Taxi-hailing Apps: A New Method for Travel Through Information Exchange

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Abstract. In this paper, we considered three major strategies in the China’s cab service market, and made comparisons pair by pair to examined under which conditions existed, one of the strategies dominated the others. We emphasized the impact of two crucial factors, information heterogeneity between informed and less-informed passengers as well as information exchange insufficiency, on the cabdriver’s earning. We also made a suggestion from the aspect of apps’ designers and government on the online cab service.

Introduction

The development of information technology facilitates information exchange among the masses and have created many new chances for marketers to develop and implement innovative selling strategies via social interaction, such as Referral Rewards programs\cite{1}, customized product and service design\cite{2}, advance selling\cite{3}, one-to-one promotion\cite{4}, probabilistic selling\cite{5} and group buying\cite{6}. In this paper, we explored similar strategies via information exchange on the cab service market, which included special cab strategy and carpool strategy. Special cab could be regarded as a format of customized service design and carpool could be seen as a format of group buying. In recent years, some companies specialized in offering online reserve cab service, like Uber and Didi, has aroused great concern in masses because widespread application of the Internet has facilitated the information exchange between the two segments of cabdriver and passenger. So it is possible to exploit convenient information resources to customize personalized cab service for travel.

Cab service is of significance in metropolitan areas. The development of online reserve cab service is exerting a strong impact on the conventional cab service market which delivered cab services either by street pick-ups or cab stand pick-ups. The interested parties wrangled over the online reserve cab service in hot discussions which include “How to lead online reserve car to a right order and prevent them from disturbing normal cab market’s order”. On this background, it is significant to study the online reserve cab service’s impact on the traditional cab market from the perspective of market strategic competition and game.

This paper contributed to the literature in several ways. First, it added to the literature on taxi service. Most existing research has focused on fare structure and fleet size regulation\cite{7}, infrastructure represented by GPS devices\cite{8} on taxi service, but ignored social interaction’s impact. So our paper explored another strategic function-that of facilitating passengers’ social interaction, which stimulated informed passengers to advocate the cabdriver and its serve to less-informed passengers via interpersonal information exchange.

Second, it contributed to the literature on information exchange. The existing research regarded information exchange as an uncertain signal to influence the results. Some literature focused on a typical supply chain which contained two segments of manufacture and retailer, and examined different factors’ impact on coordinating channel equilibrium. \cite{9} provided a general information sharing model in oligopoly with a stochastic demand and stochastic cost. \cite{10} studied vertical information exchange with two retailers. Some researchers extended the format form distinctive aspect. \cite{11} studied the horizontal competition’s impact on the information exchange equilibrium.
with many retailers. [12] added the factor of confidentiality to the model to examine its effect on the channel’s profits. Some researchers studied information exchange from the view of inventory systems. [13] studied the information exchange’s impact on the optimal economic order quantity. [14] studied the information exchange’s impact on the inventory record inaccuracy under shrinkage errors. Some researchers applied information exchange on the industry. [15] examined the impact of two variables including use of IT and social interaction ties on the quality of health care operations.

In this paper, we put forward a model to study three major kinds of strategies on China’s cab service market, which was special cab strategy, carpool strategy and hail a cab strategy. The former two belonged to information exchange strategies, while the rest belonged to non-information exchange strategy. We made comparisons pair by pair and discussed under which conditions existed, one of the three strategies was dominating.

**The Model**

**Assumptions**

We considered a two segments which consisted of a cabdriver and two passengers who distinguished in their knowledge of cab and its driver’s information. We defined one informed and one less-informed passenger. Our aim was to use a model to illustrate the cabdriver’s earning of a special cab strategy and a carpool strategy. Because taxi-hailing apps companies extracted a proportion of cabdrivers’ earning to maintain operation and make profit, for the apps companies, helping cabdrivers earn more money was equal to benefit themselves.

*Passengers Behavior.* The less-informed passenger, who were only aware of non-information exchange strategy for travel, accepted a travel price \( kP_0 \), where \( k \in (1/2,1) \) denoted government’s regulation on the cab service’s price; and the informed one, who took information exchange strategies, accepted a travel price \( P_0 + \alpha I \), where \( I \geq 0 \) was the information gap between the two types of passengers. The information gap among passengers existed for passengers’ heterogeneity on their character and desire in accepting the new method. It prevented the less-informed passenger from fully appreciating the facility of the travel. The taxi-hailing apps helped passengers order travel time precisely and prevented them from wasting waiting time, so it promoted travel value and required higher prices. Here, \( \alpha \) measured the impact of unit information on travel price and differed across passengers’ characters and their urgency of demand. If one passenger was more impatient or he had emergency need on travel, then the unit information was more important, \( \alpha \) would increase, the cabdriver claimed more payment from the passenger. For the non-information exchange strategy, passengers were lack of added value \( \alpha I \) brought by information service, so the acceptable price was lower.

*Major Strategies.* (1) Hail a Cab strategy, under which both informed and less-informed passengers hailed a taxi on the roadside without ordering a schedule via the Internet; (2) Special Cab strategy, under which a informed passenger ordered a special cab via taxi-hailing apps and special cab picked him up at his desired time; (3) Carpool strategy, under which an informed passenger, as a sales agent, self-selected to disseminate travel information, recruited less-informed passengers to carpool via taxi-hailing apps for sharing the travel fare.

**Carpool vs. Individual Cab Strategies**

*Individual cab strategies.* Assumed the informed passenger took special cab strategy, both passengers took hail a cab strategy, the marginal cost was zero. The optimal price \( (P_s^*, P_h^*) \) and the corresponding earning \( (\pi_s^*, \pi_h^*) \) were shown in Eq.1-Eq.2.

\[
\text{Special Cab strategy: } P_s^* = P_0 + \alpha I \quad \pi_s^* = P_0 + \alpha I
\]

\[
\text{Hailing a Cab strategy: } P_h^* = kP_0 \quad \pi_h^* = 2kP_0
\]
Carpool strategy. Assumed an informed and a less-informed passenger to carpool. The cabdriver faced an optimal contract design problem to maximize earning showed in Eq.3-Eq.6.

\[
\max_{P_c, \Delta I} \pi_c = \delta P_c
\]  

(3)

\[
\text{st. } \delta \left[ P_0 + \alpha \Delta I - \frac{P_c}{2} + \beta \Delta I \right] \geq 0
\]

(4)

\[
\delta \left( P_0 + \alpha \Delta I - \frac{P_c}{2} \right) = 0, \quad 0 \leq \Delta I \leq 1
\]

(5)

The Eq.3-Eq.5 was presented as a principle-agent problem between the cabdriver and the informed passenger. In the Eq.3, \( P_c \) represented the optimal price on carpool strategy. A discount factor \( \delta \in (0,1) \) reflected time delay. For the explanation, it took time for the informed passenger to reach and persuade the less-informed passenger to carpool; for cabdriver to negotiate both passengers with travel information (e.g. pick-up location, pick-up time, routes) than the other strategies. \( \delta \) was considered to be opportunity cost for cabdriver which completed more orders on the individual strategies than on the carpool strategy in some time. So a smaller \( \delta \) captured a higher difficult degree of negotiation and a higher opportunity cost for the cabdriver. The carpool strategy was feasible for the two motivations. First, cabdriver earned more wages than special cab strategy. Second, passengers shared expenditures. To travel at a cheaper price, the informed passenger must exchange travel information with the less-informed passenger. The price discount could be partly viewed as compensation to the informed passenger for their information-exchange effort. The compensation, denoted as \( \beta \Delta I \), increased with the agent’s effort level in information dissemination \( \Delta I \). The information exchange inefficiency \( \beta \in (0,1) \), which measured how difficult it was for the informed passenger to reach and persuade less-informed passengers. \( \beta \) could be influenced by social, cultural and technological factors. Specifically, the more passengers trust others, the easier it was for informed passengers to persuade less-informed passengers. A country with a collectivism culture in social environment might have smaller \( \beta \) than individualism culture.

The optimal solutions were subject to three constraints. The Eq.4 reflected partition for the informed passenger. \( P_c/2 \) represented each passenger’s expenditure, which must be sufficient low to compensate the informed one(\( P_c/2 + \beta \Delta I \)) for taking the effort to recruit others and delay the order(\( \delta \)). The informed passenger was stimulated by carpool strategy rather than special cab strategy because of \( P_c/2 + \beta \Delta I \leq P_s^* \). The Eq.5 reflected incentive compatibility for the informed passenger. The agent’s effort level was not directly observable by the cabdriver, so information exchange would be implemented only if it was the agent’s best choice. Given a carpool size of two, the agent chose the minimum \( \Delta I \) that was sufficient to persuade the less-informed one to carpool.

\text{Lemma 1.} The optimal solutions of the three strategies were given in the following table.

\begin{table}[h]
\centering
\caption{Carpool vs. Individual Cab Strategies.}
\begin{tabular}{|c|c|c|c|}
\hline
Traveling Strategy & Price & Passengers & Earning \\
\hline
Special Cab & \( P_s^* = P_0 + \alpha \Delta I \) & 1 & \( \pi_s^* = P_0 + \alpha \Delta I \) \\
\hline
Carpool & \( P_c^* = \frac{2 [P_0 + \alpha \Delta I \Gamma/(\alpha + \beta)]}{1 + \beta \Delta I} \) & 2 & \( \pi_c^* = 2 \delta [P_0 + \alpha^2 \Gamma/(\alpha + \beta)] \) \\
\hline
Hail a Cab & \( P_h^* = kP_0 \) & 2 & \( \pi_h^* = 2kP_0 \) \\
\hline
\end{tabular}
\end{table}

Lemma 1 showed the differences among the three strategies. Particularly, for each passenger, he payed the price of \( P_0 + \alpha^2 \Gamma/(\alpha + \beta) \) in carpool strategy, which payed less than special cab strategy.
but higher than hail a cab strategy. It was the consequence of interaction between price sharing and information service, which motivated passengers to carpool in the information exchange strategies. For cabdriver, the price under carpool strategy was higher than special cab strategy and hail a cab strategy, \( P_c > P_s > P_h \). Because information service increased the valuation of travel and market expansion could be achieved at a higher price. Except carpool strategy, the other two were considered to better liquidation because transaction was not delayed.

The Proposition 1 showed a formal comparison of the three maximum earnings, which stated the conditions under which each strategy dominated the others. To ensure that carpool strategy was viable, we assumed that the time delay was not too large, \( \delta \in (1/2,1) \).

**Proposition 1.** The optimal strategy was jointly determined by two factors: passenger information gap(\( I \)) and the inefficiency of disseminating information(\( \beta \)). The condition of dominating strategies were as follows: (a) special cab strategy when \( \beta > \beta_1, \max(i_1,i_3) \); (b) carpool strategy when \( \beta_1 < \beta < \beta_2, \min(i_1,i_2, i_3) > i_1 > i_2 \); (c) hail a cab strategy when \( \min(i_1,i_2) < i_1 \).

(Notations were defined in the appendix)

Proposition 1 was graphically discussed in Fig.1. As presented in Proposition 1, the carpool strategy was more profitable than the other strategies when two situation occurred: (1) passengers had a mid-range of information heterogeneity(\( i_2 < i_1 < i_3 \)), so as the information dissemination efficiency(\( \beta_1 < \beta < \beta_2 \)). (2) passengers’ information gap was large(\( \max(i_1,i_3) > i_1 > i_2 \)) and information dissemination was sufficiently efficient(\( \beta < \beta_1 \)). An information gap between informed and less-informed passengers that was too large favored special cab strategy while that was too small favored hail a cab strategy, yet each occurred for different reasons. A large information gap indicated higher difficult information exchange between informed and less-informed passengers. Hence, the cabdriver was better off obtaining higher earnings from the informed passenger at the cost of the less-informed passenger. In this case, market share of the special cab strategy ascended while of the carpool strategy was descended. A narrow information gap indicated heterogeneity between passengers didn’t differ greatly, so expanding the market to earn more became more attractive. Therefore, carpool strategy dominated the market. Under hail a cab strategy, the cabdriver expanded the market by charging a comparatively low price of the less-informed passenger and didn’t benefit from the information service. When the information gap is really small(\( i < \min(i_1,i_3) \)), this strategy was a more efficient way to expand the market, because the cabdrivers could induce earning from the less-informed one directly.

Information exchange inefficiency, \( \beta \), affected the optima of carpool strategy in several ways. First, carpool strategy can’t be beneficial when \( \beta \) was too large (\( \beta > \beta_2 \)). Carpool strategy expand the market depended on informed passenger through interpersonal communication, and its attraction

![Figure 1. Individual Strategies vs. Carpool Strategy (\( \delta = 0.65, \alpha = 0.8, P_0 = 10, k = 1 \)).](attachment:image.png)
relied on how much incentive the cost sharing compensated the information exchange effort. The higher inefficiency $\beta$ indicated higher information exchange costs, and it was less attractive for cabdrivers to expand the market via carpool strategy. Second, the information gap became wider as $\beta$ descended. Third, when interpersonal interaction became really efficient, the optima of carpool strategy was no longer limited by an upper bound of the information gap ($I_3 \to \infty$ if $\beta < \beta_1$). The results revealed that a higher information exchange inefficiency weakened the cabdrivers’ desires to take carpool strategy but strengthened their desires to take individual strategies.

In addition, the significance of the information, $\alpha$, also influenced the comparative earning among the strategies. First, a larger $\alpha$ indicated that hail a Cab strategy were less attractive than information exchange strategies. A large $\alpha$ indicated that an impatient passenger was something urgent to travel (i.e., catch a plane), so he scheduled the travel time via the apps and prevented uncertainty from hail a cab strategy. Second, a large $\alpha$ made carpool more alluring than special cab strategy when the information exchange inefficiency was enough high.

Conclusion

The paper put forward and discussed the information benefit of the information exchange strategies, special cab and carpool strategies, on the cab service market. We also studied another non-information exchange strategy, hail a cab strategy. A comparison among the three strategies uncovered the following views.

First, a crucial factor determining the earning advantage of the three strategies respectively was passenger heterogeneity in cab service knowledge. As a whole, the earning advantage needed a moderate level of passenger information heterogeneity for carpool strategy, needed a high level of passenger information heterogeneity for special cab strategy, needed a low level of passenger information heterogeneity for hail a cab strategy.

Second, the dominating strategy depended on how efficient it was for informed passengers to work as sale agents to persuade less-informed passengers to carpool. In general, the earning advantage needed a moderate level of information exchange efficiency for carpool strategy, needed a comparatively low level of exchange efficiency for special cab strategy, while it had no impact on the hail a cab strategy to attain earning advantage. Therefore, carpool might be more promising in the less-inefficiency cases. As the advancement of information technology strengthened the efficiency of social interaction, the attraction of carpool strategy might ascend prominently.

The conclusion made enlightenment for those companies which related to online cab service. When they designed the taxi-hailing apps, they should make full use of the two crucial parameters, $I$ and $\beta$, to consider their impacts on the choice of dominating strategy. In addition, all parameters including $\alpha, \beta, \delta, I, k$ were measured by market investigation and operation practice in a long time. The apps companies could use these first-hand original data and the pricing methods to calculate the dominating strategy in the distinctive conditions, which was beneficial to find out right market orientation and to elaborate right strategic decision in designing pricing algorithms of the apps.

In addition, information exchange strategies were inclined to made more earning for cabdrivers than hail a cab strategy. So the cabdrivers had strong motivations to transfer hail a cab strategy into information exchange strategies which was considered to be high-end cab service. Without strict restrictions by government, the information exchange strategies might eventually dominate the cab market, which was not beneficial for masses of passengers who only needed basic cab service for travel. To maintain interests of the masses, the policymaker could took measures to control the application of information exchange strategies from the following three aspects, (1) established a ceiling amount of legal special cab which only accounted for a small proportion of cab amount by granting authorization; (2) strengthened the enforcement of law which meant detained more illegal special cab to increase the time delay $\delta$; (3) offered financial subsidies to cab company and induced them reduce the exploitation of cabdrivers to decrease the proportion of price $k$. 
Appendix

Proof of Lemma 1

Based on the Eq.5, $P_L^* = 2P_0 + 2\alpha I$. Substituting $P_L^*$ into the carpool strategy's model, the model became $\max_{\Delta I} E[\pi_L] = \delta(2P_0 + 2\alpha \Delta I)$, s.t. $\alpha I - (\alpha + \beta)\Delta I \geq 0$ and $0 \leq \Delta I \leq I$. The optimal solution was $\Delta I^* = \alpha I / (\alpha + \beta)$, $P_C^* = 2P_0 + \alpha^2 I / (\alpha + \beta)$ and $\pi_C^* = 2\delta P_0 + \alpha^2 I / (\alpha + \beta)$.

Proof of Proposition 1

(1) Special Cab strategy vs. Hail a Cab strategy.

$\pi_S^* - \pi_H^* = (1 - 2k)P_0$. Therefore, $\pi_S^* > \pi_H^*$, if $1 > I = (2k - 1)P_0 / \alpha$.

(2) Carpool strategy vs. Hail a Cab strategy.

$\pi_C^* - \pi_H^* = 2(\delta - k)P_0 + 2\alpha^2 I / (\alpha + \beta)$. Therefore, $\pi_C^* > \pi_H^*$, if $1 > I = (k - \delta)(\alpha + \beta)P_0 / \delta \alpha^2$.

Carpool strategy vs. Special Cab strategy.

$\pi_C^* - \pi_S^* = (2\delta - 1)P_0 + [(2\delta - 1)\alpha - \beta]I / (\alpha + \beta)$. Therefore, when $\delta \in (1/2,1)$, $\pi_C^* > \pi_S^*$ if $\beta < \beta_1 = (2\delta - 1)\alpha$; $\beta > \beta_1$, and $1 < I = (\alpha + \beta)(1 - 2\delta)P_0 / [(2\delta - 1)\alpha^2 - \alpha \beta]$.

Combining the analysis (1)-(3), we draw the results that when $\delta \in (1/2,1)$, (a) $\pi_C^* > (\pi_H^*, \pi_S^*)$ in (1) when $\beta < \beta < \beta_2 = (2\delta - 1) / (k - \delta)$ and $I < I < I_1$, or (2) $\beta < \beta_1$ and $I > I_2$; (b) $\pi_S^* > (\pi_H^*, \pi_C^*)$ when $\beta > \beta_1$ and $I > \max(I_1, I_2)$; (c) $\pi_H^* > (\pi_C^*, \pi_S^*)$ when $I < \min(I_1, I_2)$.

References


