Supply-Demand Relation and Resource Allocation Model of Taxis in Internet Plus Era

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Abstract. This paper mainly studies how much effect those various subsidy schemes from taxi-hailing app companies can have on easing the difficulty in taking a taxi in the Internet plus era. First, two concepts are introduced. One is the concept of supply and demand matching index, quantifying supply and demand relation of taxis, the other being the concept of vehicle load factor, calculating the optimal supply and demand matching index, which is 0.2486. Then, the supply and demand matching indexis calculated, based on the implementation of various subsidy programs in Wuhan City.Finally, the relations between the two kinds of indexes mentioned above have been compared. It is concluded that subsidy schemes from taxi-hailing app companies can to some extent ease the difficulty in taking a taxi in the initial stage. However, in the long run, they will make the situation worse.

Problem Analysis

Whether the difficulty in taking a taxi can be alleviated, it is a relative concept.Firstly,a mathematic quantification should be conducted so as to measure the difficulty degree in taking a taxi with a reasonable index. In doing so an optimal supply and demand matching index is established in this paper.Then, specific subsidy programs from each company are investigated and relevant data are referred to quantify difficulty degrees in taking a taxi before and after the implementation of these subsidies.Finally, we compare effects different subsidy schemes have on the difficulty in taking a taxi.

Establishment of the Supply and Demand Matching Model

To obtain relations among supply and demand matching degrees, data of taxi supply quantity and demand quantity should be combined to get the mathematical quantification of supply and demand matching degrees.

Firstly, the original supply and demand matching degree is measured by the proportion of taxi supply and demand quantity of same time and same place. Then the supply and demand matching ratio is defined:

$$r = \frac{g-q}{q} \quad (1)$$

In the type (1), q stands for the taxi demand quantity and g stands for the taxi supply quantity of same time and same place.

Considering the issue analyzed in this paper is mainly about citizen's difficulty in taking a taxi, so we should stand on passengers' perspective. In doing so the situation where matching ratio symbol is positive is superior to that of negative under the same quantitative value of matching ratio. Therefore, quantization for matching degree needs to be further analyzed.

The supply and demand matching index m is defined to measure the ultimate supply and demand matching degree.

When taxi supply quantity is greater than that of demand, the symbol of supply and demand matching ratio r is positive. Then the supply and demand matching index is:

$$m = \omega_1 \cdot r \quad (2)$$

When taxi supply quantity is less than that of demand, the symbol of supply and demand matching ratio *r* is negative. Then the supply and demand matching index is:

$m = \omega_2 \cdot r$(3)

In types (2) and (3), ω_1 and ω_2 stand for constant coefficient, measuring how much effect the oversupply and supply behind demand can respectively have on matching degree from passengers' perspective. And it is defined that $\omega_1 + \omega_2 = 1$。

The type (2) and (3) are combined to form one type under mathematical derivation, resulting in the eventual presentation of supply and demand matching index *m*:

$m = r \cdot \left[\left(\frac{1}{2} + \frac{|r|}{2r}\right) \cdot \omega_1 + \left(\frac{1}{2} - \frac{|r|}{2r}\right) \cdot \omega_2\right]$(4)

In the type (4), the numerical values of ω_1 and ω_2 are determined by the ratio of taxi drivers' numbers and passenger numbers, which are selected from the year 2004 to 2013[1]. The specific determination process is as follows:

$$\begin{cases} \frac{\omega_1}{\omega_2} = \frac{sj}{ck} \\ \omega_1 + \omega_2 = 1 \end{cases} \quad (5)$$

In the type (5), sj is the number of taxi drivers, and ck is the number of taxi passengers of same time.

The number of taxi drivers and passengers from 2004 to 2013 can be found in the statistical yearbook[1]. Then they are put into the type (5) and results are: $\omega_1 = 0.58$，$\omega_2 = 0.42$。

Establishment of the Load Factor

In order to get vehicle load factor, several spots for long-term observation should be firstly selected at the place where passenger flows are concentrated. Then the number of passing taxis loaded with passengers of unit time and the total number of passing taxis of unit time are respectively recorded. And vehicle load factor is the ratio of the former and latter. The formula is as follows:

$mz = zk/sum \times 100\%$(6)

In the type (6), *mz* stands for the vehicle load factor, *zk* stands for the number of passing taxis loaded with passengers of unit time and *sum* stands for the total number of passing taxis of unit time.

Establishment of Optimal Supply and Demand Matching Index

According to the analogical thought, the number of taxis loaded with passengers is called taxi quantity demanded and the total number of passing taxis is called taxi inventory. So taxi load factor can be presented as follows:

$mz = q/g \times 100\%$(7)

Based on the above, the relation between taxi demand quantity and taxi inventory can be found. Combining the relation with the building process of supply and demand matching model, the optimal value m_0 of supply and demand matching index *m* is calculated as follows:

$m_0 = r_0 \cdot \left[\left(\frac{1}{2} + \frac{|r_0|}{2r}\right) \cdot \omega_1 + \left(\frac{1}{2} - \frac{|r_0|}{2r}\right) \cdot \omega_2\right]$(8)

In the type (8),r_0 is the current optimal supply and demand matching ratio, and specific calculation process is as follows:

$r_0 = \frac{1-mz}{mz}$(9)

According to reference[5], difficulty in taking a taxi will become the lowest if vehicle load factor mzequals 70%. After putting it into type (8), we can find:$m_0 = 0.2486$.

This definition is based on the following reasons: The difficulty in taking a taxi mainly refers to the long time waiting problem resulting from supply behind demand. Although the waiting time can be reduced in a short time by unilaterally increasing the number of taxis, the difficulty in taking a taxi cannot be fundamentally solved considering the market regulation mechanism. That is because

overmuch taxi supply in the market will lead to low income for taxi drivers. In that case, a large number of taxi drivers will turn to join other industries and the difficulty in taking a taxi would appear again after a certain period of time. According to market's self-regulatory mechanism [4], the difficulty in taking a taxi would be truly eased only when supply and demand relatively match with each other. And in taxi industry, when supply exactly equals demand, passengers tend to find it hard to take a taxi in the shortest time and end with longer waiting time. Based on the above two reasons, the more vehicle load factor is close to 70% (or supply and demand matching index is close to 0.2486), the better it is to ease the difficulty in taking a taxi.

Taxi Subsidy Schemes from Different Companies

Currently, "Didi Travel" and "Fast Taxi" are China's two most-used taxi-hailing app companies. Those main taxi-hailing subsidy schemes that have been implemented are shown in Table 1 and Table 2.

Table 1 Subsidy Schemes from Didi Travel Company

Date	Subsidy Schemes
January 10, 2014	10 yuan reduction for passenger fare, 10 yuan reward for drivers
February 17, 2014	10-15 yuan cash back for passengers, 50 yuan first order reward for new drivers (no reward change for old drivers)
February 18, 2014	12-20 yuan cash back for passengers, 10 yuan reward for drivers
March 7, 2014	6-15 yuan random reduction for passengers, 10 yuan reward for drivers
March 23, 2014	3-5 yuan cash back for passengers, 10 yuan reward for drivers
May 17, 2014	No subsidy for passengers, 10 yuan reward for drivers
July 9, 2014	2 yuan subsidy per order for drivers
August 12, 2014	No regular order-receiving subsidy

Table 2 Subsidy Schemes from Fast Taxi Company

Date	Subsidy Schemes
January 20, 2014	10 yuan cash back for passenger fare, 10 yuan reward for drivers
February 17, 2014	11 yuan cash back for passengers, 5-11 yuan cash back for drivers
February 18, 2014	13 yuan cash back per order for passengers, no subsidy change for drivers
March 4, 2014	10 yuan cash back per order for passengers, no subsidy change for drivers
March 5, 2014	5 yuan subsidy per order for passengers, no subsidy change for drivers
March 22, 2014	3-5 yuan cash back per order for passengers, no subsidy change for drivers
May 17, 2014	No subsidy for passengers, no subsidy change for drivers
July 9, 2014	2 yuan subsidy per order for drivers
August 9, 2014	No cash subsidy for drivers

Comparing previous taxi-hailing subsidy schemes respectively from Didi Travel Company and Fast Taxi Company, it is found that subsidy schemes from the two companies are similar at same periods and so are the schemes' changing trends. Therefore, a kind of analytical method is used as follows to analyze integrally subsidy schemes from the two companies.

Quantitative Analysis of Difficulty in Taking a Taxi in Wuhan City Under Subsidy

Based on the relative data [2], changes of taxi-hailing demand quantity in Wuhan City can be found under the above subsidy schemes. Due to the limitation of statistics for taxi inventory, actual taxi inventory of every day in each quarter is replaced by taxi inventory of the corresponding

quarter in this paper. Meanwhile, because of the lag effect of market regulation, the impacts that subsidy schemes have on taxi inventory generally are small in the initial quarter, and later gradually become apparent. Based on this, a table is given as follows, including changes of taxi inventory, demand quantity, and supply-demand matching index m during the period of subsidy schemes' implementation (every time quantum randomly give one day's statistic result).

Table 3 Changes of Supply and Demand Relations in Different Subsidy Schemes

Date	January 11th	February 17th	February 26th	March 14th
Inventory	19691	19691	19691	19691
Demand Quantity	13144	16987	18704	19756
Supply and Demand Matching Index m	0.2889	0.0923	0.0306	-0.0014
Date	**April 15th**	**May 20th**	**July 13th**	**August 14th**
Inventory	20734	21547	21547	21547
Demand Quantity	20821	20636	19473	19033
Supply and Demand Matching Index m	-0.0018	0.0256	0.0618	0.0766

Note: units of inventory and demand quantity: per

Conclusion Analysis

According to the data from Table 3, relations between actual value and optimal value of supply and demand matching index *m* can be found (shown in Fig.1).

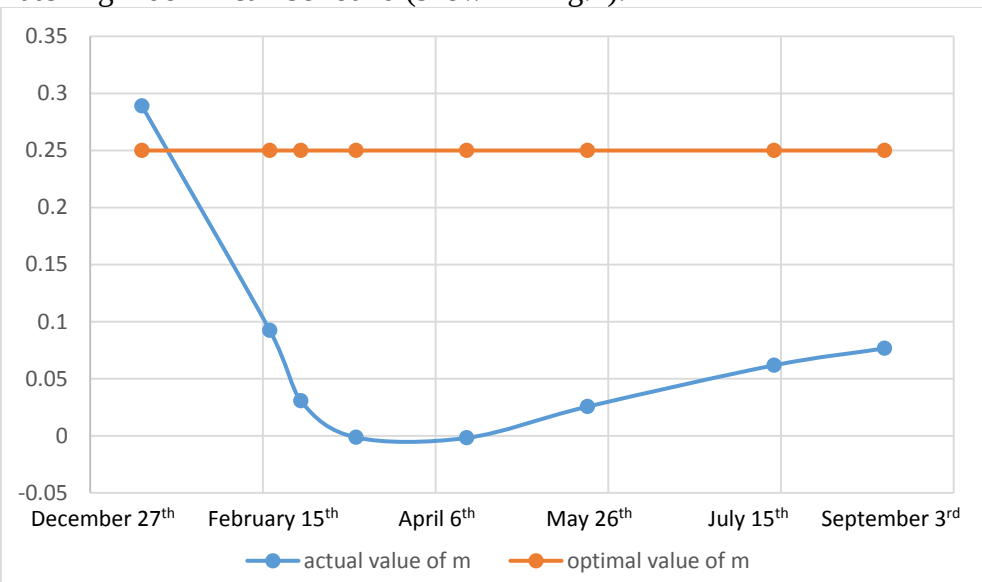

Fig.1 Comparisons among two kinds of supply and demand matching index m

Conclusions are drawn by analyzing Table 3 and Fig.1:

1. Subsidy for passengers can increase taxi demand quantity on a large scale, and has a low time-lag effect. Besides, it can to some extent reduce consumption costs in taking taxis, attracting more people to take taxis when they go out. And this influence has a relatively higher sensitivity to market compared with the changes of taxi inventory, so there is almost no lag effect.

2. Subsidy for drivers can increase taxi inventory on a certain scale, but it has time-lag effect. What's more, it can improve incomes of taxi drivers, encouraging more people to join the taxi industry. And the lag effect of this influence is mainly impacted by the lag effect of market self-regulation.

3. Subsidy schemes from different taxi companies can to some extent ease the difficulty in taking a taxi in its initial stage. In the long run, however, they will make the situation worse.

4. In the early stage of implementing subsidy schemes, values of supply and demand matching index m gradually become close to the optimal supply and demand matching index m_0, which indicates the difficulty in taking a taxi is gradually reduced compared with the traditional taxi-hailing way. But after approaching interim of the implementation, the former gradually becomes far away from the latter, which suggests the difficulty in taking a taxi is gradually increased compared with the traditional taxi-hailing way. And the fig shows obviously that the degree of deviation (from m tom_0) becomes even higher, indicating existing subsidy schemes cannot ease the difficulty in taking a taxi, but in a way increase that difficulty.

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