共享劳动力平台在促进社会人力资源的有效利用中起着关键性作用.目前市场上存在的共享劳动力平台有多种交易模式,且每种交易模式下的定价策略不同.在考虑劳动者的服务能力异质性后,分别构建了共享劳动力平台在买方定价策略和劳动者定价策略的利润函数,主要研究了劳动力平台在竞标模式下的最优定价策略.研究结果表明,当低类型劳动者提供的服务与买方的任务需求不匹配度接近高类型劳动者的时,劳动者定价策略对平台更有利,而当低类型劳动者的任务匹配度远低于高类型劳动者的时,平台的定价策略选择取决于买方对任务完成的满意程度.另外,还比较了计件模式与竞标模式,发现在劳动者定价策略下,平台在竞标模式下的利润并不总是优于计件模式.

关键词:共享劳动力;竞标模式;计件模式;买方定价策略;劳动者定价策略

Appendix

A.1 The optimal decision of buyer pricing strategy

According to the utility function of the buyer: $b(p)=\dfrac{(cl^2-p)(-l+(h-l)(ch^2-p)+p+r)}{\delta}$, when $\dfrac{\partial b(p)}{\partial p}=\dfrac{l+c(-h^3+h^2l+l^2-hl^2+l^3)+2(-1+h)p-2lp-r}{\delta}=0$ is satisfied, we can get the optimal price

$$p(r)=\frac{c(h^3-h^2l+hl^2-l^2(1+l))+r-l}{2(h-l-1)}.$$

It cannot be strictly stated that the price is optimal with the first-order condition equaling to zero. The second-order condition must be negative to ensure that the price is the optimal solution. When calculating the second-order condition $\dfrac{\partial^2 b(p)}{\partial p^2}=\dfrac{2(-1+h-l)}{\delta}$, this study finds that when $h-l<1$, $\dfrac{\partial^2 b(p)}{\partial p^2}<0$ is always satisfied. With substituting of the optimal pricing into the profit function of the platform, $\Pi=\dfrac{r(cl^2-l+r+2(h(ch-1)+r)\rho)}{1\text{-}4\rho}$ can be got. When

$\frac{\partial \Pi_B}{\partial r}=\frac{c(h^3-h^2l+l^2-hl^2+l^3)+2r-l}{2(-1+h-l)\delta}=0$, the optimal commission is $r^*=\frac{1}{2}(l-c(h^3-h^2l+l^2-hl^2+l^3))$. The second-order condition $\frac{\partial^2 \Pi_B}{\partial r^2}=\frac{1}{(h-l-1)\delta}<0$ is satisfied when $h-l<1$.

A.2 The optimal decision under the laborer pricing strategy

According to the utility functions of H-type laborer and L-type laborer: $\begin{cases} l_h=\frac{(ch^2-p_h+r)(p_l+(h-p_h)\rho-l)}{1-\rho}, \\ l_l=\frac{(h-l-p_h+p_l)(cl^2-p_l+r)}{\rho-1}, \end{cases}$

when $\frac{\partial l_h}{\partial p_h}=\frac{p_l-l+(h+ch^2-2p_h+r)\rho}{\rho-1}=0$ and $\frac{\partial l_l}{\partial p_l}=\frac{l-h+cl^2+p_h-2p_l+r}{\rho-1}=0$, $\begin{cases} p_h=\frac{p_l-l+(h+ch^2+r)\rho}{2\rho} \\ p_l=\frac{1}{2}(l-h+cl^2+p_h+r) \end{cases}$ can be got. Further solving the equations, we can get

$$\begin{cases} p_h=\frac{l(cl-1)-h+r+2(h+ch^2+r)\rho}{4\rho-1}, \\ p_l=\frac{(ch^2-h+2l(1+cl)+3r)\rho-l}{4\rho-1}. \end{cases}$$

In the same way, the second-order condition is calculated. $\frac{\partial^2 l_h}{\partial {p_h}^2}=\frac{2\rho}{1-\rho}<0$, and $\frac{\partial^2 l_l}{\partial {p_l}^2}=\frac{2}{1-\rho}<0$ are always satisfied. Substituting the optimal pricing into the profit function of the platform: $\Pi_L=\frac{r(cl^2-l+r+2(h(ch-1)+r)\rho}{1-4\rho}$. When $\frac{\partial \Pi_L}{\partial r}=\frac{l-cl^2-2(r+h(ch-1)\rho+2r\rho)}{4\rho-1}=0$, the optimal commission of the platform is $r_L^*=\frac{l-cl^2-2h(ch-1)\rho}{2+4\rho}$. $\frac{\partial^2 \Pi_L}{\partial r^2}=\frac{2+4\rho}{1-4\rho}<0$ is always satisfied.

A.3 Proof of Proposition 4.2

Substituting r_L^* into p_h and p_l, we can calculate the two first-order conditions $\frac{\partial p_h}{\partial l}=\frac{1-2cl}{2-8\rho}$ and $\frac{\partial p_l}{\partial h}=\frac{(2ch-1)(\rho-1)\rho}{1-2\rho-8\rho^2}$. Then it can be got that the two second-order conditions $\frac{\partial^2 p_h}{\partial l^2}=\frac{c}{4\rho-1}>0$ and $\frac{\partial^2 p_l}{\partial h^2}=\frac{2c(\rho-1)\rho}{1-2\rho-8\rho^2}<0$ are always satisfied.

A.4 Proof of Proposition 4.3

Considering the calculation result is too complicated, this study only shows the calculation process. It can be known from ${\Pi_B}^*=\frac{(l-c(h^3-h^2l+l^2-hl^2+l^3))^2}{8\delta(l-h+1)}$ and $\Pi_L^*=\frac{(l(cl-1)+2h(ch-1)\rho)^2}{8\rho(4\rho+1)-4}$:

(i) The laborer pricing strategy is better when $\frac{(l-c(h^3-h^2l+l^2-hl^2+l^3))^2}{8\delta(l-h+1)}<\frac{(l(cl-1)+2h(ch-1)\rho)^2}{8\rho(4\rho+1)-4}$.

(ii) The buyer pricing strategy is better when $\frac{(l-c(h^3-h^2l+l^2-hl^2+l^3))^2}{8\delta(l-h+1)}>\frac{(l(cl-1)+2h(ch-1)\rho)^2}{8\rho(4\rho+1)-4}$.

A.5 The optimal decision of laborer pricing strategy under piece mode

The utility function of the laborer under the piece mode is $\begin{cases} l_H=(h-p_H)(p_H-ch^2-s), \\ l_L=(l-p_L)(p_L-cl^2-s). \end{cases}$ When $\frac{\partial l_H}{\partial p_H}=h+ch^2-2p_H+s$ and $\frac{\partial l_L}{\partial p_L}=l+cl^2-2p_L+s=0$, the optimal price is $\begin{cases} p_H=\frac{1}{2}(h+ch^2+s), \\ p_L=\frac{1}{2}(l+cl^2+s). \end{cases}$ The two second-order conditions $\frac{\partial^2 l_H}{\partial {p_H}^2}=-2<0$ and $\frac{\partial^2 l_L}{\partial {p_L}^2}=-2<0$ are always satisfied. Substituting the optimal pricing into the profit function of the platform, we can obtain $\Pi=\frac{s(l-cl^2-s-(h(-1+ch)+s)\rho)}{2\rho}$. When $\frac{\partial \Pi}{\partial s}=\frac{l-cl^2+h(1-ch)\rho-2s(1+\rho)}{2\rho}=0$, the optimal price is $s^*=\frac{l-cl^2+h\rho-ch^2\rho}{2(1+\rho)}$. The second-order condition $\frac{\partial^2 \Pi}{\partial s^2}=-\frac{1+\rho}{\rho}<0$ is always satisfied.

A.6 Proof of Proposition 5.1

The two first-order conditions are $\frac{\partial s^*}{\partial l}=\frac{1-2cl}{2+2\rho}$ and $\frac{\partial s^*}{\partial h}=\frac{\rho-2ch\rho}{2+2\rho}$. The two second-order conditions: $\frac{\partial^2 s^*}{\partial l^2}=-\frac{c}{1+\rho}<0$ and $\frac{\partial^2 s^*}{\partial h^2}=-\frac{c\rho}{1+\rho}<0$ are always satisfied.

A.7 Proof of Proposition 5.2

Considering the calculation result is too complicated, this study only shows the calculation process. It can be known from $\Pi_L^*=\frac{(l(cl-1)+2h(ch-1)\rho)^2}{8\rho(4\rho+1)-4}$ and $\Pi^*=\frac{(l(cl-1)+h(ch-1)\rho)^2}{8\rho(1+\rho)}$:

(i) The platform's profit under the bidding mode is higher than that under the piece mode when $\frac{(l(cl-1)+h(ch-1)\rho)^2}{8\rho(1+\rho)}<\frac{(l(cl-1)+2h(ch-1)\rho)^2}{8\rho(4\rho+1)-4}$.

(ii) The platform's profit under the piece mode is higher than that under the bidding mode when $\frac{(l(cl-1)+h(ch-1)\rho)^2}{8\rho(1+\rho)}>\frac{(l(cl-1)+2h(ch-1)\rho)^2}{8\rho(4\rho+1)-4}$.

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通过稀疏 PCA 分析新冠疫情对股市的影响

黎明,温灿红*

中国科学技术大学管理学院统计与金融系,安徽合肥 230026

*通讯作者. E-mail:wench@ustc.edu.cn

摘要: 新冠疫情的爆发在全世界造成了严重的公共卫生和经济后果。评估新冠疫情对经济,尤其是股市的影响非常重要。为此,我们提出应用几种最先进的稀疏主成分分析(PCA)方法来分析 2019 年 2 月 1 日至 2021 年 2 月 1 日的沪深 300 指数股票数据,以揭示新冠疫情爆发的影响.将这段时间分为两个时期——2020 年 1 月 1 日之前和之后,在此基础上,我们尝试提取主成分并构建投资组合.结果表明,在新冠疫情爆发之后,代表市场的主成分的比例有所下降.关于前两个主成分的构成,新冠疫情爆发后,起决定作用的股票集合有很大的不同.在新冠疫情之后,医疗保健行业的股票开始在沪深 300 指数的投资组合中发挥重要作用.与沪深 300 指数相比,稀疏 PCA 方法的前两个主成分可以在组成投资组合的股票集数量少得多的情况下获得更高的回报.综上所述,新冠疫情的爆发导致沪深 300 指数股票的主成分比例和构成发生了变化.

关键词: 新冠疫情;稀疏主成分分析;股票指数